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"Promoting Research and Practice in Appropriate Technology: Energy Solutions in the Era of Climate Change"

PROCEEDINGS OF ORAL PLATFORM PRESENTATIONS

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OPENING PLENARY SESSION PAPERS

ENERGY–PLENARY SESSION PAPERS

PARALLEL SESSION - ENVIRONMENT

PARALLEL SESSION - FOOD, WATER, SHELTER and HEALTH

THE WAY FORWARD

The Historical Development of ICAT – International Conferences on Appropriate Technology

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The first ICAT was held in July 2004 in Bulawayo Zimbabwe. This effort was built on previous work by a network of academics at Howard University that started their effort with the formation of the Howard University Project on Appropriate Technology (HUPAT) in 1998. HUPAT had been involved with local and national conferences in the United States, hosted at Howard University.

The 1st ICAT addressed the theme of "A Knowledge management Approach to the Development of Appropriate Technology, with a focus on Sustainable land-based projects". This was a timely theme since Zimbabwe was concerned with projects that would assist new farmers following the 'fast track land reclamation' process. This first effort was largely possible through the support of academic staff at the National University of Science and Technology (NUST). Paper sessions addressed: industry and production; construction and architecture; transportation and solar technology; water, agriculture and environment; and knowledge management and appropriate computing. [1]

In preparation for the 2nd ICAT we actively sought to expand the international planning committee. We also increased the role of Howard University and added the Northern California Council of Black Professional Engineers (NCCBPE) as an active co-sponsor. The current interest in health in underdeveloped countries was addressed. Once again the conference was hosted by NUST in Bulawayo Zimbabwe. It took place two years after the first ICAT in July 2006. The theme that year was "Sharing the Knowledge from Research and Practice in Appropriate Technology, with a focus on Health-Related projects". The highlight of the conference was the 'health related' paper session and special talks by health experts. Other paper sessions included: knowledge management; energy and physics; water and agriculture; environmental; and architecture and small-scale industry. [2]

Active organization for the 3rd ICAT began in April 2007. We expanded our international planning committee to include 12 countries. For the first time we involved multiple universities in the host country: Kigali Institute of Science and Technology (KIST); the National University of Rwanda (NUR); Umutara Polytechnic University; Universite Libre de Kigali (ULK) and Kigali Health Institute (KHI). At an early point in the conference organizing, the Ministry of Science and Technology in the President's Office provided strong support. This has been instrumental in expanding our work in appropriate technology. The theme of this year's conference is: "Promoting Research and Practice in Appropriate Technology: Energy Solutions in the Era of climate change"

A common thread through all our conferences has been to connect research with practice and to use knowledge technology to make best practices accessible beyond the conference venue. Our commitment to the active promotion of 'technology to empower the people' will make an impact on research, practice and policy regarding science, technology and development planning.

Any vision of a better world must include a serious shift in how resources are used regarding science and technology. We believe that the work of our ICATs will make a contribution to this process.

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The Relevance of Appropriate Technology

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The first technologies ever developed, whether the club as a tool, the spear or fire, were tools appropriate to satisfy the needs of the community and enhance the community's ability and capability to survive and endure. Since the beginning of the human-technology relationship, the development of technology and the purposes and the needs these technological developments served have become increasingly complex from that early dawn. In the late twentieth century and as we enter the closing years of the first decade of the twenty-first century, in today's world of globalized and increasingly privatized resource and capital flows, the notion that an appropriate technology can be defined and characterized may seem increasingly improbable and somewhat absurd. However, as recent market and economic dysfunction have amply demonstrated, globalized privatization and unregulated transnational capital and resource flows with little government and state oversight, also means globalized and almost ubiquitous economic difficulties across diverse national economies and socio-techno-economic systems. There need for appropriate technology in such a context becomes clearer; this must take into account economic and livelihood realities of local communities, especially those in the countries of the global south.

The complexity of this socio-technological relationship must be seen in the context of over two thousand years of social and technological development which have resulted in some of the wealthiest and most prosperous of times for certain members of the global population. However, at this late stage in human civilization's development, of the six and a half billion people who inhabit this planet, almost a half have no regular and consistent access to clean, potable water. These same communities also lack access to hygienic and sanitary waste and sewage disposal systems. Almost two-thirds lack access to the world-wide web and are left on the wrong side of the digital divide – effectively being left out of the conversation and cut off from the immense wealth of resources available on-line, access to which would enhance the communities quality of life and standard of living.

This disconnect, between the harsh realities of inequitable resource distribution and access to technology, and the amazing and extraordinary technological developments and advances of the previous two centuries, speaks clearly to a desperate need for a renewed focus and emphasis on technology that is appropriate to the establishment of a just, equitable and fair global social order. This must be a global social order defined by a human-technology relationship that seeks to harness the immense creativity of the human species in their ability to respond to their environment and engineer it to their benefit for a sustainable existence within their own socio-geographical spaces.

Although E. F. Shumaker [1] introduced into the western scientific and rational consciousness the notion of small as beautiful and technologies that responded to human communities at scales that were manageable, controllable and appropriate to the context of its development and application, indigenous peoples from across the globe have developed and implemented technological solutions relevant to their time and space; indeed relevant and appropriate to their socio-economic and socio-ecological niches and habitats. These repositories of indigenous knowledge have ranged from the oral (such as the oral traditions of the Native American Indians and various African tribes and nations) to the documented and written (such as technological and scientific handbooks from India, China and the Arab nations), and these can provide a rich resource for current practitioner's as we seek to develop solutions to problems that have grown as complex as some of the proposed solutions.

Clearly, then, in the context of desperate global need for technological inputs into communities to raise standards of living and quality of life indicators from their current abysmal levels, the relevance of appropriate technology cannot be disputed. In the context of the 21st century, the principles and criteria that define and determine appropriateness of technologies must be re-articulated and under scored. Appropriate technology means many different things to different people and we need to be clear in our understanding of what is in fact appropriate. Generic searches on the internet reveal thousands of sites that respond to the search engines calling, revealing that meanings can often be elusive and illusory.

Nevertheless, although appropriate technology, or AT, is difficult to define and its development and implementation have been a source of debate for some time [2], there is general agreement on some of the governing characteristics of appropriate technology. It is clear that AT should normally require only small amounts of capital. AT must emphasize, wherever possible, the use of local materials. Implementation of AT's should focus on relatively labor intensive technological solutions that individual's in community's can participate in. This suggests that AT should tends towards the smaller scale and be affordable. The community based nature of AT requires that the technological solutions being developed should be understandable, controllable and maintainable without unduly high levels of education and training; at the same time, AT should be adaptable and include local communities in innovation and implementation. Finally, adverse impacts on the environment should be avoided and the sustainable nature of the technological solution should be emphasized [2]. Naturally, given the huge divide in resource access and availability, AT will encompass diverse sets of tools, processes and technologies, but will be focused on sustainable development.

The rationale of AT resides in its empowerment of people at the grass roots community level. Development professionals agree that local needs can be met more effectively with the community working to address their own problems. The rationale is also grounded in minimization of financial, transportation, education, advertising, management and energy services and costs with the goal of engendering self-sustaining and expanding reservoirs of skills within a community. The result is a lowering of economic, social and political dependency, and a move towards sustainable development that is focused on people's needs and is grounded in empowerment through education, technology transfer, capacity building and local control.

At this historical moment, appropriate technology as a concept and a movement could never be more relevant. The diverse set of technologies that are part of the different focus areas of the conference demonstrates the variegated needs that appropriate technologies can be developed and implemented to satisfy in a sustainable manner. The papers speak to the ever-present need to develop and extend these efforts.

The papers in this conference have been organized around the four broad categories. The primary focus is energy and the plenary papers present research and applications of appropriate energy technologies including solar, biogas and wind. The second focus area is the environment – papers in this area focus on waste minimization and remediation of environmental pollution. The third separate focus area is information and communication technologies. The fourth area is a broad umbrella grouping that includes papers on food, water, shelter and health.

The appropriate technologies that are being presented and discussed at the conference will range from the basic technologies required for water supply and sanitation to the more sophisticated and complex including alternative energy technologies focused on renewable resroucres to the wireless rural internet that will enable villagers in diverse and remote rural communities to be valued participants in the global economy.

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Laboratory Scale Biogas Production from Banana Tree Residues

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Key words*:* Banana tree, Biomethanisation, Biogas, Effluents.

Abstract
The present study aimed mainly at recovering all the residues of banana by producing a firewood alternative source of energy: the biogas, and an organic fertilizer: the effluent. Before conducting an anaerobic fermentation, all the parts of banana tree have been weighed in order to determine their weight to weight ratio. Thereafter, they have been cut into small pieces of almost 2cm, and then aerobically fermented for one week prior to an anaerobic fermentation (biomethanisation). The anaerobic fermentation was carried out during 79 days under a mean temperature of 37.4°C. Experiments have been done in two laboratory digesters of 50L each, the first have received the residues alone and the second the residues mixed with cow dung. The best results were obtained under those last conditions since with a mixture of 12.6Kg (banana stems): 2.1Kg (banana leaves): 1.5Kg (ripened banana peels): 5.4Kg (cow dung): 17.5Kg (water), a total volume of biogas of 733897.6ml, a daily volume production of 9289.84ml, a productivity of 0.2698m^3/Kg.DM, a biogas composition of 58.07% CH_4 and 41.93% CO_2 and a calorific heat value of 21,647 kJ/m^3 were obtained. Moreover, the effluents constitute a fertilizer of good quality.

Introduction

Banana tree is an important crop to Rwandan population. Due to its dietary, economic as well as social values, banana tree has been qualified as the « cow of the poor » [1]. In fact, on top of serving as food, it is used to prepare a traditional drink, locally known as «URWAGWA » which contributes to income generation for many families and, especially in rural areas, plays a vital role during social festivities like dowry hand over, marriage, *etc*. As a matter of fact, banana contributes to 60-80% of household income in major banana growing zones [2] like the Eastern part, the Western region coastal to Lake Kivu and the volcanic region in the Northern part of the country. Climatic conditions for banana are a mean temperature of 15-30°C, an altitude of 1000 to 1200 m and enough rainfall exceeding 100mm/month [3;4]. Though many banana varieties including the one for cooking, the one for dessert and the one meant to produce local wine exist in Rwanda, the last variety is predominant and counts for 60% [2]. The present work focuses on a predominant wine producing variety locally called « GISUBI ». In 2004, Rwanda produced 2469741 tones of all banana varieties on a total cultivated area of 363383 ha, *i.e.* a mean yield of 6.8 tones/ha [5]. Banana plantation occupies on itself 23% of the total arable land [2] and its production is almost the half of the total subsistence crops. Therefore, at harvest, banana tree generates a lot of wastes since the edible part of it is only 8.54% of the total biomass. Therefore, banana tree residues represent undoubtedly a good choice and an appropriate biomass for biogas production in Rwanda since they are sufficiently abundant and easily accessible to the majority of the population. Hence, biogas production from those residues could be one of possible solutions in order to reduce the problem of lack of energy at the household level in

Rwanda but also in order to preserve our forests which are being intensively cut. Particularly, in case of biogas production it is advisable to use all the parts of banana tree: stems, leaves and peels since they all are biodegradable.

The main objective of this study is to test, at the laboratory scale, the ability of all banana tree residues, to produce biogas. The specific objectives are:

- To produce, from banana tree residues, an alternative fuel in replacement of wood;
- To produce an organic fertilizer from banana tree residues;
- To minimise the use of animal biomass in biogas generation.

Material and methods

Raw material was composed of different parts of banana tree which are stem, leaves and peels. All this raw material has been collected at Mpare, Huye district, Southern province during dry season of July. The weight of each component was determined prior to any physical treatment in order to determine the weight/weight ratio of each. Before being loaded into the laboratory digesters, the banana tree components were cut into small pieces of 2cm and then put into an open cask where they aerobically fermented during one week. The purpose of this composting process is to make the wax material which would complicate the anaerobic fermentation, loose [6]. During this aerobic fermentation, one litre of water was poured over the composting mass which was turned up and down every day in order to facilitate the process as well as to allow equal air distribution. After one week of anaerobic fermentation the material was introduced into 50 litre digesters together with a certain quantity of active sludge from a well functioning digester. This sludge, called innoculum, represents 30% of the total load [6]. Table 1 represents the quantities of different raw materials loaded while Figures 1 and 2 describes the laboratory digesters used which will be symbolised by Dig I and Dig II.

Table 1 Quantities and ratios of different raw material loaded

Different biomass (Kg)	**Digesters**			
	Dig I		**Dig II**	
	Quantity (Kg)	**Ratio**	**Quantity (Kg)**	**Ratio**
Stems	12.6	8.4	12.6	8.4
Leaves	2.1	1.4	2.1	1.4
Peels	1.5	1	1.5	1
Water	17.5	11.7	17.5	11.7
Cow dung	0	-	5.4	3.6
Inoculum	4	-	4	-
Total	37.7	-	43.1	-
Dry Matter (DM)	1.79	5.3%	2.72	6.3%
C/N Ratio	-	40.6	-	37.9

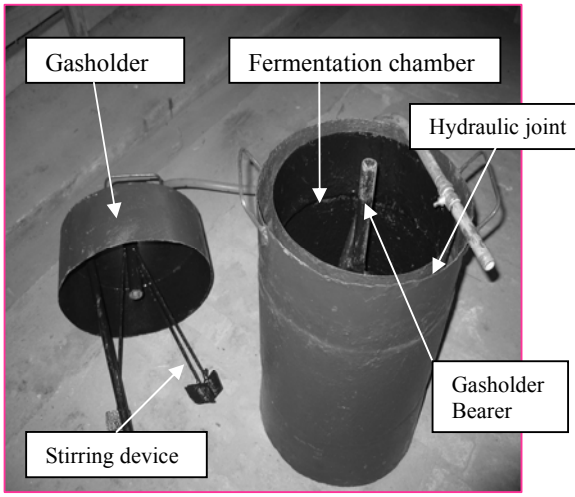

Figure 1 Laboratory digester

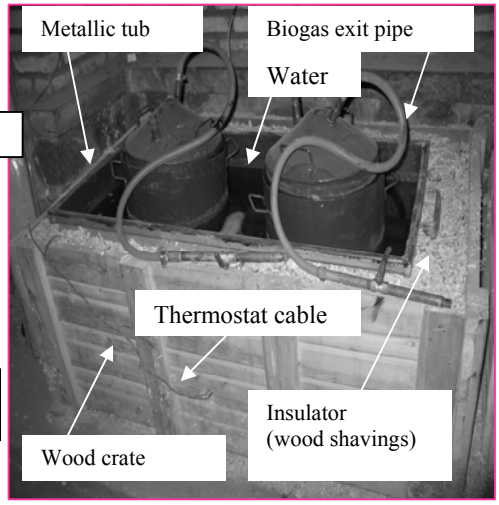

Figure 2 Heat stabilisation box

Dry matters content (DM) of raw material was determined by drying a fresh sample into an oven set to 105°C [7]. The result in percentage is a ratio between a constant weight of the sample over the weight of the fresh sample before drying. Volatile matters content (VM) was determined by calcination of DM at 600°C [7]. From the ash obtained the percentage of VM was determined.

The wet oxidation method following Schlichting and Blume in 1966 [8] was used to determine the total carbon. After digestion of a sample in presence of a concentrated acid (H_2SO_4, 97%) with the aid of an oxidising agent ($K_2Cr_2O_7$, 2N), the concentration was given by a u.v/visible spectrophotometer at a wavelength of 578nm. The milligrams (the result of a spectrophotometer) are converted into percentage as follows:

$$\%\, C = \frac{mg\ of\ carbone\ (spectrophotometer)}{10 \times weight\ of\ the\ sample(g)}$$

The total nitrogen was determined using the classical Kjeldahl method as described by Blume (1966) and USDA (1972) while the total phosphorus was determined by the ascorbic acid method by IITA (1978) [8].

Ammonium, NH_4^+, was analysed using the Nessler reagent method [7]. The nitrite NO_2^- and nitrate NO_3^- ions were analysed following the α-naphtylamine in presence of sulfanilic acid and the phenoldisulfonic acid methods respectively [9]. Various ions including sodium, potassium, calcium, magnesium, iron, manganese, zinc and copper were also analysed on an atomic absorption spectrophotometer at their respective wavelengths [8].

The volume as well as the composition of biogas were determined by an Orsat apparatus. The leading principle of this apparatus is the ability of some gases to be absorbed into specific solutions. In presence of an alkaline solution, KOH 40% in our case, the CO_2 was absorbed forming a soluble salt (K_2CO_3). Hence with a known volume of biogas (100mL) it was possible to quantify the absorbed gas (CO_2) and the remaining one was taken as methane. The biogas heating value was calculated from the fact that the heat value of pure methane is 37,278 kJ/m^3 [10]. This value was then multiplied by the biogas percentage in methane.

Results and discussion

Weights of different parts of banana

Weights of different parts of banana, their relative ratios values and percentages are presented in Table 2.

Table 2 Weight, ratios and percentages of different parts of banana (Kg)

Sample	Fresh banana	Stems	Leaves	Ripe banana	Peels
1	8.00	28.00	3.50	7.00	3.00
2	10.00	35.00	5.00	9.00	4.00
3	12.00	38.00	7.50	10.80	4.80
4	13.00	45.80	8.00	11.40	5.80
5	15.00	52.60	9.50	13.50	6.20
Average	11.60	39.88	6.70	10.34	4.76
Ratio	**2.44**	**8.38**	**1.41**	**2.17**	**1.00**
%	**14.48**	**49.77**	**8.36**	**12.91**	**5.94**

The weights and ratios of different parts of banana were determined in order to determine the ratios at which they will be loaded into digesters in order to maximise the use of all the residues. From table 2 it can be noticed the high percentage of stems (almost 50%) compared to other parts of banana tree.

Results of raw material analysis

Table 3 summarises the results from the analyses of raw materials

Table 3 Results of different parameters analysed in raw material

Parameter	Stem	Leaves	Peels	Cow dung
Dry matter (%)	6.67	26.88	25.58	17.2
Humidity (%)	93.33	73.12	74.5	82.8
Ash (%)	9.09	16.67	18.87	-
Volatiles matter (%)	90.91	83.33	81.13	-
C (%)	35.4	51.3	51.6	41.70
N (%)	1.1	1.1	0.5	1.40
C/N ratios	32.18	46.64	103.20	29.8
P (ppm)	300	1125	1400	743.75
Na (ppm)	580	540	550	-
K (ppm)	72900	23100	44400	15200
Ca (ppm)	18700	21400	9500	62200
Mg (ppm)	3000	7300	4200	-
Fe (ppm)	510	304	420	-
Mn (ppm)	150	660	100	-
Zn (ppm)	110	64	76	-
Cu (ppm)	4	6	4	-

The results of analysis of banana tree residues show that the stems contain less dry matters than the peels and the leaves. In all the cases the results are higher than the optimal values of the literature which recommends between 5 and 10% of dry matters for a continuous fermentation. C/N ratio is also high for the leaves and the peels but it is normal for the cow dung and the stems. The recommended C/N ratio ranges between 20 and 30 [6]. To adjust these two important parameters, a dilution with water was carried out. As far as cations are concerned, their contents are far lower than the thresholds of inhibition [6].

The trends of volume of biogas produced and temperature

Figure 3 exhibits the trend of the total volume of biogas produced

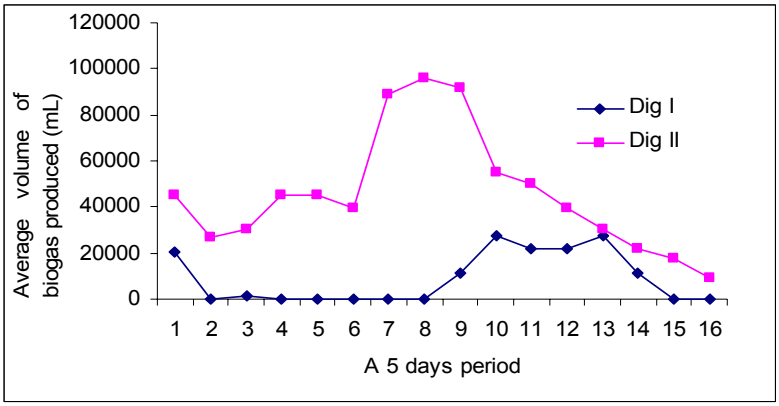

Figure 3 The biogas total volume trend

The gas starts to appear one day after the loading. As this gas was not combustible, it could be simply the air entered during the loading. During 5 days which followed the loading, the gas was combustible only after removal of CO_2. If the trend of the curves is considered, we note that Dig II knew a normal fermentation with a progressive rise from the 2nd period (the 6th day of biogas production); it is from this day that the gas is perfectly combustible and from the 50th day (10th period) the quantity of biogas starts to regress. The pick of fermentation appears after 40 days approximately. As for Dig I, one notes that it did not follow a normal fermentation. Indeed, a small quantity of biogas was produced after 40 days for a period of 30 days. This difference could be explained by the contribution of cow dung in the Dig II which, being a source of nitrogen, contributed to adjust the C/N ratio. During a period of 79 days (experimental retention time), the total volumes were 142749 mL for Dig I and 733898 mL for Dig II. The temperature remained in the mesophilic range during all the experiments and did not know enormous fluctuations. This shows that the results obtained can be reliable at least with regard to the influence of the temperature. The mean temperature was 37.4°C.

Productivity calculation

From the total volume and the retention time another important parameter, productivity has been calculated as indicated in Table 4.

Table 4 Productivity of the two laboratory digesters

Parameter	**Digester**	
	Dig I	**Dig II**
A : Dry matter (Kg)	1.79	2.72
B : The quantity under fermentation (Kg)	37.7	43.1
C : Total volume of biogas (mL)	142749	733898
D : Retention time (Days)	79	79
E = C/D : Mean production (mL/d)	1806.95	9289.84
$Cx10^{-6}/A$: Productivity (m^3/Kg DM)	0.0797	0.2698
$Ex10^{-6}/Bx10^{-3}$: Productivity (m^3/m^3/d)	0.0479	0.2155

The productivity, expressed in m^3/KgDM, is a significant parameter because it accounts for the production capacity of biogas by a given biomass. When it is expressed in m^3/m^3/d, it is related to the digester and shows its output of biogas per unit of volume expressed as m^3. Comparing the data obtained with those of the literature, we find that the

productivity of banana residues (269.8L/Kg DM) is comparable to that of trees leaves which is 252 L/KgDM and is far higher than that of the sole cow dung which is only 205 L/KgDM[6]. The value of 0.2155 $m^3/m^3/d$ is also comparable with that of the literature which is 0.2 to 0.5$m^3/m^3/d$ [6;11].

Evolution of the biogas composition

The biogas composition in methane and carbon dioxide is expressed as mean percentage for each period of 5 days on Figure 4.

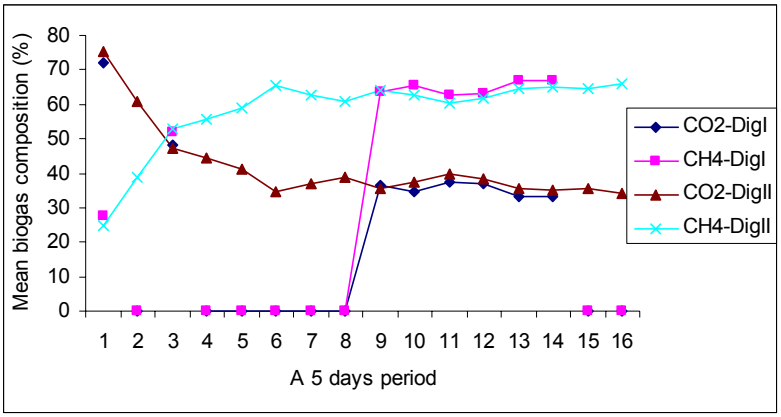

Figure 4 Biogas composition trend for the two digesters

The profile of biogas composition is a normal trend for the second digester (Dig II) whilst Dig I exhibits an irregular biogas production. Hence the biomethanisation succeeded in Dig II. Indeed, a normal fermentation is characterised by a progressive increase in CH_4 and a progressive decrease of CO_2 with time. The mean composition of biogas and its heating value were also calculated as it appears on Table 5.

Table 5 Mean composition and heating value of biogas

Mean biogas composition and heating value	Dig I	Dig II
Mean CO_2 (%)	41.4	41.93
Mean CH_4 (%)	58.6	58.07
Calculated heating value (kJ/m^3)	21,845	21,647

The mean biogas composition in methane achieved with banana tree residues (58.07% for Dig II and 58.6% for Dig I) is similar to that of tree leaves (58.07%), to that of sole cow dung and to that of maize stalks (59%) [6;12].

pH trend

The pH trend of the biomass under fermentation as a function of time is presented on Figure 5. It can be noted that the pH remained almost unchanged. The literature estimates the optimal pH for fermentation between 6.8 and 7.5. For values lower than 6.8 there is an acid inhibition and over 7.5, an ammoniacal inhibition [6;12]. However, Dig II which gave a better yield, exhibits values which slightly exceed those of the literature. One can thus consider that the bacteria can always be active in an interval of +/-0.1 or even 0.2 units of pH. Indeed, the maximum of production was recorded between the 30^{th} and the 45^{th} day when the pH raised from 7.40 to 7.68. As for Dig I, its low yield would not be ascribable to the pH

because it is always close to neutrality. The causes are thus to seek elsewhere in particular in the C/N ratio.

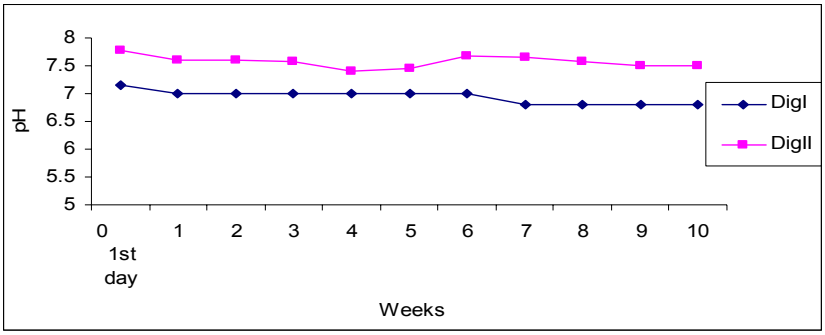

Figure 5 The pH trend of the biomass under fermentation

Effluent analyses

Table 6 Results of effluents analyses

Parameter	Digester	
	DigI	DigII
pH-H_2O	7.2	8.78
pH-KCl	6.58	7.85
C (%)	45.9	40.1
N (%)	2.7	2.3
NH_4^+ (mg/l)	49	58
NO_2^- (mg/l)	4.4	4.6

Parameter	Digester	
	DigI	DigII
NO_3^-(mg/l)	35	40
P(ppm)	2125	2150
K(ppm)	16500	34600
Ca(ppm)	23200	34500
Mg(ppm)	8300	13500
Na(ppm)	980	1780

The results from the analysis of the effluents are encouraging in the case of Dig II since they are similar to those obtained for the cow dung alone. Indeed, the effluents of the dung of cow contain 2.3 to 4.7%N, 0.9 to 2.1%P, 4.2 to 7.6%Ca and 0.6 with 1.1%Mg [11]. Assuming that the soil requires the maximum of nutritive elements, one hectare needs 33Kg N, 11Kg P and 48 kg K [12]. The results out of the present study show that if an $8m^3$ batch digester is considered, the quantity of the effluents obtained is 8 tons which contain 184 kg N, 17.2 kg P and 276.8 kg K. These contents largely exceed those which are proposed for one hectare. Reference made to phosphorus which is often a limiting element, we note that its content is almost twice higher that the recommended one.

Conclusion and recommendations

During this study the objectives were met. Indeed, from banana tree residues, biogas and a fertilizer of good quality were produced. The results obtained on the productivity and the effluents show that the biomethanisation of these residues can be exploited on a large scale, especially in rural area of Rwandan where banana constitutes the main cash crop. However it was found that banana tree residues cannot be expected as a source of biogas alone; an animal biomass, cow dung in this case, has to bee mixed with them. In particular, this study contributed to reduce the use of cow dung for the production of biogas since 5 to 7 cows are needed to make function an $8m^3$ biogas plant running on cow dung alone[12] whilst the introduction of banana residues reduces the numbers of cows to 2, *i.e.* a reduction of 60 %. Finally it can be noticed that, although this study contributed a lot to the reduction of the quantity of cow dung, it cannot guarantee that the technology of biogas will be easily popularized in Rwanda where building materials are still very expensive. Therefore another study on alternate building materials to bricks and cement, materials currently used, would be

of a great importance. Another study on the applicability of the results at large scale and for a continuous type of digesters has to be carried out also.

Acknowledgement

Gratitude is conveyed to the Institute of Scientific and Technological Research (IRST) for having availed its biogas production laboratory for the main part of the present work.

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Studies on Alcohol Production from Sweet Potato

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Key words: sweet potato- alcohol – fermentation – distillations

Abstract

There is nothing new in the use of alcohol made from root crops as a motor fuel. Alcohol is an excellent alternative motor fuel for petrol engines. The reason alcohol fuel has not been fully exploited is that, up until now; gasoline has been cheap, available, and easy to produce. However, nowadays, crude oil is getting scarce, and the historic price difference between alcohol and gasoline is getting narrower. Alcohol fuel can be an important part of the solution for Rwanda because there is tremendous scope to use bulk production of sweet potato into alcohol. The total sweet potato production in both seasons is found to be 1,607,296 tones/year. The average productivity of Sweet potato in the country irrespective of seasons is found to be 8.9 tones/ha. If all of the available agricultural surplus were converted to ethanol, alcohol would supply less than 5% of motor fuel needs.
There is a need for alternate use of sweet potato because it cannot be stored for longer periods without decay. This study has the specific objective of producing local beer from sweet potato and to test the alcohol content of it. The study reveals the fact that the alcohol production from sweet potato increases up to 48 hours of fermentation thereafter the alcohol content decreases, though the fermentation is continued. It is found that the average alcohol content in 24, 48 and 96 hours of fermentation of sweet potato malt yields 13.0, 13.2 and 12.80 % of alcohol.

INTRODUCTION

Currently there is a big push to find and develop alternative sources of energy so that dwindling reserves of crude oil and other fossil fuels may be conserved. As Edward Teller[4], one of the America's leading physicists points out: "No single prescription exists for a solution to the energy problem. Energy conservation is not enough. Petroleum is not enough. Coal is not enough. Nuclear energy is not enough. Solar and geothermal energy are not enough. New ideas and developments will not be enough by themselves. Only the proper combination of all of these will suffice", it showed the importance of alcohol extraction as a fuel for engines in Rwanda.

Alcohol fuel can be an important fuel for Rwanda because there is tremendous scope to use bulk production of sweet potato into alcohol. If all of the available agricultural surplus were converted to ethanol, alcohol would supply less than 5% of motor fuel needs. The most important aspect of this 5% is it can be renewed each year, and each litre of alcohol produced will save a litre of petroleum oil.

Sweet potato is widely grown in Rwanda as a food crop. Sweet potatoes contain average about 22% starch and 5-6% sugar for a total of 27-28% fermentable material. A tonne should yield up to 182 Kg of alcohol. Sweet potatoes are cooked and converted in a manner similar to potatoes with the exception that they contain only about 66% water and

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some dilution is necessary. Sweet potato contains saccharine (sugar) materials in which the carbohydrate (the actual substance from which the alcohol is made) is present in the form of simple, directly fermentable six and twelve carbon sugar molecules such as glucose, fructose, and maltose. Hence, sweet potato has the potential for alcohol production.

REVIEW OF LITERATURE

There is nothing new in the use of alcohol as a motor fuel. Mathewson[1] stated that when Nikolaus Otto invented the internal combustion engine, gasoline was not available. Ethyl alcohol at 180-190 proof was the specified fuel. The model "T" Ford was designed to run on the available crude gasoline, alcohol, or any combination of the two. Kusmayanto [2] stated that there are two kinds of biofuel derived from crops, i.e ethanol and biodiesel. Ethanol can be produced from any grain, root, tubers, fruits containing fermentable carbohydrates. Mays [3] experimentally found out that sweet potato can yield alcohol of 5821 litre/ha from the crop yield of 462 tonnes/ha.

MATERIALS AND METHODS

Cooking of sweet potato

The sweet potato is cleaned with water to remove the soil and other foreign materials. It is cut into small pieces and put inside the cooking vessel. Water is added at the rate of 100 ml for every 200 gm of sweet potato. It is cooked well in the electrical stove. Cooking is accomplished by heating the mixture of sweet potato and water to a slow boil and holding at this temperature for 30-60 minutes. Generally, the mash is sufficiently cooked when it is soft and mash. During cooking, it is stirred well.

Water for dilution of mash

Dilution is simply the addition of water to adjust the amount of sugar in the mash or the amount of alcohol in the beer. It is necessary because the yeast, used later in the fermentation process, can be killed by high concentration of alcohol. Also, during the mashing and conversion of starchy material, dilution is necessary to make the mash easier to stir and handle. The object of dilution is to end up with a beer of 10% or more alcohol when fermentation is complete. The dilution of water with the mash prepared is 400 ml for the 200 gm of sweet potato.

Mash Cooling

After cooking, the content is diluted with water. It is allowed for cooling in the same container. The temperature recorded is 45ºC. At this temperature of mash, yeast is added. The amount of yeast added is 2 gm in the diluted mash prepared.

Fermentor

A glass flask of one liter capacity is taken as a container for fermentation of the mash. The cooked, cooled, diluted mash with yeast is transferred into the fermentation container for microbial action on starch and saccharine materials in the mash.

Rotating distillation unit

Rotating distillation unit consist of a stationery electrical heater. On the top of the heater, a closed glass beaker is placed. This beaker is filled with the fermented mash of sweet potato and yeast. This beaker is made to rotate by a electrical motor fitted in the system. The beaker is also connected with a cooling tower, which is also made of glass. Cold water enters inside the cooling tower, it cools the alcoholic vapor and get the heat from the vapour.

There is a continuous flow of cold water entering into the cooling tower and exiting as hot water from the tower is also arranged. The glass beaker containing the fermented mash is heated to a temperature 78ºC by means of a temperature controller. It is the boiling point of

alcohol. The vapour thus produced is condensed in the cooling tower and then the vapor is converted into a mixture of alcohol and water. This mixture is collected separately.

Hydrometer

A hydrometer is a device used to find out the density of a mixture of water and alcohol. It is a little float with calibrated stems used to measure the density of the mixture of liquid of water and alcohol. The alcohol content of the mixture can be obtained from the standard two way table plotted with temperature and density of the mixture..

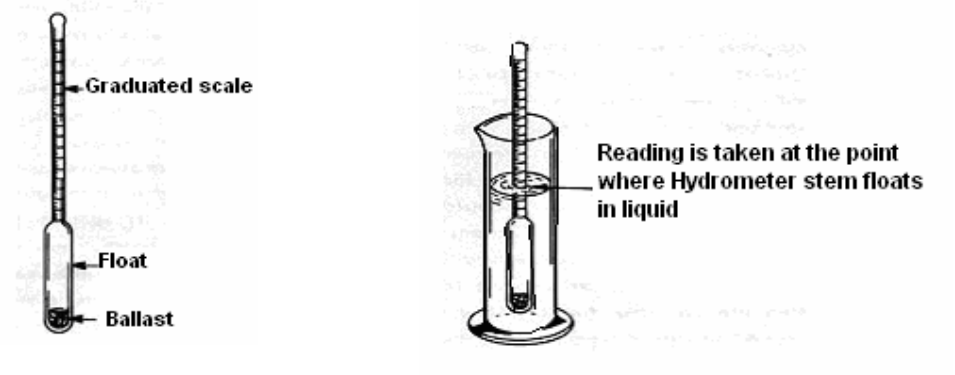

Fig 1: Hydrometer used to measure the density of a mixture of alcohol and water

An electronic balance was used to measure the weight of sweet potato to prepare the cooking material for mash. A sieve of hole size less than 1 mm is used to filter the fermented mash of the sweet potato to separate the waste materials and the beer.

Experimental layout for alcohol distillation from sweet potato

The beer produced from sweet potato in different periods of fermentation is taken up for finding the alcohol content. The experimental layout is shown below for easy under standing.

Table 1: Experimental layout for distillation of Beer prepared from Sweet potato

Fermentation Stages	Replication	Fermentation hours
S1	R1	24
	R2	24
	R3	24
S2	R1	48
	R2	48
	R3	48
S3	R1	96
	R2	96
	R3	96

Note : S- stages of fermentation, R – replication of the experiments

Beer produced in 9 different experiments with different periods of fermentation are distilled to find out the alcohol content. The flow chart for the alcohol production from sweet potato is given below:

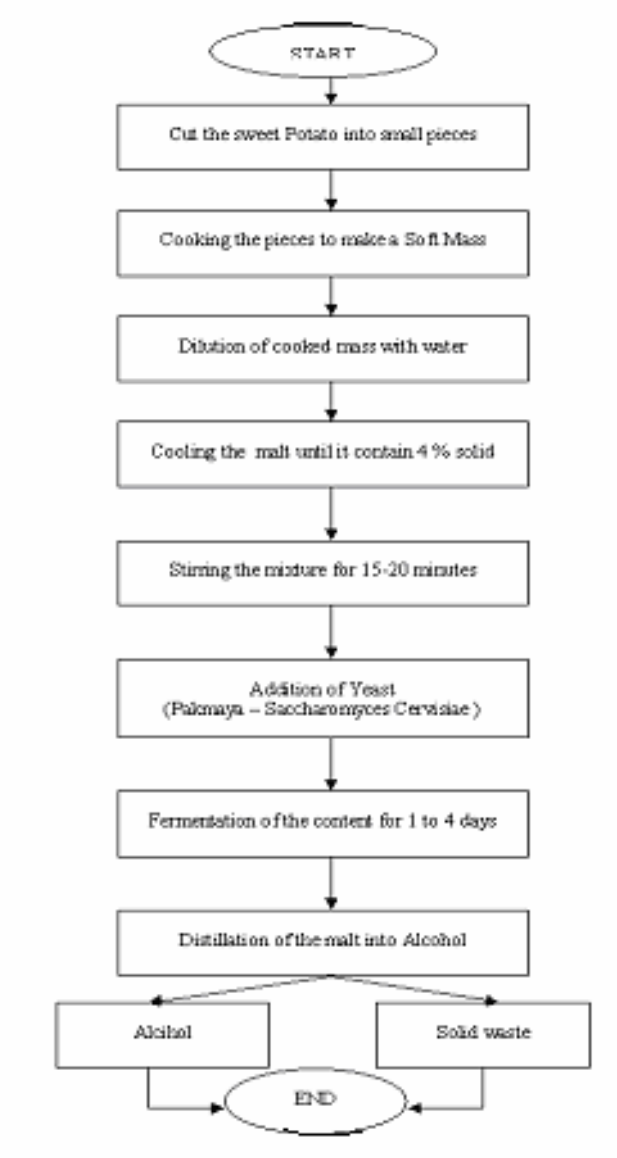

Fig 1: Flow chart for preparation of alcohol from sweet potato

Alcohol content from standard tables.

The beer produced from the sweet potato is distilled in the rotating evaporation type distillation unit. Alcohol is evaporated at the temperature of 78ºC. The alcoholic vapor is cooled by a circulating cold water tube around the vapors. The condensed vapor is collected in the form of distilled alcohol in a container. Alcohol thus produced also has water content. The amount of alcohol collected is measured and water is added to make it 100 ml. The density of the mixture is found out by a standard hydrometer. The temperature of the mixture is found out by means of a accurate thermometer. When the temperature and density of the mixture is known, the alcohol content is found out by using a standard table. The standard table is a two way table containing the density of alcohol water mixture and the temperature of the mixture, which gives the alcohol content. The standard table to find out the alcohol content is given in Annexure.

RESULTS AND DISCUSSIONS

Area of cultivation and productivity of sweet potato in Rwanda

Table 2 brings out the fact that the mean productivity of sweet potato in different parts of the country in Season – A is 11.5 tonnes/hectare and 6.3 tonnes/hectare in Season – B. The average productivity of sweet potato in the country irrespective of seasons is worked out to be 8.9 tonnes/ha.

Table 2: Area of cultivation and productivity of sweet potato

Province	Season – A			Season – B		
	Cultivated area, Ha	Production, tonnes	Productivity, tonnes/ha	Cultivated area, ha	Production, tones	Productivity, tonnes/ha
Byumba	10761	112780	10.5	6888	64564	9.4
Cyangugu	4643	68636	14.8	6762	34826	5.2
Gikongoro	6783	63165	9.3	8160	30525	3.7
Gisenyi	7066	39614	5.6	11424	35330	3.1
Gitarama	14687	117438	8.0	14259	117499	8.2
Kibungo	8580	127701	14.9	9350	66926	7.2
Kibuye	6551	65206	10.0	6490	32756	5
Kigali	11508	195541	17.0	11495	115076	10
Ruhengeri	8883	116084	13.1	11669	57740	4.9
Mean	8829.1	100685	11.5	9610.8	61693.6	6.3

Source : MINAGRI (Rwanda Development Indicator)

Alcohol content of sweet potato beers in different fermentation period

Three replications for 24, 48 and 96 hours of fermentation of sweet potato based beer is carried out to find out the alcohol content. Alcohol produced in 9 different experiments with different periods of fermentation are distilled to find out the alcohol content.

The sweet potato beer of nine samples each weighing 250 ml is produced in the laboratory. Three samples are fermented for 24 hours, the second three samples are fermented for 48 hours and the third three samples are fermented for 96 hours. Data is tabulated in Table 3.

Table 3 reveals the fact that the average alcohol content in 24, 48 and 96 hours of fermentation of sweet potato malt yields 13.0, 13.2 and 12.80 % of alcohol. It is also found that the alcohol content increases up to 48 hours of fermentation thereafter the alcohol content decreases. The reason assigned for increase of alcohol content initially is due to more microbial activity and its multiplication, which consumes the sugar and starch in the beer and produces more and more alcohol. After 48 hours, the feed material present in the beer is almost consumed up by the microbes, there is not enough feed material for further microbial activity, the microbes becomes dormant or it may die for want of sugar and starch or it may consume some alcohol.

Table 3: Alcohol content of sweet potato in 24, 48 and 96 hours of fermentation time.

Fermentation time (Hours) and replications	Distillate collected ml	Dilution with water, ml	Density after dilution, gm / cc	Temp. °C of diluted mixture	Density of 99% pure Ethonol gm / cc	Alcohol % .in 250 ml sample taken	Alcohol %.in diluted distillate
24 Hours							
R1	80	20 (80/100)	0.960	22	0.780	31.92	12.7
R2	60	40 (60/100	0.960	18	0.780	33.48	13.4
R3	82	18 (82/100	0.960	23	0.780	32.18	12.9
Average alcohol content in 24 hours of fermentation, %							13.0
48 Hours							
R1	80	20 (80/100	0.960	19	0.780	33.22	13.3
R2	75	25 (75/100	0.960	20	0.780	32.96	13.2
R3	70	30 (70/100	0.960	21	0.780	32.69	13.0
Average alcohol content in 48 hours of fermentation, %							13.2
96 Hours							
R1	85	15 (85/100	0.960	21	0.780	32.69	13.0
R2	90	20 (80/100	0.960	23	0.780	32.18	12.8
R3	90	10 (90/100	0.960	24	0.780	31.92	12.7
Average alcohol content in 96 hours of fermentation, %							12.80

SUMMARY AND CONCLUSIONS

The study revealed the fact that Rwanda has total cultivated area of sweet potato in both season A and B is 175,592 ha/year and the total sweet potato production in both seasons is found to be 1,607,296 tonnes/year. The mean productivity of sweet potato in different parts of the country in season–A is 11.5 tonnes/hectare and 6.3 tonnes/hectare in season–B. The average productivity of sweet potato in the country irrespective of seasons is worked out to be 8.9 tonnes/ha. Hence; there is a need for alternate use of sweet potato because it cannot be stored for longer periods without decay. The alcohol production from sweet potato showed the fact that the alcohol content increases up to 48 hours of fermentation thereafter the alcohol content decreases. It is found that the average alcohol content in 24, 48 and 96 hours of fermentation of sweet potato malt yields 13.0, 13.2 and 12.80 % of alcohol.

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Finding Solutions to Lighting Problems for the Rural Poor

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Key Words: Rural Light demand, Local Turbine manufacturers in informal sector, LED technology, Affordable Pico and Micro Hydro Projects.

Abstract
This paper discusses how technological advancement and its adaptation by the informal sector has given birth to a revolutionary solution to lighting problems for the rural poor. Thomas Edison's seemingly forward-looking statement that "we will make electricity so cheap that only the rich will burn candles" was true enough for the industrialized world, but it did not anticipate the plight of 1.6 billion people—more than the world's population in Edison's time—who 100 years later still have no access to electricity. Due to population growth, barriers to electrification, poverty and other factors, Edison's dream has remained a dream that until now seems un-surmountable. Estimates by the World Bank show that only two percent of rural Sub-Saharan Africans have access to "modern energy" and electricity. That means at least 500 million people do not. Lighting has been a primary need for the rural areas whose use of fuel from outdated lighting technology typically comprises up to 15 percent of a person's annual income.

The informal sector has been very active in trying to meet this need which has been ignored by the formal sector. To realize this demystification of technology as the reserve for western very sophisticated plants has been necessary. Entry to the informal sector by engineers and technicians has led to the development of affordable technology to generate electricity and distribute it to the rural. This includes the manufacture of affordable small water turbines and wind mills.

New Technological advancement in White Light Emitting (WLED) which consumes very little energy and can light for more than 50,000 hours now makes electricity affordable to the poor. Small electricity projects can now reach up to ten times more people. By manufacturing affordable wind and water turbines and use of WLEDs Edison's dream will become a reality for the rural poor.

Introduction

Thomas Edison's seemingly forward-looking statement that "we will make electricity so cheap that only the rich will burn candles" was true enough for the industrialized world, but it did not anticipate the plight of 1.6 billion people—more than the world's population in Edison's time—who 100 years later still have no access to electricity. Due to population growth, poverty, barriers to electrification, and other factors, the International Energy Agency projects that this number will decline very gradually (by less than 1% per year!) between now and the year 2030.

This paper takes a look at the lighting problems faced by the rural households. It focuses on solutions that our company "Clean Air Energy Solutions" has been researching and implementing, that we believe will enable this group to start benefiting from electricity using renewable energy. It demonstrates how the informal sector can reduce the cost of electricity generating equipment to make them more affordable and how when combined with

advancement in lighting technology the solution is on hand. It also addresses other viable energy solutions that the electricity generated can be used for when it's not fully utilised for lighting. It lays its emphasis on lighting as we feel the large energy needs for heating and cooking can best be met using other renewable energy solutions such as Biogas and Biomass using energy efficient cookers and heaters.

Lighting in the Households

The major sources of lighting for rural households in Kenya and most of Africa South of the Sahara are kerosene and firewood. According to a sturdy conducted by the Kenyan Ministry of Energy in year 2001 on Kenya's demand, supply and policy strategy ; -

- Kerosene is used by approximately 94% of rural households for lighting.
- .The annual per capita consumption of Kerosene at the household level is 90 Litres.
- Electricity only reaches 3.8% of the rural households in Kenya mostly near the large towns.

Kerosene has been for a long time been the more reliable lighting source for the rural households. Above sturdy also show that although one in four people today obtain light exclusively with kerosene, candles and biomass they receive only 0.1% of the resulting lighting energy services. As an illustration of the inefficiencies involved, users of kerosene lighting in Africa pay 600 times more per unit of useful energy services than do those in electrified homes with incandescent lamps in Europe.

The International Energy Agency estimates that, in aggregate, the fuel-based lighting costs the world's poor $38 billion each year, plus ~190 megatons of CO2 emissions, the most important greenhouse gas. This does not even include the costs for candles and batteries. Efforts to address the issue clearly have immense potential benefits for equity, development, and the environment.

Kerosene lamps emit significant amounts of Carbon monoxide and unburned hydrocarbons. This courses indoor pollution, which is hazardous to human health. This is particularly detrimental to school children who must sit very close to the lamps to read. The combustion of one litre of Kerosene produces about 2.5 kg of Carbon dioxide (1). Acute respiratory infections ranked fourth in the share of the burden of diseases in sub-Saharan Africa (accounting for 7% of the total) (2).

The cost of fuel has recently escalated to prices that most of the rural poor can no longer afford. Those who have school going children are forced to use up high percentages of their income for kerosene increasing poverty in the rural areas. Unfortunately due to increased demand for electricity and exhaustion of large scale hydro potential sites the Kenya Electricity Generating Company has become increasingly dependent of diesel driven generators raising the cost of grid electricity tremendously. Small generator sets using fossil fuels have also been popular with imports to Uganda between 1993 and 1997 of estimated total capacity of about 69,955 Megawatts (3).

Presence of good sources of light improves livelihood of the population and makes it possible for households to increase their working hours beyond daylight. Affordable clean energy services will improve the income and health of the households hence reduction of poverty.

Alternative Clean Lighting Solutions.

Electricity is produced mainly from hydropower in most of Africa South of the Sahara However sites with large potentials are quickly running out and alternatives have to be explored. Geothermal energy has become an important source for electricity especially in Kenya with an installed capacity from Olkaria II of 64MW and Olkaria III of a further 64MW. However, its exploitation is very expensive and it's only tapped by use of expensive

technology to supply the main grid. Solar lighting from photovoltaic panels for charging batteries have also become popular with the more affluent rural households but the use is still limited to less than 0.15% of the households due to high initial installations cost of about US $ 625 for a 50 Wp PV System (4). Wind energy has not been used for lighting to any significant degree in the region because of installation cost being very high compared to energy produced from fossil fuels. However with the enormous increase in fossil fuel costs and the resulting green house gas emissions its use is also increasingly becoming viable. Africa and the Middle East annual wind energy potentials is estimated at 76,000 Terawatts-hrs of which 16% is realizable (5).

Barriers to Rural Electrification.

The most important barriers to promotion in rural electrification have been high initial investment costs of renewable energy technologies and inadequate financial intermediaries. Connection to the grid is very expensive for the rural poor who are mainly located far from the grid. Electricity demands by industries and the urban area already outstrips the local hydro electricity supply with most of the large hydro-power potential sites having already been exploited. Current alternatives include geothermal which is very expensive, and utilization of hydro power from sites with potentials lower than 1000kW. These sites have previously not been exploited as they were deemed to be expensive and uneconomical due to cost of small water turbines and distance from the main grid.

Solutions to Rural Electrification Barriers

The popularisation of small hydro-power plants in Kenya especially by Intermediate Technology Development Group (ITDG) has raised a lot of interest by the informal sector in this sector. Through its training about four companies are successfully installing affordable hydro power solutions in Kenya. This has been made possible by availability of information on Micro-Hydro design and locally made equipment.

Project cost for Small Hydro power projects

Using simple but reliable civil works and locally manufactured water turbines coupled with high quality but affordable alternator, electrical control systems and affordable distribution systems that meet regulatory standards most projects are achievable through contributions of about US $ 3.57 Per watt that the beneficiary receive from the projects. Pico and Mini Hydro Electricity projects have been criticized as not feasible as they produce very little amounts of power, are far from the main grids and that the cost per watt is high compared to large hydro power projects. However the value of return is much greater because beneficiaries only require very small amount of electricity basically for lighting, large populations normally live near the sites and can be connected using simple mini grids, Initial Connection fees to the main grid is more expensive than contributions for a small hydro project, cost of power after installation is very low as compared to current Kenya Power and lighting tariffs.

Connection to the main grid in Kenya costs US $ 570 with minimum monthly charges of about US $ 14. Fuel levies have recently doubled the electricity costs in Kenya. Most of the rural poor are unable to raise the installation charges and many of those who do are normally disconnected after a short period due to the very high cost of grid electricity. The comparison below reveals that grid electricity is beyond the reach of the rural poor households as its capital cost is almost 3-5 times their annual income. Renewables, however, are more affordable as they cost a fraction of the annual household income.

Table 1.

Affordability Analysis of Grid Electricity, Solar PV & Pico-hydro by the Poor

	Grid Electricity	Solar PV	Pico-Hydro mini-grid serving 110 households (1.1kw)	Pico-Hydro mini-grid serving 110 households (2.2kw)
Annual Household income (US $)[1]	818	818	818	818
Capital cost per Household Incl. internal wiring $ fittings(US $)	2360-3840	325	56	54
Capital cost per Household as a % of annual household income	289-469%	40%	7%	7
Total upfront cost per household (US$)	2,393-3873	398	162	151
Total upfront cost as a % of annual household income (US$)	293-473%	49%	20%	18%

Source: Kenital, 2003 (6); Maher, 2002a & 2002b (7); ITDG, 2004 (8); Institute of Economic Affairs/Friedrich Ebert Stiftung, 2002 (9); UNDP, 2001 (10); Republic of Kenya, 200a (11).

[1]Only applies to household income in the Kirinyaga District where the two pico-hydro projects are installed. Comparatively, household income is estimated to be US $ 1,825 deriving from the US $1 per capita per day threshold; approximately US $ 1800 (2002) based on National GNP; and, about US $ 957.

Pico-hydro

Ndima Pico-hydro power project (ITDG)

Located near Kerugoya in Kirinyaga District of Central Province this project was installed in 2001 to produce 3kW for a mini grid to supply 100 homes with lighting. The total cost of the projected is estimated at US $ 70,000 with service lines to 100 homes. It is now more than six years old since supply started in 2002 and serves 150 members with very few members being permanently disconnected since. Each household can use three 7 watt energy saver bulbs all lighted during the peak hours. Using LED lights each homestead can now use 6 lights of 1.5watt each and have a radio or a low watt Television operating at the same time. Membership can be increased to 200 homes with the use of LED lights. Other uses of the energy during of peak hours includes use of electric equipment for processing animal feeds, lighting and heating for chicken at night, a barber shop and security lighting for the community.

This project was made possible by member contributions from the community of US $ 300 with the balance being met by ITDG and the ministry of Energy. The community has been able to maintain the project through monthly payments of US $ 3. Benefits have included clean energy for lighting, Radio, Television and for food processors. Reductions have been seen in use of kerosene, diesel, dry cells and battery charging from grid power as illustrated below.

The project is currently being upgraded by the community to increase the output to better serve the beneficiaries. Other projects have also been developed in the area with a Micro-Hydro project producing 14kW situated only 1km up stream. The success of these projects prove that they are viable and indeed cheaper than the large projects and have minimum ecological impacts are they are mostly runoff the river projects.

Table 2

Energy Source	Pre-electrification average expenditure (Kshs.)	Post-electrification average expenditure (Kshs.)	Percentage decrease (%)
Kathamba Pico-Hydro Installation			
Lighting			
Kerosene	340	94	72
Candles	62.5	0	100
Entertainment (radio & TV)			
Battery Charging	90	0	100
Dry Cells (non-rechargeable)	241	93	61
Thima Pico-hydro Installation			
Lighting			
Kerosene	323	149	54
Candles	33	0	100
Entertainment (radio & TV)			
Battery Charging	146	75*	49*
Dry Cells (non-rechargeable)	207	66	68

Source: Adapted from Balla, 2003 (13)

Locally Manufactured Water Turbines

Manufacture of affordable high quality turbines with efficiency higher than 75% has been made possible by: -

- The availability of simple high quality designs
- Experienced personnel in the informal sector
- Availability of materials required.

However, the lack of foundries that can manufacture turbine bodies and runners restricts the fabrication of some types of turbines that would be best suited for some of the sites. Locally manufactured turbines are priced at about 70% less than new imported turbines and 40% less than reconditioned imported turbines. Most Pico to Micro-Hydro sites require custom made turbines and they are not only expensive to import but they also take about 8 months before delivery. Availability for readymade turbines for Pico, Micro and Mini Hydro projects is also very limited as most sites have unique characteristics which make uniformity very hard. Quantities required are also very small for large manufactures locally and abroad to be interested in. Imports from Asia are also more expensive than locally made turbines and of less quality. Local manufacturers are also able to support their turbines better as compared to distant manufactures where cost of returning the equipment or receiving parts is expensive and takes long.

High quality efficient Cross flow, Pelton, Kaplan and Reversed Pump turbines can now be fabricated at affordable prices locally. Fortunately most of our local sites can be served very well by the two types. Turgo, Francis and Kaplan turbines are hard to fabricate to precision that would result to good efficiency. Francis turbines would be applicable for sites with high volumes of water with low heads that would not be served by the Pelton or

Crossflow turbines. This makes it necessary and thus the need for foundries that would manufacture high quality reaction runners and cylindrical sophisticated bodies.

Technology Advancement in Lighting – WLED
Fig 4.

Light Comparison Table

Lamp Type	Homemade Kerosene	Incandescent	Compact Fluorescent	WLED
Efficiency (Lumens/Watt)	0.03	5-18	25-50	90-110
Rated Life (Hours)	Supply of kerosene	1,000	6,500 – 15,000	50,000 to 100,000
Durability	Fragile and dangerous	Very fragile	Very fragile	Durable
Power consumption (Watt)	0.04 – 0.06 Litres/hour	45W	7W	2W
CCT deg K	1,800 deg.	2,652 deg.	4,200 deg.	5,000 deg
CRI	80	98	62	82
$ after 50,000 Hours	$1,251	$175	$131	$20

Source: Light Up The World, 2007 http://www.lutw.org/techapproach.htm, Philips Lumileds Lighting Co.

New advancement in technology in lighting has recently improved efficiency in lighting using White Light Emitting Diodes (WLED). LEDs are diodes, which is a semiconductor device that will conduct electricity in only one direction. The device is fabricated from layers of silicon and seeded with atoms of phosphorus, germanium, arsenic or other rare-earth elements. The layers of the device are called the die and the junction between the materials is where the light is generated. The electricity enters from one side of the die and exits out the other. As the current passes through the LED device, the materials that makes up the junction react and light is emitted. Different materials and designs have different colored lights and intensities. LEDs are now bright enough to be considered for applications that traditionally use incandescent bulbs.

Technical advances have dramatically improved the reliability and the performance of the LEDs since they were invented in the 1960's. The lifetime for the well engineered new generation of LEDs is around 100,000 hours of use, or 30 to 40 years of normal operation. Because they are a semiconductor device, they are also very rugged and are not subject to fail when dropped or vibrated, as do incandescent and fluorescent lights.

The original LEDs only emitted light of one frequency or color of light. These were blues, greens, yellows, oranges or reds and they were unsuited for domestic lighting. Recent innovations in materials, doping and die structure have developed high brightness LEDs that emit light in all visible frequencies to produce white light.

LED technology has developed rapidly with the achievement by Cree, Inc. (US) demonstrating a 65 lm/W commercial use light in September 2003 and a 131 lm/W by 2006 at 20 mA. Nichia Corporation has developed a white light LED with luminous efficacy of 150 lm/W at a forward current of 20 mA which will revolutionize the LED market if available in the market next year as planned at an affordable price. Curently the highest efficiency high-power white LED is claimed by Philips Lumileds Lighting Co. with a luminous efficacy of 115 lm/W (350 mA).

Some of the benefits that WLED give include: -

- LED's convert about 90% of the electricity into light. A 1 Watt LED Emits approx 100 Lumens as compared to Incandescent bulbs with only 17 Lumens to a watt and 50 Lumens for Compact Fluorescent tubes (6)
- LED's work at low and save voltage
- LED's generate very low heat thus efficient and save to touch.
- LED's Lasts about 100,000 hours about 5 years continuously without replacement
- No damaging Ultraviolet so they do not cause fading to artwork
- Not fragile or sensitive to shake
- Directional so emits higher percentage of light in the desired direction.
- Colored LED lights produce just needed colors thus no need for filtration

Table 5.

COMPARISON OF BENEFICIARY COST FOR A 10KW MICRO-HYDRO PROJECT

BULB TYPE	PROJECT WATTS	BULB WATTS	4 BULBS WATTS	TOTAL BENEFICIARIES	PROJECT COST [1] US $	CONTRIBUTION PER BENEFICIARY US $
Incandescent bulbs	10,000	45	180	56	57,142	1000
Compact Fluorescent bulbs	10,000	7	28	357	64,285	200
WLED	10,000	1.5	6	1,667	85714	51

Source: My own Estimates based on lumens per watt achievable from each technology.
[1] Estimated project cost increases by larger distribution system for increased beneficiaries.

Conclusion

At an approximate cost of US $ 51 per beneficiary using LED bulbs, lighting for rural poor is now feasible where Pico to Micro-Hydro sites are found. Solar and wind turbine mini-grids should also be feasible. Local manufacturing of affordable turbines and new technology in lighting by use of White Light Emitting Diodes (WLED) has now made small hydro projects viable and affordable to the rural households. Small hydro projects can now serve many more beneficiaries than was possible before reducing each beneficiary's contribution. By being able to extract some of the 65% hydro-potential that has been considered not feasible the potentials of lighting the rural poor and also the increased input to the grid would be massive. Development of affordable and efficient wind power generating equipment is the new frontier and a challenge that when conquered a true solution for lighting for the rural households will be in hand. Locally we have made no significant progress in the manufacture

of Solar lighting equipment and photovoltaic technology products are all imported. However the assembly of photovoltaic cells locally can drastically reduce the cost making it more affordable to the rural poor.

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Using Wind Energy for Harvesting and Providing Sustainable Safe Groundwater for a Rural Community in the Masendu Ward in Zimbabwe

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Abstract
Masendu Ward is a Rural Community in Zimbabwe with a population of approximately 16500. It lies in a semi - arid region with a low average seasonal rainfall resulting in a general water shortage. Unavailability of reliable water sources is a cause for concern which weakens the community to cope with development needs. This is exacerbated by the emigration of young people to neighboring countries in search of employment leaving the very young and very old to fetch water. This paper is an offshoot of a community intervention project funded by Kellogg Foundation through the Institute of Rural Technologies. It looks at harnessing the use of windmills as an alternative source of energy. The aim is to supply sufficient water to the Community by establishing suitable sites for boreholes and installing improved windmills. It highlights community involvement in the fabrication of the new windmill system. It is an experimental intervention study that results in water availability leading to community development and engagement in commercial activities. The project team designed and constructed a windmill with a 100% improved throughput and less material content on the wheel. Results pertaining to the improvement of windmill efficiency are an ongoing issue.

Introduction

A windmill is a machine that converts wind energy to usable energy through the rotation of a wheel made up of adjustable blades. It is an environmentally friendly way of pumping water which has been used for a long time. It does not require human power and uses wind a renewable source of energy. Most Rural communities in Zimbabwe are characterized by the unavailability of safe drinking water. While this is not prevalent in all rural areas, Masendu ward has such a problem that affects development of the community. The ward is in the Bulilimamangwe Rural District in the Matabeleland South province of Zimbabwe. The ward consists of six villages covering nearly 42km^2 with a population of approximately 16500 [1]. The villages together have a common problem of water shortage for domestic and agricultural activities. This is as a result of the ward being located in the semi-arid region that has a low average seasonal rainfall of 493mm [2]. It becomes prudent to alleviate the problem of water shortage by utilisation of technological means for groundwater abstraction. Wind energy was the main focus of progression to resolving the problem. Wind is a renewable resource that can be put to good use and in areas where there is no electricity, it becomes quite useful. In this development, the project team looked and encompassed skills transfer and capacity building for community members.

Statement of the problem.

There is a general water shortage in the ward to carter for domestic, livestock and commercial use. Boreholes have been sunk by the District Development Fund (DDF) and

these use manual hand pumps. Many have become dysfunctional due to various reasons. Most youths have emigrated to neighbouring countries in search of employment leaving the very young and very old to fetch water from the manual hand pumps. A survey of the community has indicated that there is a perceived aquifer in one of the villages (Luvuluma). Windmill power is an appropriate alternative for driving pumps required to draw water from boreholes to the surface, especially considering that there is limited electricity supply in the ward and the use of hand pumps is laborious.

Hypothesis

The people in the community are convinced that there is an underground aquifer in Luvuluma village and that can be a source of ground water. The wind blows all year round though at varying speeds and directions. This wind power can be utilized for driving water pumps. There are 3 windmills in the ward and these are not properly working due to lack of maintenance and spare parts.

Aim and Objectives

To utilize wind energy to provide consistently sufficient safe water supply to the Masendu community simultaneously capacity building local cadres.

In order to achieve this, the project team will focus on the following areas

- To establish the extent of water shortage and provide a solution to the problem using appropriate technology.
- To design, manufacture, install and commission windmill pumps and related water reticulation infrastructure at suitable sites.
- To train the community in maintaining and repairing windmill equipment.
- To, through research, acquire knowledge in renewable energy utilisation.

Study Design

This study is two fold as it is experimental and interventional. Experimental in that it involves the assessment of current windmill technology and formatting efficiency improvements. It is interventional in that while the research is being done, the community requires water supply and hence the current technologies are utilized to urgently intervene and provide water.

Theoretical framework

To benefit from appropriate technology, an efficient energy supply system is required. Several energy sources including electricity, hand pumps and windmills have been employed for pumping water. Electricity is expensive and is therefore not an option for most rural communities (e.g. Masendu) in the developing countries. Wind energy is an economic alternative source for pumping water where wind conditions are reliable. A windmill is a machine that converts wind energy into usable energy through the rotation of a wheel made up of adjustable blades, [3] and has been in existence since A.D. 500. This method is efficient, does not require human power, is environmentally friendly and is cheap [4].
Windmill with a drive mechanism that incorporates gears has been found to be durable [5]. In 1886, Thomas Perry designed the aerodynamic multi-bladed windmill [6], which is in

common use in Zimbabwe. The use of windmills in Zimbabwe has deteriorated, as they seem to have inherent faults. The gear box that converts rotational motional into vertical reciprocating motion fails often and hence rendering them unusable a few years after installation.

Water consumption was found to be significantly correlated to explanatory variables such as “household size” and “age of the household’s head” [7]. With these variables, water consumption can vary from 100-170litres per person per day [7]. The Masendu community has varying household sizes and livestock. Some villages engage in gardening activities while others do brick moulding. All these factors affect water consumption.

Sandstones characterize Masendu area and this type of geology is known to be very high yielding in underground water. Studies in the Nyamandhlovu-Tsholotsho areas that lie to the north of Masendu ward [8] as well as areas around Bulawayo [9] with a similar geological outlook have shown high groundwater potential. Oral discussion with community members have shown that Luvuluma village lies on top of an aquifer that stretches from Nyamandhlovu and boreholes in that area have good yields at an average depth of 50 meters.

Methodology

The methodology used directed effort towards provision of water to the community as an urgent intervention while at the same time making improvements and research comparisons on boreholes pumped by electric pumps with those pumped by windmills. Interviews were conducted with community members with each village providing two representatives to be part of the research team. These representatives were given questionnaires to establish water requirements for their respective villages.

A survey visit was done to the Provincial headquarters and the district offices of the District Development Fund (DDF) in Gwanda and Plumtree respectively. The aim of these visits was to establish the number and status of boreholes and the challenges that the DDF is facing in repairing and maintaining existing boreholes.

Windmill manufacturers were visited and the researchers’ engineering intervention was intended to improving the durability of functionality and efficiency of the windmill system.

Masendu Central village houses a cultural centre for the ward that is going through major development. At this cultural centre there is a small fabrication workshop doing a commercial activity in the area. As part of capacity building, the researchers were working together with two key members of this cooperative for skills transfer and capacity building. Members of this cooperative have no formal qualification in fabrication or business management. Fabrication work is done by semi-skilled workers. Furthermore various community cadre teams collaborated with the Institute of Rural Technology (IRT) research team other than the cooperative members referred above.

Results

The results are presented under the ensuing subheadings thus;

Water demand survey

Table 1 below shows the estimated population, used to derive the water demand, in the ward by village. Water consumption per person each day was pegged at an average of 100 litres.

Table 1 Ward Water demand survey by village

Village (Estimated population)	Number of Boreholes	Water yield per village at average of 2000l/hr per borehole	Estimated daily Water demand (litres /day)	Water deficit per day in each village
Masendu Central (3600)	8	128,000	360,000	-232,000
Thandawani (3000)	1	16,000	300,000	-284,000
Tjeboroma (3200)	1	16,000	320,000	-304,000
Mambo (2400)	7	112,000	240,000	-128,000
Luvuluma (2000)	Not established		200,000	-200,000
Makumbi (2300)	Not established		230,000	-230,000
TOTAL			**1,650,000**	**-1,378,000**

The ward has an overall water demand in excess of 1,650,000liters each day. This demand is compared with the current capacity of installed boreholes giving a daily water deficit of 1,378,000litres per day for the ward. It is important to note that at this stage, the demand estimation excludes water demand by livestock and gardening activities.

The research looked at the borehole distribution and calculated an estimate of the output that is expected per day. This is on the assumption that each borehole has a yield of 2000liters per hour and pumping is done 8 hours a day. Information in Table 1 considers water from all boreholes noted as supply for the ward. This is considered with the background information that some of the boreholes in the ward have salty water and have not been abandoned.

Ward Water points Audit

An audit of the current number of boreholes in the ward was conducted. Table 2 shows a breakdown of the boreholes distribution in the six villages, the record of boreholes sited by the IRT team and intervention work done.

A survey of the villages showed that the boreholes are distributed regardless of the population distribution and this leaves some homesteads in the villages more exposed to water shortage than others. The IRT team pegged and facilitated drilling of some boreholes in the ward as indicated in the table above.

In view of the ward setup and population of people and boreholes, the research team did an analysis to establish the adequacy and need of water in the water. This paper is an offshoot of a project to provide water in all the villages. What has been done to date is only a step towards provision of sustainable water sources for the ward at large. No work has been done in Mambo and Makumbi villages as the team has not started work in these villages. The pilot project was set for Masendu Central, Thandawani and Tjeboroma villages.

Table 2 Village Water points distribution

Village	Number of Boreholes			Comment
	Current / In existence	New sites pegged /surveyed	Drilled this project.	
Masendu Central	8	6	1	Complete drilling and installation of electric pump on 1 site, where water is already being drawn.
Thandawani	1	1	1	Complete fabrication and installation of windmill and tank for garden irrigation and livestock watering. Has a dam, which supplies more water although it quickly dries out.
Tjeboroma	1	2	1	Drilling complete and windmill fabrication in progress.
Mambo	7	0	0	Boreholes quickly dry out due to alleged lack of adequate ground water
Luvuluma	No. not established	3	1	1 flushed unsuccessfully
Makumbi	No. not established	Yet to be surveyed and pegged	0	No work was done by the IRT researchers in this village.

District Development Fund (DDF) Operations

DDF has a water infrastructure maintenance team that is based in the ward. It is however currently not fully equipped and hence not attending to maintenance of boreholes in the area. This results in the exacerbation of the water shortage problems in the ward. An interview with the District water engineer at DDF revealed the following problems.

- Knowledgeable workers who are experienced in borehole installations and maintenance have left the country.
- Due to the economic hardships in the country, DDF is currently under-funded hence has inadequate money to carryout repairs for the boreholes as necessary.
- There is a general shortage of spare parts so repair and maintenance activities cannot be completed.
- If underground pipes leak, DDF would remove and not replace the leaking pipe and hence the pumping cylinder would be above the water table and this result in the borehole quickly drying up.

Windmill design, fabrication and installation

The research team designed a windmill which takes from the traditional windmill with specific improvements for efficiency of use. The main improvements to note are on the wheel, gearbox and the supporting structure. The wheel of the windmill is a 3meter diameter one with blades made of reinforced 0.8mm galvanised sheets. This reduced the total weight of the wheel material translating directly to savings in material used. Other windmills in operation are made of 1mm-1.2mm galvanised sheets. The advantage to reduced weight in this way is that the windmill is capable to turn easily from slow wind speeds as compared to those with thick and heavier blades.

The gearbox for assessed windmill manufacturers in Zimbabwe from 3 main manufacturers have an average stroke length of 150mm. Our design influences a stroke of 300mm in a borehole cylinder of 900mm. This improvement gives a 100% increase in water throughput per wheel rotation.

There was also resulting and persistent bearing failure at the connection of the gearbox to the supporting structure and an improvement for use of thrust bearings reduces the number of failures. The main support structure was so designed to withstand all calculated forces while remaining economic for construction. As such the designed windmill offers a cost saving of 35% compared to other manufacturer's windmills.

The picture in Fig.1 below shows the IRT water group team working on one of the windmill wheels in their workshop.

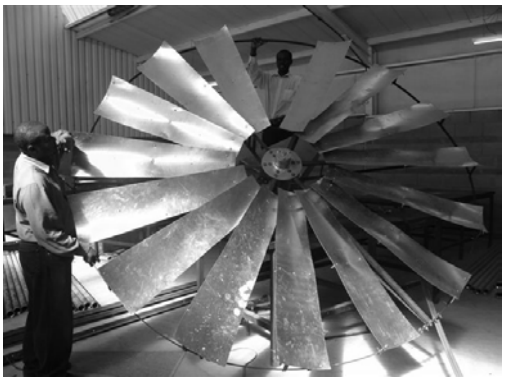

Figure 1. Nicholas Tayisepi and William Goriwondo holding the wheel in the workshop.

Each village in the ward will have a windmill/windmills installed. The water shortage in the ward can be alleviated by installation of water abstraction systems that use wind energy as a source of power. Apart from Masendu Central village and the cultural centre in particular, all other villages have no electricity. This gives use of Windmills an urge over electric pumps. The emigration of young people in the ward also gives windmills an urge of hand pumps as windmill power does not get tired as long as wind is blowing. In the same way, water would be pumped into storage tanks for use later when the wind is not blowing. Windmill power whenever wind blows and storage tanks are not full would be used to pump water that would become available when required.

Challenges

Promoting the use of new technology in developing countries face a major challenge in that the deserving communities will be requiring urgent assistance and research takes time to deliver. As in this case, there was a push to have water for the communities; all recommendations and findings were not implemented as at present though these would be implemented at project completion. This cause a problem in developing countries for the use of appropriate technology would be delayed.

This project was conducted in a hyperinflationary environment which made it difficult and caused a lot of distortions. The challenges appeared throughout the life cycle of the project.

Community level challenges

The community have cadres that are responsible for Water and Sanitation as well as others that are responsible for Infrastructure development. These were attached to the project and would be expected to perform manual work together with the project team. As this was a voluntary exercise, team members lost interest along the way as they did not recognise with the project. 4 cadres were selected to work with the research team together with 3members from Bazose cooperative. Of the 7 members, only 4 consistently worked with the IRT

research team. The other 3 disappeared and hence did not benefit from the intended skills transfer and community capacity building.

Material and services supplies

As this was an experimental project, the Bill of Materials would be largely dependent on the final quantities. This was not the case since the project was also interventional with the need to urgently provide water to the community. The hyperinflationary environment compounded the problem. This meant that all quotations given by suppliers would be valid for 24hrs. The project team was not responsible for procurement and by the time the orders are placed, materials prices may have gone up or may have been sold out. This presented a great challenge for the researchers. You are always rushing to have materials procured effectively while they are still available.

Conclusion

There is a significant shortage of water in the ward which warrants great improvement in the water supply situation. The IRT research team set to replace the use of hand pumping with an improved type of windmill and this would provide a facility for water storage as opposed to collecting just enough when hand pumping is in use. An improvement to the windmill structure and gearbox was done and this is intended to replace the traditional manual pumping of water and hence improvement to irrigation at Thandawani garden. On completion all the target areas will have improved water supply. Capacity building and skills transfer was achieved as Bazose cooperative members and community cadres were trained on-the-job during the project. These would be available to attend to regular maintenance and minor repairs of windmill pump systems. Future work in the ward involves the possibility of totally providing for infrastructure to meet the total water demand of all households in the ward and their anticipated development needs. Lack of access to a reliable source of water impedes community development as community members spend lots of time abstracting water.

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Estimation of Global Solar Radiation in Rwanda using Empirical Models

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Keywords: Global solar radiation, Angström, Energy, Photovoltaic, Rwanda.

Abstract

Understanding solar radiation data is essential for modeling solar energy systems. The purpose of the present study was to estimate global solar radiation on horizontal surface using sunshine-based models. Angström-type polynomials of first and second order have been developed from long term records of monthly mean daily sunshine hour values and measured daily global solar radiation on horizontal surface at Kigali, Rwanda. Coefficients of those polynomials were derived using least square regression analysis. These coefficients were then used for the estimation of solar radiation in other places of Rwanda where measures of solar radiation do not exist but sunshine records are available.

Introduction

While Rwanda has adequate solar energy potential to support its energy demand, it is therefore important to harness that resource in view to find solution to energy shortage and environmental degradation the country is being faced to. Solar energy is now considered to be the most effective and economic alternative resource [10]. In developing countries, such as Rwanda, interest in solar energy applications has been growing in providing electricity and water supply in rural areas. Understanding solar radiation data is essential for modeling solar energy systems. Solar radiation is used directly to produce electricity for photovoltaic (PV) systems and solar thermal systems. Therefore, precise knowledge of historical global solar radiation at a location of study is required for the design and estimation of the performance of any solar energy system.

In Rwanda, quite few stations have been measuring the daily solar radiation on a consistent basis. Geostationary satellites give estimates of incident radiation on large regions (1° by 1° or larger grid-cells) but their non-precise historical databases have limited applications for local studies [5], [9]. In the absence and shortage of reliable solar radiation data, hence, it is necessary to approximate solar radiation by the use of empirical model in order to estimate and predict global solar radiation. These models use historical meteorological data of the location under study. Empirical models are classified in three categories: sunshine-based models, temperature-based models and cloud-based models [4], [6], [8], [11]. Recently some studies on modeling solar radiation have been done in Rwanda [2], [7], but yet comparative studies on techniques used and results are still needed.

In this work, Angstrom-type polynomials of first and second order have been developed for approximating the global solar radiation in Rwanda from a long term records of monthly mean daily sunshine hour values and measured daily global solar radiation on horizontal surface at Kigali International Airport station, Rwanda. Correlation coefficients obtained from the least square regression were then used to estimate solar radiation at locations where only sunshine records were available.

Data and methods

Data

In Rwanda, recorded global solar radiation data on horizontal surface were obtained for only one station located at the International Airport of Kigali (Lat: 01° 58S, Lon: 030° 08E, Alt: 1,490m). The remaining primary surface weather stations are recording daily temperature, pressure, relative humidity, precipitation, wind speed and direction, and sunshine duration. While the secondary stations (not mentioned in the present study) are recording temperature, pressure, relative humidity and precipitation. Data were provided by the Department of Meteorology in the Ministry of Infrastructure (Rwanda). Table1 presents the locations of stations and the period of observation for which global solar radiation R_G and sunshine duration S were measured.

Table1: Location of stations and period of observations of global solar radiation and daily sunshine duration.

Station	Altitude	Latitude	Longitude	R_G	S
Kigali	1,490m	01°58' S	30°08' E	1984-87	1971-now
Butare	1,760m	02°36' S	29°44' E	-	1988-93
Kamembe	1,591m	02°28' S	28°55' E	-	1988-99
Gisenyi	1,554m	01°40' S	29°15' E	-	1986-93
Gikongoro	1,930m	02°29' S	29° 34' E	-	1990-99
Kibungo	1,680m	02°10' S	30 ° 32' E	-	1990-92

Description of the model for the estimation of solar radiation

The global solar radiation reaching the earth's surface is made up of two components, direct and diffuse. Direct radiation is the part which travels unobstructed through space and the atmosphere to the surface, and diffused radiation is the part scattered by atmospheric components such as gases molecules, aerosols, dust and clouds.

At the top of the atmosphere, extra-terrestrial solar radiation, also known as Angot radiation (Whm^{-2}/day^{-1}) can be calculated using the following expression:

$$R_0 = I_0 \frac{24}{\pi}(1 + 0.033\cos(\frac{2\pi}{365}J)\cos\phi\cos\delta\sin\omega_s + \frac{2\pi}{360}\omega_s\sin\phi\sin\delta) \qquad (1)$$

Global solar radiation reaching the Earth's surface can be estimated by empirical models when measured data are available. The simplest model commonly used to estimate average daily solar radiation on horizontal surface is the well-known Angström equation [1], [3]:

$$\frac{\overline{R}_G}{\overline{R}_0} = \alpha_1 + \alpha_2(\frac{\overline{S}}{\overline{S}_0}) \qquad (2)$$

Angström had suggested values of 0.2 and 0.5 for empirical coefficients α_1 *and* α_2 respectively.

In the present study, Angström model was compared to a second degree polynomial function of monthly average daily sunshine hours of the form:

$$\frac{\overline{R}_G}{\overline{R}_0} = \alpha_3 + \alpha_4(\frac{\overline{S}}{\overline{S}_0}) + \alpha_5(\frac{\overline{S}}{\overline{S}_0})^2 \qquad (3)$$

Results and Discussion

Linear and polynomial least square regression techniques were developed based on equations (1), (2) and (3), and observed global solar radiation at Kigali International Airport station. The computed values for the coefficients of regression are $\alpha_1 = 0.2416$, $\alpha_2 = 0.6411$, $\alpha_3 = 0.0696$, $\alpha_4 = 1.3261$, $\alpha_4 = 1.3261$, $\alpha_5 = -0.6674$.

The linear Angström equation is then given by:

$$\frac{\overline{R}_G}{\overline{R}_0} = 0.2416 + 0.6411\left(\frac{\overline{S}}{\overline{S}_0}\right) \quad (4)$$

And the second degree polynomial function is given by:

$$\frac{\overline{R}_G}{\overline{R}_0} = 0.0696 + 1.3261\left(\frac{\overline{S}}{\overline{S}_0}\right) - 0.6674\left(\frac{\overline{S}}{\overline{S}_0}\right)^2 \quad (5)$$

Values of $\overline{R}_G$ (4) and $\overline{R}_G$ (5) corresponding to the estimated global solar radiation respectively with equations (4) and (5) are presented in Table2 and are compared to the measured values $\overline{R}_{Gobs}$. The deviations between the estimated and measured values given by R^2 (%), RMSE (%) and MBE (%) are presented in Table3. The poor correlation observed in Figure1, Figure2 and Table2, during the rainy season period (November to April) is probably due to large differences in the characteristics of the sky during this period. Nevertheless, the two models are slightly in good agreement with the observed data, and hence they can simply be applied to estimate monthly average daily global radiation from monthly average daily sunshine hours, which are available in primary stations across the country. The results in Table4 give an annual solar radiation of 5269 Wh/m^2/day for Rwanda while the commonly given value in literature or web site is 5.15 kWh/m^2/day. In [7], the monthly value obtained by the authors using a non linear meteorological radiation models (MRM) with satellite data was varying between about 4.3 and 5.2 kWh/m^2/day. In the present study in Table3, the minimum value for the station of Kigali (R_G (4) = 4942 Wh/m^2/day, R_G (5) = 4960 Wh/m^2/day) occurs in May, while the maximum value (R_G (4) = 5721Wh/m^2/day, R_G (5) = 5738Wh/m^2/day).

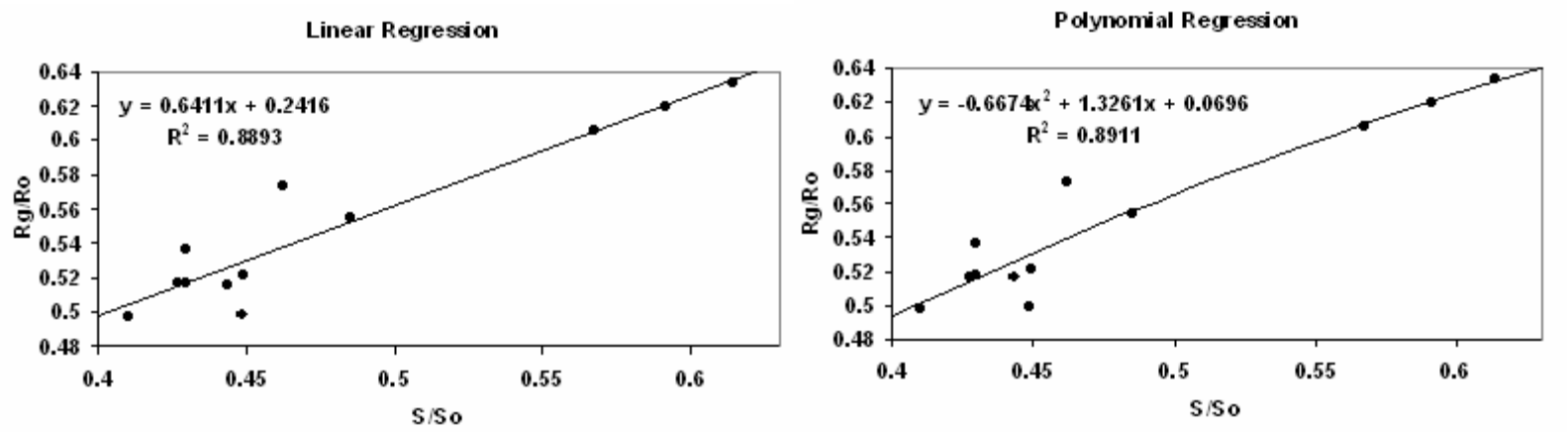

Figure1: Least square linear regression and polynomial regression between R_G/R_0 and S/S_0

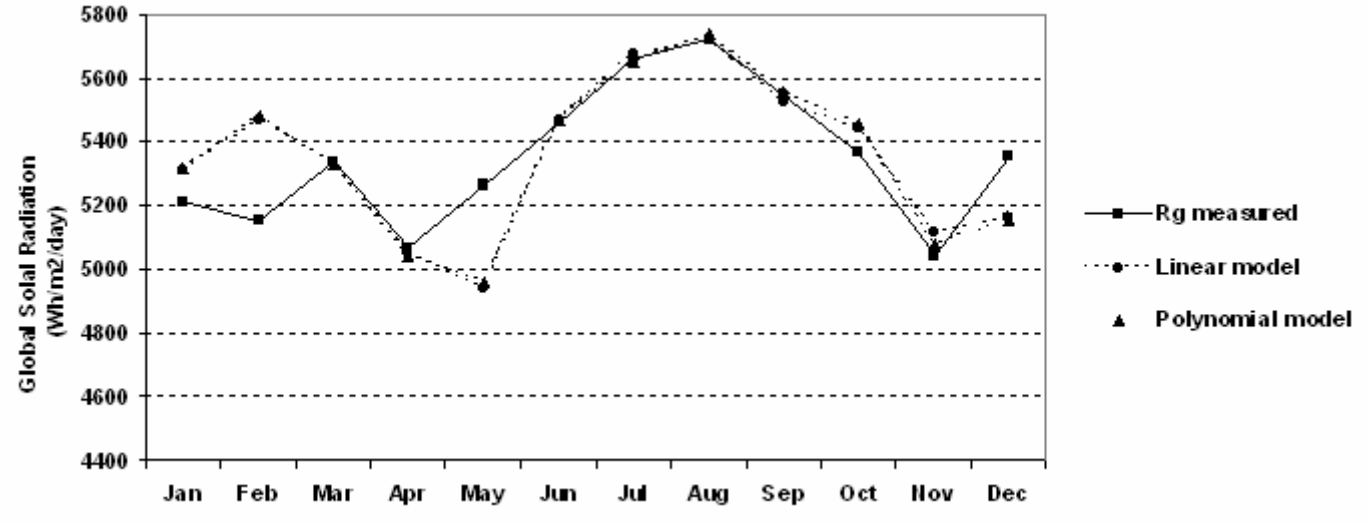

Figure2: Comparison of Global solar radiation and estimates of global solar radiation from equations (4) and (5) at International Airport station of Kigali.

Table2: Comparison between the observed global solar radiation R_{Gobs} and estimation of global solar radiation from equations (4) $R_{G\,(4)}$ and (5) $R_{G\,(5)}$ at the station of Kigali.

Month	R_{Gobs}	$R_G(4)$	R_G	RE(4)	RE(5)
Jan	5211	5311	5315	-1.91	-2.00
Feb	5156	5473	5483	-6.15	-6.34
Mar	5339	5336	5326	0.06	0.25
April	5067	5055	5043	0.24	0.47
May	5267	4942	4960	6.16	5.82
Jun	5461	5472	5469	-0.20	-0.14
Jul	5664	5680	5652	-0.28	0.21
Aug	5722	5721	5738	0.02	-0.27
Sep	5544	5525	5557	0.35	-0.23
Oct	5367	5447	5457	-1.49	-1.67
Nov	5042	5114	5079	-1.43	-0.75
Dec	5356	5161	5151	3.63	3.81
Annual	**5350**	**5353**	**5352**	**-0.06**	**-0.05**

Table3: Values of R^2, RMSE (%), MBE (%)

Model	R^2	RMSE (%)	MBE (%)
Linear	0.8893	2.78	-0.062
Polynomial	0.8911	2.77	-0.054

Table4: Annual values of the ratio S/S_0, extraterrestrial solar radiation R_0, estimate of Global solar radiation R_G in Rwanda, and the ratio R_G/R_0.

Station	Annual S/S_0	Annual R_0 $Wh/m^2/day$	Annual R_G $Wh/m^2/day$	Annual R_G/R_0
Kigali	0.477	10098	5335	0.53
Butare	0.502	10164	5488	0.54
Kamembe	0.414	10150	4937	0.49
Gisenyi	0.454	10067	5196	0.52
Gikongoro	0.507	10152	5529	0.54
Kibungo	0.446	10119	5131	0.51
Average	**0.466**	**10125**	**5269**	**0.52**

Rwanda, being a small country but with difference in terrain at different locations, the computed coefficients $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ obtained by least square regression techniques have been used to estimate global solar radiation at places where there is no equipment to measure that quantity but sunshine duration has been measured.

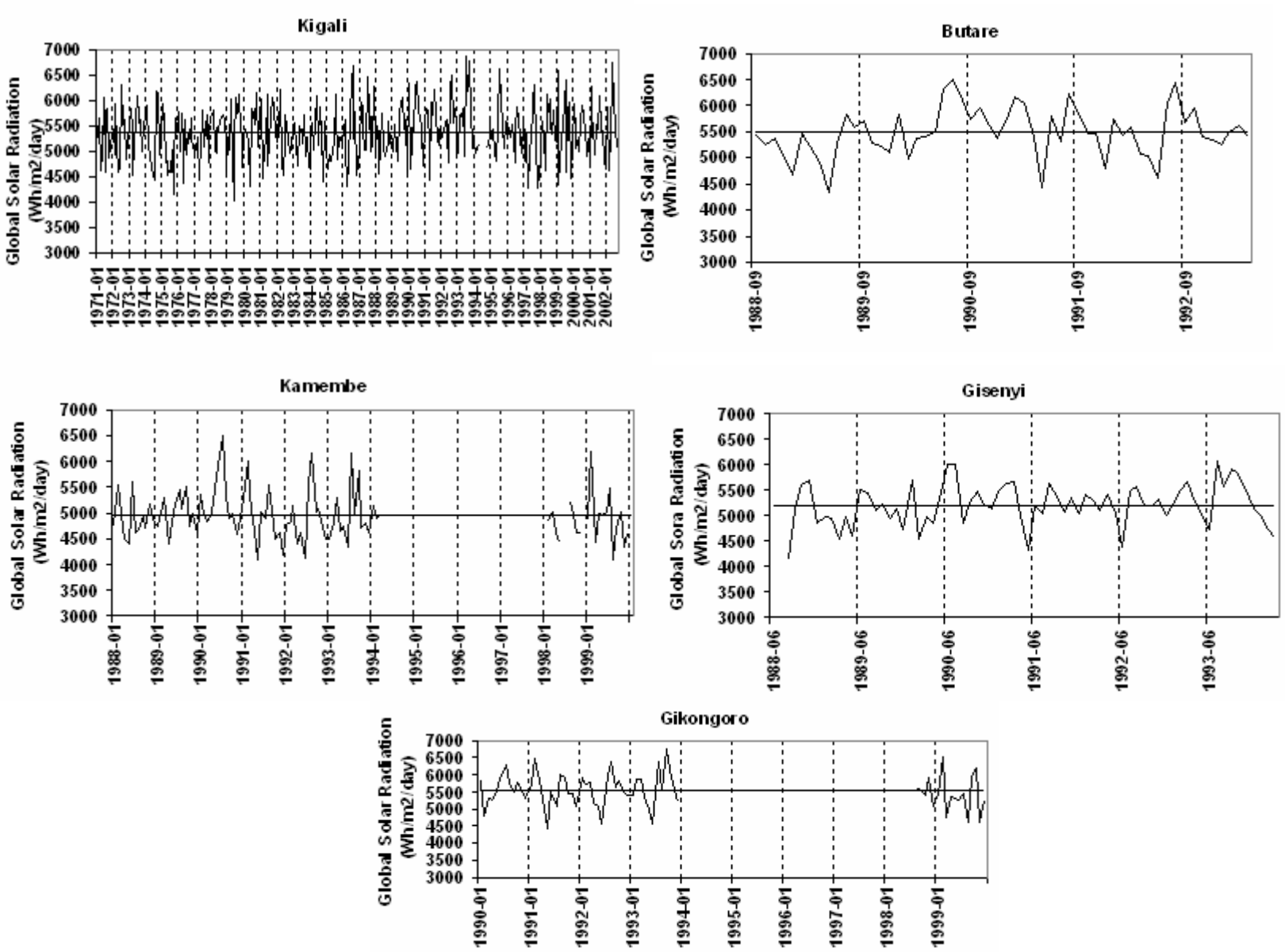

Figure3: Estimated Global Solar Radiation for the five studied sites

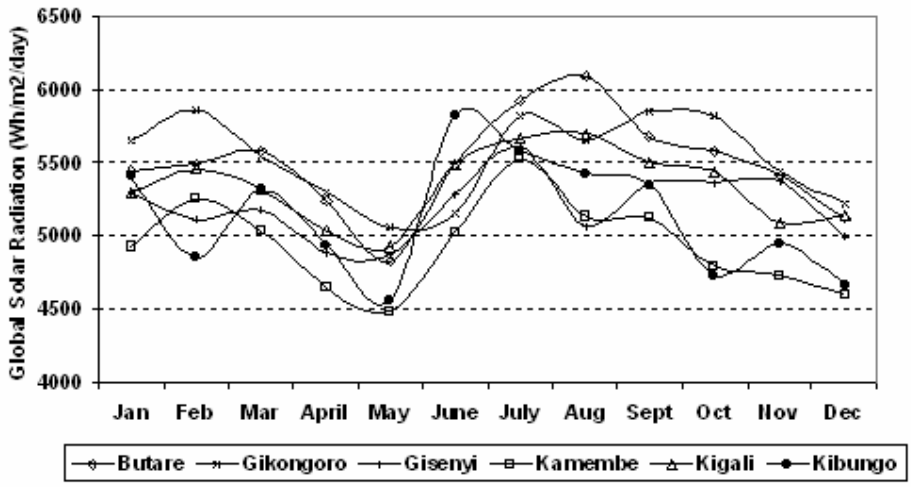

Figure4: Monthly average of estimated global solar radiation on the sites of Rwanda

Conclusion

The empirical Angström-type linear model and a second degree polynomial model both based on sunshine duration have been studied in this work. The two models were compared with the data collected on the site of Kigali International Airport station. From the comparison of the results of these models it was observed that the estimated were in good agreement with the observed data and the two models were slightly similar. This has led to choose one of the two models to be applied for all stations of Rwanda where measures of sunshine duration exist but facilities of recording global solar data do not exist. The estimated data can further be used in the design and estimation of performance of solar systems in Rwanda.

Acknowledgement

The authors are grateful to the Meteorological Department of the Ministry of Infrastructure (Rwanda) for having provided the necessary data, the National University of Rwanda for providing requisite for data processing.

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Nomenclature

Astronomical quantities and solar quantities

$\delta = (23.5\frac{\pi}{180})\sin(2\pi(284+J)/365)$: Solar Declination (radian)

J=1,365, Julian day

$\phi = (\frac{2\pi}{360}) \times Latitude$: Latitude at the place (radian)

$\omega_s = arc\cos(-\tan\phi\tan\delta)$: Sunset Hour Angle (radian)

$\pi = 4.0 \times \arctan(1.0)$

$I_0 = 1367\ Wm^{-2}$: Solar Constant

R_0: Extra Terrestrial Solar Radiation ($Whm^{-2}day^{-1}$)

$\overline{R}_0$: Monthly Average Daily Extra Terrestrial Solar Radiation ($Whm^{-2}day^{-1}$)

R_G: Daily Global Solar Radiation on horizontal surface ($Whm^{-2}day^{-1}$)

$\overline{R}_G$: Monthly Average Daily Global Solar Radiation on horizontal surface ($Whm^{-2}day^{-1}$)

$S_0 = \frac{2}{15}\omega_s\frac{180}{\pi}$ Day Length

$\overline{S}_0 = \frac{2}{15}\omega_s\frac{180}{\pi}$: Monthly Average Day Length

S: Daily Sunshine Hours

$\overline{S}$: Monthly Average Daily Sunshine Hours

Statistics quantities

$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$: Coefficients of regressions

$Qmes_i$: Measured quantity

$Qest_i$: Estimated quantity

$\overline{Q}mes = \frac{1}{N-1}\sum_{i=1}^{N} Qmes_i$: mean of $Qmes_i$, $i = 1, N$

$\overline{Q}est_i = \frac{1}{N-1}\sum_{i=1}^{N} Qest_i$: mean of $Qest_i$, $i = 1, N$

$R = \frac{\sum(Qmes_i - \overline{Q}mes)(Qest_i - \overline{Q}est)}{\sqrt{\sum(Qmes_i - \overline{Q}mes)^2 \sum Qest_i - \overline{Q}est)^2}}$: Correlation coefficient between $Qmes_i$ and $Qest_i$ quantities

R^2: Coefficient of determination

$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Qmes_i - Qest_i)^2}{N}}$: Root Mean Square Error

$RRMSE = \frac{RMSE}{\overline{Q}mes}$: Relative Root Mean Square Error

N **:** Number of observations

Design of a Combined Solar Energy System for a Remote Flux Tower and a Rural Community

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Key words: Solar Energy, Flux Tower, Rural Electrification, RETScreen®, Photovoltaic

Abstract

In this paper, we report on the design and proposed implementation of a solar photovoltaic (PV) system to power a rural community in conjunction with the development and implementation of a PV system to supply a flux tower for remote weather monitoring sited adjacent to the village. The flux tower is part of the broader NASA African Monsoon Multidisciplinary Analysis field campaign and funding for the tower PV system is being leveraged to support the needs of the community who will be the de facto caretakers of the remote, infrequently visited flux tower. The design of the system was based on the estimated power needs for the FLUX tower combined with that of the village community. Community need was defined after a meeting including the village chief, community members and students and faculty of Howard University who were part of the project. The community understood that the design was constrained by the budget allocation for the flux tower PV system, but nevertheless engaged in discussion about their needs and arrived at a consensus, where community members agreed to allocate at least one light bulb for one room in each village house, lights in two toilets and two kitchen areas and two power outlets accessible to all villagers. The system was designed utilizing RETScreen®, a free software[1], applying their PV System modules. The output from RETScreen demonstrated the need for two sets of PV arrays, one to support demand from the village and the second to support the FLUX tower instruments. For the village system, an inverter was required to enable villagers to utilize AC, while the FLUX tower system was routed directly through a charge controller to the batteries, and all instruments, which were DC powered. The entire project was conducted using students enrolled in independent study elective courses. The paper provides some background on solar energy and discusses the rationale with particular attention to a wind-powered alternative. The design output for system implementation from RETScreen® is presented and the appropriateness of the technology selection is discussed.

INTRODUCTION

Especially in the African context, the development and implementation of alternative, decentralized energy generation systems is imperative for development to occur in a sustainable way. Using large centralized power generation facilities to feed electricity to rural and remote communities and locations is expensive and non-viable in Africa away from the major cities, primarily due to the lack of a well-dispersed electric grid. The benefits of utilizing renewable energy technologies as the basis for decentralized energy generation have been discussed at length in the popular and professional press and need not be re-stated here [2]. It is sufficient to reiterate that continued use of non-renewable fossil fuels is resulting in increased green house

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gas (GHG) emissions and attendant increased drivers for climate change. Hence, implementation of a solar energy system serves the purposes of both providing energy to communities previously without power and to do so without contributing to any increases in GHG emissions.

The energy situation in Senegal, as in much of sub Saharan Africa, is critical with very low rates of rural electrification, rising from 5% in 1998 to only 9% by 2003. The national grid, shown in Figure 1, generated about 514 MW in 2003, the bulk of which was thermoelectric (448 MW) with an additional 66 MW from hydroelectric power [3]. Senegal faces the usual problems of having to import the entire fossil fuel requirement for its thermal power plants, while facing massive deforestation as rural communities and the poor have only forest-based biomass to use as fuel. Rural electrification used to be based on the extension of existing networks and installation of diesel power generators; however, increasing energy costs and the need to address GHG emissions are forcing governments to look for de-centralized systems that utilize renewable and alternative energy.

Successive governments have undertaken rural electrification projects which resulted in 558 electrified localities by 2000, but this is less than 8%. The government views rural electrification as a **powerful tool to reduce poverty and has** created the Agence Sénégalaise pour L'Electrification Rurale [4] whose mission targets a 30% rural electrification rate by 2015.

Decentralized alternative energy systems include solar, microhydro, geothermal, wind and biogas, amongst others [5]. The selection of the appropriate alternative energy technology follows heuristics that have been established before, such as the SHTEFIE[‡] analysis for technology selection, which weighs various factors, including social, technological, and financial considerations, in the final selection of the appropriate technology. Given the Senegalese situation, there is abundant sunshine, on average 8.5 hrs of sunshine per day, and solar energy becomes an option. Annual solar radiation is estimated at 2.18MWh/m^2, enough to provide electricity to all Senegal, had the government the resources to harness that energy! The major drawbacks, including large initial capital outlay costs, availability of solar PV panels, and efficiency of panels, are serious and substantive hindrances to the widespread adoption and implementation of solar energy system.

Solar energy has been used in many traditional technologies for centuries, and has come into widespread modern use where other power supplies or connection to a central grid are absent, such as in remote locations and in space. While traveling through the atmosphere 6% of the incoming solar radiation (insolation) is reflected and 16% is absorbed resulting in a peak irradiance at the equator of 1,020 W/m² [6]. Average atmospheric conditions (clouds, dust, pollutants) further reduce insolation by 20% through reflection and 3% through absorption. Many technologies have been developed to make use of solar radiation. Some of these technologies make direct use of the solar energy (e.g. to provide light, heat, etc.), while others produce electricity. Specific direct-use technologies include solar hot water systems that use sunlight to heat water, Trombe walls that passively heat by channeling heated air into ventilation system while storing heat in a thermal mass which can be radiated in the evening, and a solar box cooker, which traps the sun's energy in an insulated box and which has been used for cooking, pasteurization and fruit canning. Solar cells, also referred to as photovoltaic cells, are

[‡] Please see http://www.lboro.ac.uk/well/resources/technical-briefs/49-choosing-an-appropriate-technology.pdf

devices or banks of devices that use the photovoltaic effect of semiconductors to generate electricity directly from sunlight.

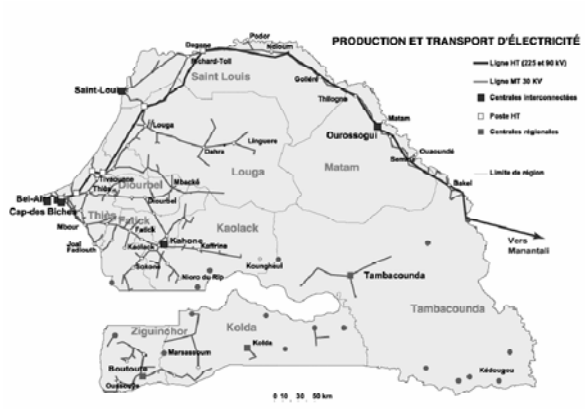

Figure 1: Electric Grid in Senegal [1]

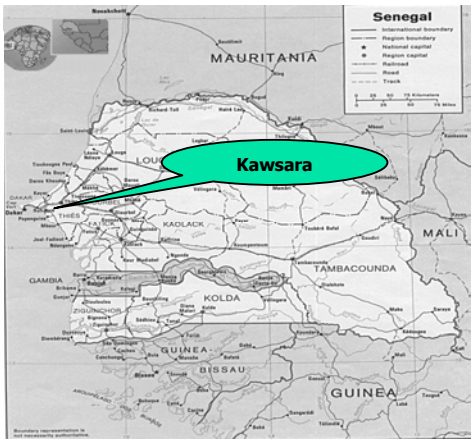

Figure 2: Senegal and Kawsara [1]

Although solar energy has many benefits, it should be remembered that solar electricity tends to be expensive compared to grid electricity. Solar heat and electricity are not available at night and may be unavailable due to weather conditions – thus energy storage technology or complementary power systems are required. Solar cells also produce direct current (DC) which must be converted to alternating current (AC) when used in currently existing distribution grids, which usually incurs an energy loss of 4 – 12%. New 50 watt solar panels cost about $4.25 a watt, or around $212 for a 50 watt panel, in quantity. For 120 watt panels, the cost is $700, or $5.83 per watt. For an average urban middle class residence, a robust solar electric system will cost about US$20,000.

Wind may provide a potential alternative, although the average wind speed at the Senegalese location may not be high enough to sustain sufficient wind power generation Wind power is harnessed through turbines rotating through the force of wind on large blades, and the turbine is usually placed on top of a tower over ten meters high to capture wind at that altitude. These wind towers are usually built together on "wind farms" that are large scale and can feed into the general grid. However, small individual turbines can also provide electricity to rural residences or grid-isolated locations. Wind energy is plentiful, renewable, widely distributed, clean, and releases no toxic atmospheric or greenhouse gas emissions.

Selection of a suitable site is key to the success of wind energy. Power available from the wind is a function of the cube of the wind speed, which means that, all other things being equal, a turbine at a site with 5 meters/second (m/s) winds will produce nearly twice as much power as a turbine at a location where the wind averages 4 m/s. Good wind resource assessment is critical. In general, winds exceeding 5 m/s (11 mph) are required for cost-effective application of small grid-connected wind machines, while wind farms require wind speeds of 6 m/s (13 mph). For applications that are not grid-connected, these requirements may vary, depending on the other power alternatives available and their costs. Drawbacks to wind energy include intermittent or inconsistent wind, some communities consider them an eyesore, and they can negatively affect bird migration patterns and pose a danger to the birds themselves. In the early 1980's, when the first utility-scale wind turbines were installed, wind-generated electricity cost as much as 30 cents per kilowatt-hour; now, state-of-the-art wind power plants are generating electricity at less than 5 cents/kWh, and costs are continuing to decline as more and larger plants are built and advanced technology is introduced.

PROJECT BACKGROUND

As part of the NASA African Monsoon Multidisciplinary Analysis (http://www.joss.ucar.edu/amma) field campaign, a remote weather monitoring station was established in the village of Kawsara (Figure 2), about 50 km outside Dakar. Faculty and students from Howard University (HU) participated in the NAMMA field campaign, allowing students and scientists to make measurements in Senegal to characterize bulk properties of mesoscale convective systems. Data being acquired include wind speed and direction, cloud shapes and contents, rainfall rates, temperature, humidity, and atmospheric pressure, all of which provide informational input into models of weather patterns over western Africa and how these influence hurricane formation. A 10-meter flux tower has been established at the site and faculty from Universite Cheik Anti Diop (UCAD) and HU developed a plan to leverage NASA support for a solar-powered remote flux tower to also provide minimal power requirements for the Kawsara village community, who would be the care takers of the flux tower site.

In June of 2007, two faculty members and two students conducted an assessment site visit to Kawsara. During the visit, students were first introduced to the principles of alternative energy systems in general with specific focus on wind and solar based energy generation. Students also received lectures on the energy situation in Senegal in general and Kawsara in particular. This was followed by introduction to the RETScreen® software[§] including the modules on clean energy systems, green house gas emission reduction calculations, wind energy and photovoltaic solar energy systems. Following two days of lectures and demonstrations, students were taken to the Kawsara Village community where the Flux tower placement site was located.

Energy Needs Assessment

At the village, students met with the community and the village headman where the project was explained and discussed. It was agreed that the current situation would be surveyed and then the minimum expectations and provision established. The village community had never had a connection to the central grid. There was a diesel generator that had either been purchased or provided, but there were no funds to purchase diesel fuel to run the generator, so this equipment lay in dis-use, rusting, in a shed. When it was purchased, rudimentary wiring had been put in place for two light bulbs and a power socket. Some members of the community also had cell phones, but they had no socket which they could use as a charge point. Discussion of the lighting situation lead to the agreement to provide one light bulb to each dwelling, a light bulb in two of the common toilet rooms (see Figure 2A and B) that were present in the village and two light bulbs where there was a communal kitchen area.

Table 1 shows lights and power that would be supplied to the village and the various individuals and families in the community, showing the final outcome of the evaluations and discussion with the community and village Chief and what was agreed upon.

Students drew up the plan with the location of each light bulb and outlet and then the plan was shown to the villagers who agreed with the number, distribution and location of the light bulbs and power supply points. The needs assessment also provided the necessary inputs into the RETScreen® analysis software as the solar system configuration was designed and developed.

[§] RETScreen® is a free software available for download from http://www.retscreen.net and provides complete textbooks and training manuals for diverse renewable energy applications.

Flux tower energy requirements were also supplied as input into separate runs of the RETScreen PV module. The designs that resulted from both these evaluations are presented in the following section.

Figure 2A: A house in Kawsara, Senegal village.

Figure 2B: Two toilets in the

TABLE 1: KAWSARA VILLAGE SITE SURVEY ON JUNE 27, 2007

HOUSE	INDOOR		OUTDOOR		TOILET
	EXISTING	EXPECTED	EXISTING	EXPECTED	
	13 W Bulbs		13 W Bulbs		7W Bulb
Abdoulaye	**3**	**3**	**1**		
Cowboy	**2**		**1**		
Baisall	**2**		**1**		
Common Cooking	**1**				
Rassoul	**3**		**2**		
Fall	**2**	**2**	**1**		
Maribout	**4**		**2**		**2**
Chief	**3**		**1**		
House 8		**4**		**1**	
House 9		**4**		**1**	
House 10		**4**		**1**	
TOTAL	**20**	**17**	**9**	**3**	**2**

TWO ADDITONAL OUTLETS 300W TO BE INSTALLED IN COMMUNITY AREAS

Design for Village

The system configuration for the village resulted in a total need of forty-nine (49) 13W light bulbs with a total wattage of 637W, two (2) 7W light bulbs and two (2) 300W power outlets. All of this is AC requirements, resulting in the total AC wattage for village community of 1251W (= 637W + 14W + 600W). Usage of three (3) hours per day is assumed with the result of total wattage hours per day of 3,753 Watt-hrs. For all such solar systems, installed battery capacity will depend on the number of days of autonomy assumed. For the

village, the team assumed three (3) days of autonomy, requiring total battery capacity of 22518 Watt-hrs. The battery bank size can be computed from the ratio of the battery capacity to the chosen battery voltage. Using 12V batteries, the battery bank size is 1,876.5 Amp-Hrs. The typical rating for a 12V battery is 105 AmpHr so that the total number of batteries required for the village would be [Number of Batteries = Battery Bank Capacity / 105 AmpHr] which results in a requirement of nineteen (19) batteries.

Number of Solar Panels

For the solar panels, investigations in the market revealed that a 130W 12V solar panel was available off the shelf with no delays in shipping and delivery. The number of solar panels required can thus be calculated with knowledge of the amount of sunlight per day and the total Watt-hrs required. The calculated watt-hr requirement is 3,753 W-h. Using 120W panels and assuming 8 hours of sunlight, the number of panels required is calculated as twelve. However, after factoring in the efficiency of the solar panels, only about 5 to 6% of the incoming solar radiation is converted to electricity. Thus, accounting for the efficiency, we would need sixteen (16) panels, which can be arranged in two rows of eight (8) panels each, as shown in Figure 3 below. The RETScreen® software performed all the computations once the site location was entered along with the energy requirements.

Inverter Size

Since the rural community would require alternating current (AC) for its applications, the direct current (DC) from the panels and battery bank will be routed through an inverter so that the entire wattage for the village is AC. Since the total wattage hours are 3753W-hr for three hours daily, two 2,000W inverters will satisfy systems requirements.

Design for Flux Tower

The flux tower is comprised of various meteorological instruments, all of which run on direct current (DC). The instruments and there power requirements are show in Table 2. It is estimated that the radiometer, sonic anemometer, data logger, humidity/temp probes, and soil probe will be a total of 3 amps. Operation will be continuous at 24hrs every day.

The total current requirement for the flux tower instrumentation is 5 amps, and with a voltage utilization of 12V, the total power requirements are 60 Watts 24 hours per day, corresponding to a total of 1440 Watt-Hrs. For this system, the battery capacity to provide three (3) days of autonomy can be computed for a battery with nominal voltage of 12V and a rating of 105 AmpHrs, and the calculation yields a requirement for six (6) batteries, which will be connected in parallel.

Solar Panels:

For the flux tower, the solar panels are also assumed to be 120W 12V panels, and we assume 8 hours of sunshine per day. Based on the requirements and factoring in the efficiency, six (6) panels will be required, connected in parallel.

TABLE 2: FLUX TOWER INSTRUMENTS	
• Sonic anemometer	= 1 amp (24 hr)
• net radiometer	= 1 amp (24 hr)
• data logger	= 1 amp (24 hr)
• barometer	= 0.2 amp (24 hr)
• humidity/temperature probe	= 0.2 amp (24 hr)
• propeller anemometer	= 0.2 amp (24 hr)
• carbon dioxide and water vapor gas analyzer	= 1.2 amps (24 hr)
• ozone gas analyzer	= 1.2 amps (24 hr)
• soil probe	= 0.2 amps (24 hr)
• data acquisition	= 3-4 amps (once a month for 1 hour)

Discussion and Conclusion

Based on the evaluations and system calculations performed through the RETScreen ® software, this paper demonstrates the successful design and development of a solar supply system utilizing the RETScreen ® PV module. For the supply of energy to both the rural community and the flux tower, a total of twenty-two panels will be required. For the village, we will need twelve (12) 2V, 700 Ah batteries, and six (6) 12V, 105 Ah batteries for the flux tower. AC power for the village will be supplied through an inverter, while the DC power to the flux tower will be controlled through a 12V 30A regulator.

This project demonstrated the leveraging of a government funded scientific research project to support the development of a renewable energy system to satisfy needs of a rural community who until then had not had electricity. It also shows that engineering students can be engaged in appropriate technology projects as part of satisfying degree requirements in a manner that enhances student's global social understanding and environmental sensitivity and awareness. Finally, the paper provides a documentary record of a project that demonstrates the successful design, development and proposed implementation of a PV-based system utilizing RETScreen® software and the utility of the software as both a teaching and design tool.

Acknowledgments
The authors would like to acknowledge the support of NSF grant ATM-0621529.

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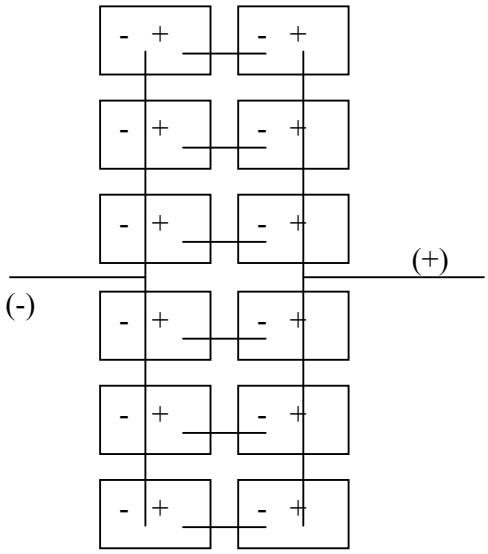

Figure 3: Eight (8) 120W 12V Solar Panels in Series- Design for Village Solar Supply

An Experimental Study of the Combustion Characteristic of Low-Density Biomass Briquettes

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Key words: briquettes, briquetting, biomass combustion, solid fuels, stoves

ABSTRACT

In many parts of the developing world, wood is becoming a scarce resource. Densifying waste crop residues into biomass briquettes can provide an alternative household solid fuel, especially in rural areas. They can be manufactured industrially and on a small rural scale using a simple hand-press, making them also very viable for poorer communities. Compared with wood, biomass briquettes are unique in that they provide opportunity to control in the manufacturing process the fuel density, moisture content, size and geometry. As well as the material properties, all these factors have been shown to have a significant effect on biomass burn rates. For a particular stove and cooking situation it is useful to be able to optimise the steady-state burn rate and minimise the emissions, improving efficiency and reducing exposure to smoke for those in the household. This paper forms part of a study seeking to better understand and later optimise biomass briquettes for different cooking situations. Here, preliminary results of a parametric study are presented for the variation of steady-state combustion rate with the density and geometry of a biomass briquette, burning in free air. Results are given for rectangular briquette slabs and for cylindrical briquettes with a central hole. A simple semi-empirical model is presented that explains the trend in the results. It is found that cylindrical briquette with holes burn faster than slabs with an equivalent surface area to volume ratio.

INTRODUCTION

Nearly half the world's population, almost all in developing countries cook using biomass solid fuels [1], predominantly wood [2, 3, 4]. With deforestation becoming a major problem in many parts of the developing world, there is increased scarcity of wood for household cooking. This especially affects remote rural communities that have no access to fuels such as liquid petroleum gas (LPG) and who depend substantially on burning collected local biomass for their energy needs [5, 2]. In regions of many developing countries it is not uncommon for women to spend more than 6 hours each day collecting and preparing the wood despite the fact that there are often vast quantities of waste biomass residues available with the potential to be used as fuel. Cooking is then often done over open fires, which are highly inefficient transferring only 5-10% of the fuel's energy to the cooking pot. Diminishing forest resources and increasing population make this a pressing issue and solutions are urgently needed, not only to meet energy demands in an environmentally friendly manner, but also to address pressing human health issues. In addition to their low efficiency, simple stoves such as the three-stone fire are smoky and are often used in enclosed spaces with limited ventilation, especially in the more wet tropical regions. Indeed, burning biomass such as solid wood fuels, cow dung and agricultural residues and coal is likely to be the largest source of indoor air pollution globally, and to the greatest extent in developing countries [1]. Open fires emit substantial amounts of pollutants, including respirable particles, carbon monoxide, nitrogen and sulphur oxides, and benzene. The small particles in wood-smoke can bypass the normal body defence mechanisms and penetrate deep into the alveoli of the lungs, harming the respiratory system and there have been clear links made between

their inhalation and disease [1]. These smoke problems particularly and considerably affect women and young children who, in developing nations are typically responsible for the domestic duties in the home.

In addressing these problems, much work has been done around the world on designing and optimising improved stoves with the aim of increasing combustion efficiency and improving thermal heat transfer to the pot. With the improved designs thermal efficiency can be increased to 25-30 %. These stoves, however, continue to use wood as a fuel. Biomass residues from agriculture and industry can provide an alternative to solid wood fuel. They can be found in abundance in many parts of the world, for example in Malaysia there are significant quantities of residues left over from palm nut processing [6], and in Ghana there are large quantities of sawdust residues produced by the timber industry [7]. On a rural level in developing nations, typically about 3-5 tons of agricultural residues are produced per acre [8]. Residues however, are often small in size when compared with solid biomass, burn rapidly with fluctuating power output and produce more emission products resulting from incomplete combustion. These conspire to make firewood the fuel of preference. They also have problems associated with their transportation and storage. This paper is part of a study exploring one option for solving the technical problems associated with residues by upgrading the biomass material by its densification into regularly shaped homogenous briquettes [6]. In this way the energy density of the fuel is increased, handling characteristics are improved [9], transportation is made more feasible and burn rate can be controlled [10].

Briquettes are not a new concept, in fact they are becoming well established in the field and there is a growing network of people manufacturing them on both rural and industrial scales. Notably an organisation called the Legacy Foundation in America has developed a low-pressure wet-briquetting process that uses a simple wooden press and has pioneered a successful training program for their production from crop residues aimed at rural communities in developing nations. The result has been the establishment of many small-scale briquetting enterprises that generate income and provide an alternative fuel for rural village communities [11]. The briquettes produced have a central hole, which is believed by many to improve the combustion characteristics of the briquette. This paper is part of a study in which the combustion behaviour of biomass briquettes is being experimentally investigated. The aim is to more rigorously understand the role of the central hole in combustion and to develop a simple semi-empirical combustion model that will predict the briquette burn rate.

Olorunnisola provides a good review on the manufacture of briquettes [9]. Various authors have studied the feasibility of briquetting different residues and investigated important parameters involved in briquette manufacture. This has involved the effect of compressive pressure, material moisture content, the time the material is in compression (dwell time), and binder content on briquette durability, mechanical strength, density, handling characteristics and the relaxation behaviour of the briquette when taken out of the mould [10, 9, 12].

Briquettes can either be burnt in woodstoves or in specially designed stoves. In terms of briquette combustion, the effect of density on the burn rate of briquettes has been investigated by Chin-Chin et al. [10]. Various authors have undertaken a proximate analysis for different biomass materials (for example [13, 6, 14]). Most combustion work relating to solid biomass is focused on wood. Kandpal shows that the burn rate of wood fuel in a stove has a significant effect on the stove's thermal efficiency, and that there is an optimum fuel burn rate giving maximum efficiency for a given stove/pot configuration [15]. Being able to control fuel burn rate is therefore essential if we are to optimise thermal performance of any stove. The significant effect of fuel size on the burn rate has been observed by several authors

[16, 17], but there is not a parametric study of the effect of briquette geometry on the burn rate, which is essential to optimise briquettes for a particular stove and cooking situation.

This paper considers how briquette geometry affects burn-rate. In the methodology section the method of manufacture of briquettes of a consistent quality is described, followed by the set-up of the combustion rig and method used for measuring their burn rate. The results section presents the observed trends and fits a simple numerical model to the data. A discussion of these results ensues in the section on modelling briquette combustion, followed by some conclusions and a description of further studies that are planned.

METHODOLOGY

Briquette production

The manufacture of briquettes in more rural locations is of the central interest in of this study. It is possible to form briquettes from waste crop residues, in locations with limited equipment availability, using a wet process with a hand operated press [8]. In this study newspaper was chosen as the material for the briquettes, because it is readily available in the UK and bonds easily. Furthermore, because of its fibrous nature it is likely to behave in a similar way in the densification process to other fibrous organic residue matter, such as maize husks. It is this type of material that is more likely to be available for briquetting in rural locations.

The paper was soaked for at least 5 days and pulped in an industrial food-mixer. The briquettes were then formed by compression of the pulp into a mould with an Instron compression test machine using a range of pressures to achieve different briquette densities. Different shaped moulds were used: a large rectangular mould and cylindrical moulds with a central solid cylinder passing through the centre along the central axis. The effect of pulp moisture content on the briquettes' final density was minimal; on compression water is squeezed out until an equilibrium reaction force is attained at a particular pressure.

After forming, the briquettes were oven dried at 105°C to reach 0% moisture content. This was done to minimise the effect of this variable during these preliminary experiments because of the difficulty found in controlling moisture content. It should be noted that pyrolysis does not occur at this drying temperature. On removal from the oven the briquettes were then placed in a sealed container containing silica gel (which removes all the moisture from the air) and were allowed to cool to room temperature. All irregular parts of the briquette were removed from the edges. In order to produce briquettes of different surface area to volume ratios (A/V ratios), the large rectangular blocks were taken and cut with a band-saw into slabs of different dimensions and then oven dried again. The cylindrical briquettes were cut to the required heights and if required turned on a lathe to different diameters.

A stereometric method [18] was used to determine briquette density. This was chosen over displacement methods in order to ensure the briquettes, which would later be burnt, remained dry and were not structurally affected by the measurement. In this stereometric method the briquettes were weighed using a mass balance to a precision of ±0.01g. The dimensions of each briquette were measured using callipers as follows: For slabs, the height and width of the briquette were both measured by taking three approximately equally spaced positions along the edges and the mean calculated, the thickness was measured at each of the four corners of a slab and the mean taken: For cylindrical briquettes with central holes, the height was measured in four positions 90° to each other around the briquette, the external diameter of the briquette was measured in three positions, at the top, middle and bottom, the diameter of the internal hole was measured twice at each end in perpendicular directions. The volume of the nearest geometrical shape was then calculated and hence the density

determined. Briquettes were then put back in the oven for a short time to drive off any atmospheric moisture that may have been absorbed and then transported in the sealed silica gel filled container to the combustion rig to be burnt immediately.

Combustion tests

In each test a single briquette was placed alone in the centre of a steel wire mesh grid resting on two supporting fire retardant bricks, allowing the free flow of air around the briquette. This was positioned on top of a mass balance (Metler tornado) interfaced with a PC to record instantaneous measurements of the mass every 10 seconds throughout the combustion process. Smoke was extracted using an extraction hood method [19]. The extraction rate was set so that it was sufficient to capture all smoke, but had no visible effect on a match flame held in the position normally occupied by the briquette. Ballard- Tremeer et al. [20, 19] have statistically shown, to a 95% confidence level, that such extraction rates have no effect on the burn rate.

Each briquette was ignited by placing a small amount of firelighter on a platform 4cm directly beneath, but unconnected to the mass balance. Enough firelighter was used to ensure the whole of the bottom surface of the briquette was ignited simultaneously, avoiding flame spread in the transverse directions. The firelighter was left in until the briquette was well ignited and had entered into its steady state burn phase. Mass loss was recorded every 10 seconds until the mass of the briquette was 5% of its initial mass. Mass loss readings were normalised by initial briquette mass, and a graph of normalised mass was plotted against time. Figure 1 shows a sample curve of a mass/initial mass versus time. There are three phases of the burn marked: Phase (1) is the ignition phase, phase (2) the steady state flaming combustion phase and (3) is when the flame dies and the briquette decomposes further by a char combustion mechanism. The gradient of phase (2) is the normalised steady-state combustion rate, referred to here as the normalised burn rate (NBR). For each briquette burnt, these graphs were plotted and this quantity was calculated. The next section the results for NBR are presented for briquettes of different geometries and the trends described.

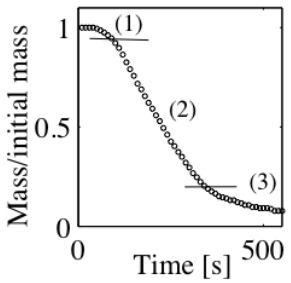

Figure 6: A typical curve showing the decrease of mass/initial mass of a briquette as a function of time throughout its burn. There are three distinct combustion phases marked and these are described in the text

RESULTS

The effect of density on burn rate

Figure 2 shows curves of how the normalised burn rate of slab briquettes varies as a function of the briquettes A/V ratio. The curves show that burn rate varies as linear function of the A/V ratio, with a positive gradient that is greater the lower the briquette density. Therefore, lower density briquettes have a faster normalised burn rate compared to higher density briquettes. In practical terms, slabs with a high area to volume ratio will be those that are either thin or short. In designing a briquette, it is clear from these results that its area to volume ratio has a very significant effect on the rate. A typical briquette of density 276

kgm^{-3}, with a height of 30 mm, an external diameter of 70mm and internal hole diameter of 25 mm would have an A/V ratio of 0.15 mm $^{-1}$ and a mass of 27.8 g, therefore, according to line (2) in Figure 2, it will have a normalised burn rate of 0.0015 s^{-1} giving a steady state burn rate for a single briquette of 0.042 gs^{-1}. Changing the height of this briquette to 45mm would decrease the area/volume ratio to 0.13 mm^{-1}, resulting in a decreasing in burn rate to 0.02 gs^{-1}, a reduction of over 50%. This clearly demonstrates the significance of A/V ratio in briquette design.

The effect of briquette area to volume ratio on the burn rate for briquettes with slab geometry

Figure 3 shows how normalised burn rate varies as a function of briquette density. The six curves are for different A/V ratios, the lower one having the lowest at 0.2 mm ± 0.005^{-1} and the most upper one having an A/V ratio of 0.35 mm ± 0.009^{-1}. There is an exponential decrease in the normalised burn rate with increasing density according to the equation:

$$\text{Normalised burn rate (NBR)} = Qe^{-P\rho_B} \qquad \textbf{(Equation 1)}$$

where ρ=briquette density in kgm^{-3} and P can be assumed constant and has a value of 0.0023 ± 0.00005.

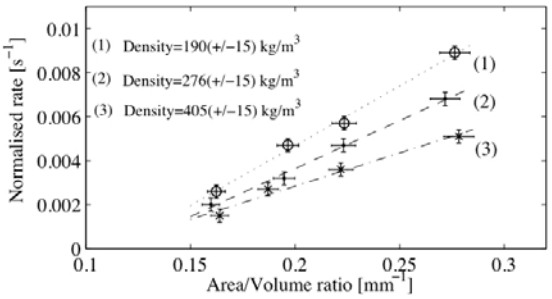

Figure 7: A graph showing the variation in normalised rate for three different briquette densities

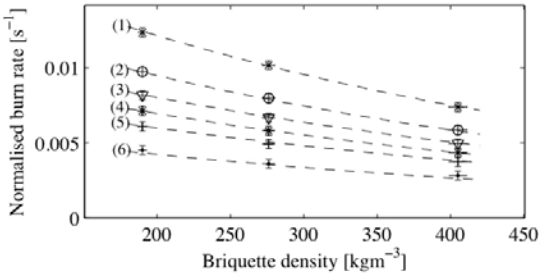

Figure 8: The variation in normalised burn rate of a briquette with briquette density for different area/volume ratios of the briquette. For curve (1) A/V= 0.35 ± 0.009 mm^{-1}, (2) A/V=0.30 ± 0.008 mm^{-1}, (3) A/V=0.27 ± 0.007 mm^{-1}, (4) A/V=0.25 ± 0.007 mm^{-1}, (5) A/V=0.23 ± 0.006 mm^{-1}, (6) A/V=0.2 ± 0.005 mm^{-1}.The dashed curves show that for each data set the points follow an exponential relationship of the form given in equation 1.

There is a linear relationship between the constant Q for each curve as and the A/V ratio, such that Q =0.074* (A/V)-0.0076. This exponential dependence on density is confirmed by Chin Chin et al. [10] who studied the effect of briquette density on burn rate for a number of different materials. Although their study does not consider newspaper briquettes, the value P found here is of the same order of magnitude as values for other biomass materials, which can be found from simple manipulation of their data. Consequently, for any given A/V ratio, Q can be calculated and with P, now a known constant, the normalised burn rate of a briquette with slab geometry burning in free air can be found according to the equation:

$$NBR = (0.074(A/V) - 0.0076)e^{(-0.0023\rho_B} \qquad \textbf{(Equation 2)}$$

This equation demonstrates the significance of a briquettes density and its A/V ratio in determining its burn rate. This equation allows the power output of a briquette to be written as:

$$Power = NBR * M_i * Cal \quad \textbf{(Equation 3)}$$

where M_i is the initial mass of the briquette and Cal is its calorific value. It also allows the steady state burn time of the briquette to be approximately calculated as:

$$T = \frac{0.8}{\mathrm{NBR}} \quad \textbf{(Equation 4)}$$

where T is the steady state burn time of the briquette. 0.8 appears in the numerator because approximately in each case 80% of the briquette mass is burnt in the steady state phase. These equations apply specifically to slab-shaped briquettes burning in free air. However, density and the A/V ratio is a physical properties of a briquette, thus these effects will also be very significant in determining the rate in other combustion other conditions. For example this could be in a fixed bed with many briquettes or in briquette stoves. Other conditions have not been investigated as part of this paper, but forms part of the overall research into briquette combustion of which this study is part.

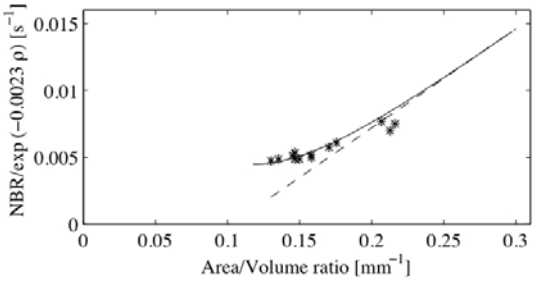

Figure 9: A graph showing the normalised burn rate/exp(-0.0023ρ) for different A/V ratios for cylindrical briquettes, where A/V is varied by changing the briquette height and keeping the other parameters constant. The internal diameter of the briquette= 22.1 ± 0.1 mm and the external diameter is 62.2 ± 0.3 mm. The dashed line give the curve expected for slabs according to equation divided by the factor: exp(-0.0023ρ).

The burn rate of briquettes with central holes

Figure 4 shows the variation of normalised burn rate/exp(-0.0023ρ) to remove the effect of density) for cylinders with a central hole, where the A/V ratio is varied by changing the cylinder height. The dashed line is for briquettes of slab geometry and it is clear that these results deviate significantly from this line. As the height is increased the A/V ratio of the briquettes decreases. In other words cylindrical briquettes with central holes will have a higher burn rate than slabs of the same A/V ratio. It is important to note that the curve describing this change in rate will never cross the y-axis. This is because as the briquette height increases, the rate of decrease of briquette A/V ratio deceases, until the point where increasing the height further has no effect on A/V ratio. In other words, for a given internal hole diameter and external diameter of a cylindrical briquette there is a maximum height beyond which further increases in the height will not change the effective A/V ratio of a dashed curve describing slab-geometry, giving the cylindrical briquette with a central hole an increasingly higher rate compared to what would have been achieved from the same A/V ratio with slab shaped geometry. The solid black line is a fit of a semi-empirical model that considers the effects of the re-radiation that occurs inside the central hole. This is described in the combustion modelling section. If the briquette height is kept constant and the central hole the same diameter, and the A/V ratio varied by changing the external diameter of the briquette, the resulting curve has the same gradient as that of the slabs, but is shifted to a higher position on the graph. In this case the re-radiative effects and losses inside the central hole are kept constant by maintaining a constant height.

Discussion

Combustion modeling: In this section we offer a quantitative explanation of why the A/V ratio is important, and explain the trend observed for cylindrical briquettes (with central holes) of varying heights (see figure 4). A solid with a large surface area will transfer heat into the mass which it bounds more quickly than if the surface area were small. A large surface area will therefore lead to a more rapidly changing temperature profile passing through the solid mass. Many authors have assumed, with much success, the kinetics of pyrolysis to follow, in a first approximation, a unimolecular law according to the expression (for example [21, 22, 23]):

$$\frac{dm}{dt} = -km_1 e^{\frac{-E}{RT}} \qquad \textbf{(Equation 5)}$$

where k is the pyrolysis rate constant and E is an activation energy, both quantities determined from experiment and assumed constant for a given material.

The greater the rate of heat transfer into the solid, the more rapid the temperature increase of the material, and the more quickly elements of the material reach high enough temperatures for pyrolysis. The result is a greater overall rate of pyrolysis, and therefore an increase in the overall mass burn rate of the solid.

The central hole in the centre of cylindrical briquettes provides an insulated combustion zone resulting in less heat transfer by radiation to the surroundings from this surface. This produces higher temperatures within the hole compared to the outer briquette surface which is in contact with the atmosphere. The steeper temperature gradients result in an increased rate of heat transfer into the solid at this surface, a heat wave moves inside the solid, rapidly increasing its temperature. The result is a faster rate of pyrolysis compared to the outer briquette surface which is exposed to the atmosphere. This increased rate in pyrolysis in the central hole region compared to the outer surface explains the deviation of the burn rate cylindrical briquettes from slabs in figure 4. The deviation becomes greater with increasing height because not all radiation emitted from the surface is reabsorbed within the hole, a fraction is radiated into the atmosphere and this fraction is a function of the briquette height. The proportion of radiation that is emitted and reabsorbed within the surface of the central hole is known as the view factor and can be calculated by considering how much each unit area of the surface in the hole 'sees' the other parts of the internal surface. An element towards the top of the briquette will 'see' a greater portion of atmosphere than an element located in the centre of the hole, and thus the element in the centre will have a greater view factor. As the height increases, the heat lost by radiation from surface elements closer to the top and bottom of the hole becomes a lower proportion of the total central-hole view factor, increasing the overall view factor of the central hole region. As the height tends to infinity, the view factor tends to one and the rate tends to a limiting value determined by the chemical kinetics of combustion. A lower proportion of heat lost to the atmosphere by radiation results in higher temperatures and thus faster a pyrolysis rate.

The solid line is a computational model of this effect which suggests that radiation to the atmosphere is the dominant means by which heat is transferred away from the briquettes surface. These results clearly demonstrate the important role of boundary conditions in determining the briquette burn rate.

Conclsuions and Further Work Planned

This study has shown the burn rate of biomass briquettes is steady and controllable. Particularly it has been found that the A/V ratio of the briquette, its density and the boundary conditions are all significant in determining the burn rate. An empirical expression for the burn rate of a biomass briquette of slab shaped geometry burning in free air is given. Knowing the normalised burn rate of a particular geometry allows an expression for the briquette power output and the total burn time of the steady state phase to be calculated and

equations are given here for slab geometry. Slab briquettes have been compared with cylindrical briquettes with central holes, and it has been shown that the central hole causes this form of briquette to burn faster than slabs with an equivalent A/V ratio.

The next stage of this work is the further development of the numerical model and the derivation of a more general expression for briquette burn rate. The study will then look into understanding the burning of briquettes in stoves for cooking and consider the effects of the briquettes physical parameters on harmful emissions. The aim is a more rigorous understanding of the biomass briquette in order that its burn characteristics can be controlled and optimised for a given stove and cooking situation. Ultimately, the results will allow the briquette moulds and hand-presses to be designed to form briquettes with desired burn characteristics.

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Comparative Study of Utilization of Internal Combustion Generator Engines and Hydropower Plants in Solving Rwandan Electrical Energy Problem

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Key words: Hydroelectric energy, thermoelectric energy, cheap electric energy.

Abstract

As energy becomes the current catchphrase in business, industry, and society, energy alternatives are becoming increasingly popular. Hydroelectricity exists as one option to economically, meet the growing demand for energy and is discussed in this paper. Numerous factors exist which must be considered when building hydropower plants; whether the concerns are global or local, each has been measured when discussing this renewable energy source.

*The **internal combustion engine (ICE)** is a heat engine in which the burning of a fuel, e.g. gas oil, occurs in a confined space called a combustion chamber. This option of thermally produced electrical energy was adopted by our country Rwanda as a temporary measure to address the immediate energy need and to avoid system collapse. This is because the electric energy produced in Rwanda is practically insufficient. Only a small percentage of naturally endowed energy is tapped. Moreover, Rwanda has significant hydro-electric potential which could constitute a significant source of electric power once entirely exploited. Presently **the cost of kWh** of electric energy produced in Rwanda is about **0.22USD** due to the high cost of gas oil. Thermally produced electrical energy constitutes about 50% of the total electrical energy produced in Rwanda. The objective of this paper is to analyze the problem of electrical energy deficiency in our country, explore and find a more practicable and lasting solution to the problem, minimize cost of maintenance, reduce the amount of thermally produced electrical energy and to provide sufficient and cheap electricity to Rwandan population. In carrying out this research, different modes of data collection and methods have been used, such as: interviews, library and web researches, observations and analysis of data.*

INTRODUCTION

The electric power energy that our country produces is practically insufficient. Only a small part of naturally endowed energy is tapped. Rwanda has significant hydroelectric potential which could go a long way to solving the energy problem once entirely exploited.
The introduction of generating units known as ICGEs into the Rwandan electric power system made a considerable impact, 50% of the total energy produced in Rwanda. In this comparative study it is clearly shown that the hydroelectric energy is very cheap, clean and renewable compared to the ICGE's thermoelectric energy.

STATEMENT OF THE PROBLEM

Considering the Rwandan population and the amount of electric energy generated by existing power plants, we can conclude that Rwanda is a country without sufficient electrical energy. The greater percentage of electric energy produced is used in some parts of the country, majorly in urban cities, leaving the greater part of the country without electrical power energy. The growth and expansion of different towns of the country especially Kigali city, the industrial city of the country, and the vision of the government for a sustainable development, have stretched the already insufficient available electrical energy, meaning that the generated energy is no longer sufficient even for the installed load.

As a temporary urgent measure to address this problem, the Rwandan government adopted the option of using Diesel Powered Generator Engines (DPGEs). That implies, an increased consumption of petroleum product (fuel-oil), thus running the station at a very high cost. In fact, DPGEs require large quantities of fuel-oil to keep the station running with the attendant high cost of station maintenance. This results in a very high cost of electricity in our country and constitutes a great obstacle to the investors and the development of the country in general.

HYPOTHESES

- Hydropower energy is the most available, practical and lasting solution to solving the problem of insufficient electric energy production in Rwanda.
- Thermal energy is a temporary solution to solving the problem of insufficient electric energy production in Rwanda, but it is expensive to run and maintain.
- The problem of insufficient production of electric energy can be solved by exploiting all hydropower renewable sources (generated not only within Rwandan territory, but also in partnership with neighboring countries).

COMPARISON BETWEEN GENERATED POWER AND POWER DEMAND

1. Demand in Electrical Energy

According to the data we got from ELECTROGAZ the demand is approximated to be about 60MW considering only the installed areas. This is due to continuous growth and expansion of different towns of the country especially, the industrial town of the country Kigali city, and the vision of the government for a sustainable development.

2. Present Production

In 2005, in addition to the dwindling hydroelectric power generation, ELECTROGAZ with the help of Government rehabilitated Jabana and Gatsata Diesel generators to alleviate the power crisis in the country. This was closely followed by the rental power from Aggreko Gikondo and Mukungwa that have been connected to Rwandan network from November 2005. The actual national produced energy is given in the table 1 below.

Production Unit	Number of Generator Units	Number of Generator Units currently in use	Installed Power (MW)	Current Production (MW)
1. HYDROELECTRIC POWER PLANT				
Ntaruka	3	1	11.25	1.2 – 3
Mukungwa	2	1	12	3 – 5
Gisenyi	2	2	1.2	0.5 – 1
Gihira	2	1	1.8	1
2. THERMAL POWER PLANT				
Gatsata	3	1	4.7	4
Jabana	6	6	7.8	7.6
Gikondo Rental Power	14	12	10	10
Mukungwa Rental Power	7	6	5	5
3. IMPORTED POWER				15.5
TOTAL				**50.5**

Table 1: Actual situation of Energy Production

3. Comparison

When we compare the present demand in electric energy, that is equal to 60MW, and the present production, that is summed up to 50.5MW, we have a deficit in demand which equals 9.5MW. Thus load shedding is unavoidable.

Recall that this concerns only the areas that have electric utility. And we know that there are yet many towns and villages without electricity. [2]

HYDROPOWER PLANNED PROJECTS TO SOLVE THE INSUFFICIENT SUPPLY OF ELECTRICAL ENERGY

The present study confirms that Rwanda is endowed with natural hydroelectric potential. This exploitable potential is found nearly on twenty sites, of different capacities and varies according to selected criteria of classification.

The sites whose realization and exploitation can be carried out independently by Rwanda are those situated inside the country, at various basins of which the widest is Nyabarongo. The realization of exploitation of other sites will require collaboration with neighboring countries because they are border-rivers. However, there are some constraints in exploiting some of these sites namely:

- Small size of the site.
- Topographical nature of Rwanda preventing accumulation of large quantities of water.
- Long transmission lines that are required for interconnection to these sites.
- The quality of river water.

Hydropower Exploitable Sites

i) Internal Exploitable Sites

An evaluation of the most exploitable hydroelectric potential in Rwanda is summarized and presented in this paragraph. The exploitation of the listed sites is based on technical criteria

and as well as economical. Among the Internal sites that are of much interest include Rukarara, Mukungwa II and Nyabarongo.
The selection criteria for the above mentioned sites are as follows:

❖ **Rukarara:**

- Good quality of water.
- 5 sites in cascade with head comprising between 28 and 40m.
- Its water flow is 5.3m^3/s when using only the river and 8.6m^3/s when an artificial reservoir is made.
- Proximity to consumption centers of Gikongoro and Butare.
- Proximity to existing network, facilitating easy connection.
- Total guaranteed producible energy: 64GWh/year.
- Estimated capacity: 11MW.

Presently, this site is under construction.

❖ **Mukungwa II:**

- Good quality of water and the head is 40m.
- Flow regulated by Mukungwa I power station is 13.50m^3/s.
- Proximity to consumption center of Ruhengeri.
- Proximity to existing network, facilitating easy connection.
- Guaranteed producible energy: 16GWh/year.
- Estimated capacity: 4MW.

❖ **Nyabarongo:**

The Government of Rwanda contracted an agreement with two Indian Companies to execute the construction of Nyabarongo hydropower plant project at the cost of $97.5 million (US Dollars) on Wednesday, July 09, 2008, which when completed, will generate about 27.5MW.

ii) Frontier Exploitable Sites

The largely untapped hydroelectric potential of River Rusizi and Rusumo falls on the country's boarders are two examples in this regard.

❖ **Rusizi site**

River Rusizi runs about 42km on the border between Rwanda and the DRC (Democratic Republic of Congo). On this section a fall of about 460m is available, with a medium flow rate of about 65m^3/s. Indeed the flow is regularized by the Lake Kivu with little or without solid transportation, the slope is significant. Some part of this river has been harnessed namely, Rusizi I and II hydropower plants, but there is a possibility to construct yet another plant (Rusizi III) with a capacity of about 82MW.

❖ **Rusumo site**

On the Akagera River, the OBK (Organisation du Basin de la Kagera) carried out research on the site of Rusumo, and results showed that an estimated capacity of 61.5MW and annual production of 270GWh is realizable.

The 61.5MW Rusumo falls and 82MW Rusizi III hydropower schemes would be relatively large and would cost approximately $170 million (US Dollars) each. [3]

ECONOMIC IMPACT OF ICGEs IN RWANDAN ELECTRICAL NETWORK

As it has been stated previously, these ICGEs burn many liters of fuel oil and above this, they are less efficient. And as known, our country is deprived of the fossil reserves, whereas the fuel oil is imported from abroad at a high cost as it is shown in the Table 2 below.

Power Station	2005		2006	
	Consumption in *l* (liters)	Fuel cost in USD	Consumption in *l* (liters)	Fuel cost in USD
Jabana	6,607,450	5,480,070	5,028,640	4,395,877
Gatsata	4,576,450	3,208,410	338,716	271,051
RP Gikondo	2,798,873	2,231,189	23,612,938	16,233,895
RP Mukungwa	-------	-------	7,310,727	5,124,820
Total	13,982,773	**10,919,669**	36,291,021	**26,025,643**

Table 2: Annual Fuel Consumptions and Costs in 2005 and 2006

In Table 2, we can see that the total annual fuel consumption increased in 2006. And that means more money was spent to keep the ICGEs running. Notice also that in our calculations and data analysis we have not considered the lubricating oil costs and the maintenance costs which are also substantial.

COMPARISON BETWEEN THE USE OF ICGEs AND HPPs IN RWANDAN POWER SYSTEM

From the data we got from ELECTROGAZ and the engineering calculations we made, the production cost for our hydropower plants is $\$0.01/kWh = 5.46RwF/kWh$, and the production cost for our diesel power plants is $\$0.128/kWh = 69.904RwF/kWh$. From the above results, it is obvious that thermal plants are run at a much higher cost than hydro plants for the same kWh. [2]

ECONOMIC INTERCHANGE OF POWER

Another problem that is encountered by a power system operator has to do with determining when it is economical to buy power from or sell power to other systems. Whenever power is purchased and received into a system, the power that usually must be produced to carry system load is reduced by the amount of power received from the other system. Conversely, whenever power is sold, power production must equal the system load plus the amount.

When the power output of generating units is increased, the unit incremental cost and also the system incremental cost increase. Conversely, when the power is received from another system, as unit loading is decreased, the system incremental cost also decreases.

When power is sold, the additional incremental production cost must be determined in order to be able to quote a price to the prospective purchaser of the power. When power is purchased, production cost will be reduced and this saving has a value that must be determined. The value of saving in a purchased transaction is called the **decremental value**. The definitions of these two terms are as follows:

- Incremental cost is the additional cost incurred to generate an added amount of power.
- Decremental value is the cost saved by not generating an amount of power.

The seller's quoted price (incremental cost) in $\$/kWh$ is given by:

$$i_{cost} = \left(\frac{OriginalCost + NewCost}{2}\right) \times \left(\frac{1}{PenaltyFactor}\right)$$

The buyer's decremental value for the purchaser also in $\$/kWh$ is given by:

$$d_{cost} = \left(\frac{OriginalCost + NewCost}{2}\right) \times \left(PenaltyFactor\right)$$

In purchase and sale transactions, it is customary to split the savings between buying and selling systems. In other words, the average of the sum of the buyer's decremental value and the seller's incremental cost.

$$Av_{\cos t} = \left(i_{\cos t} + d_{\cos t}\right)/2$$

The purchasing system would pay the amount equal to the calculated average in $\$/kWh$ and would save the difference between what it would have cost to generate the power and the cost of the purchased power, that is $\left(d_{\cos t} - Av_{\cos t}\right)$, which represents for example at 1MW delivery, a **saving of** $\$\left(\left(d_{\cos t} - Av_{\cos t}\right)\times 1000\right)$ **per hour.** The seller would benefit by the same amount. [2]

NUMERICAL APPLICATION

From what we got previously, we have seen that the:

- Production cost (Hydro) is of $\$0.01/kWh$,and the
- Production cost (Thermal) is $\$0.128/kWh$.

The average production cost for both types of power plants in our country is

$$\$\left(\frac{0.01+0.128}{2}\right)/kWh = \$0.069/kWh$$

Our country also purchases power from neighboring systems such as SNEL (D.R.C.) and SINELAC. The costs of $1kWh$ from each plant are given as follows:

- SNEL: $0.043DTS/kWh = 36.543RwF/kWh = \$0.066/kWh$
- SINELAC: $0.055DTS/kWh = 46.741RwF/kWh = \$0.085/kWh$

DTS (Droit de Tirage Special) is the type of currency and according to the rate of exchange from the National Bank of Rwanda, 1DTS = 849.839RwF and $1USD = 546.761RwF.

The average cost of the purchased power is

$$\$\left(\frac{0.066+0.085}{2}\right)/kWh = \$0.075/kWh$$

Let's now suppose that $\$0.069/kWh$ is the original cost of the power produced in our country and $\$0.075/kWh$ is the new cost of the power purchased from neighboring systems.

From the data we collected from ELECTROGAZ, the transmission losses during that period are 22% equivalent to a loss factor of 0.22. Thus, the penalty factor is given by

$$L = \frac{1}{1-LossFactor} = \frac{1}{1-0.22} = 1.28$$

Having calculated the above results, we can now find the incremental cost i_{cost} and the decremental cost d_{cost} as follows:

- $i_{\cos t} = \left(\frac{0.069+0.075}{2}\right)\times\left(\frac{1}{1.28}\right) = \$0.056/kWh$
- $d_{\cos t} = \left(\frac{0.069+0.075}{2}\right)\times(1.28) = \$0.092/kWh$

The average of the sum of the buyer's decremental value and the seller's incremental cost is:

$$Av_{\cos t} = \left(\frac{0.056+0.092}{2}\right) = \$0.074/kWh$$

Our country would pay the amount of $\$0.074/kWh$ and would save, for example at 1MW delivery,

$$\$\left((0.092-0.074)\times 1000\right)/h = \mathbf{\$18}/h$$

The seller would benefit by the same amount. [2]

ADVANTAGES OF HPPs OVER ICGEs IN RWANDAN POWER SYSTEM

HPPs(Hydropower Plants)	ICGE(Internal Combustion Generator Engines)
✓ Clean, renewable and reliable energy source.	▪ Not renewable energy source, it pollutes the atmosphere.
✓ Cheap electricity.	▪ High energy tariff.
✓ It has operational flexibility.	▪ Standby reserve.
✓ Low running cost.	▪ High running cost.
✓ Low maintenance cost.	▪ High maintenance cost.
✓ High efficiency.	▪ High consumption of petroleum products.
✓ No waste products.	▪ Much noise and pollutants.
➢ Since Rwanda is endowed with hydroelectric potentials, the use of HPPs is practical and the right choice.	➢ The use of ICGEs in our country is an immediate solution but not a lasting one.

CONCLUSION

Generation and the supply of electricity under various economic, environmental, social and political constraints is one of the major challenges in this 21st century. The best energy is the cheapest [Prof. Rubbia, Nobel Price, physics].

In our study, we compared the utilization of Internal Combustion Generator Engines and Hydropower Plants in solving Rwandan problem of insufficient electric power supply and analyzed data collected from different sources (e.g. ELECTROGAZ, Aggreko and MININFRA). From this study we have been able to prove that hydropower energy is the most available, practical and lasting solution to solving the problem of insufficient electrical energy production in Rwanda. Notice that the cost of 1kWh of electric energy produced in Rwanda is too expensive, about the highest in Africa due to the introduction of the ICGEs, which consume large quantities of petroleum products.

We hope that by the time the vision 2020 brings all the exploitable sites into operation the cost of 1kWh of electric energy in Rwanda will become the cheapest within the East African Community.

RECOMMENDATIONS

We make the following recommendations:

- **To the Rwandan Government**
  - The Government should restructure ELECTROGAZ with the aim to increase private sector participation and improve managerial and operational performance.
  - The Government should expedite action on the ongoing methane project and boost power electric energy production since about 82% of Rwandan population lives in rural areas and the majority of them don't have access to electricity.
  - Regional cooperation between Rwanda and her neighbors can solve some energy problems.
- Lastly, to the electricity consumers we recommend that bills be paid promptly and illegal connections be discouraged.

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Breeding a Better Stove: the Use of Genetic Algorithms and Computational Fluid Dynamics to Improve Stove Design

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Key words: combustion, stoves, wood, genetic algorithms, computational fluid dynamics.

Abstract
Half the world cooks using wood, often on open fires or on inefficient stoves. Collecting firewood is often left to women and children. As well as reducing the time available for education and other activities, there are many cases of women being raped while trying to collect firewood outside of refugee camps in the Darfur region. The aim of this research is to produce optimised wood stoves, reducing the amount of wood required, hence reducing carbon emissions, and improving the quality of life, particularly for women and children.
Our approach is to use computational fluid dynamics and genetic algorithms to improve the combustion conditions in wood-burning cook-stoves. In the initial experimental phase, open wood fires were characterised in terms of burn-rate, and gas temperature and velocity. Several stove designs were also assessed, including the three-stone fire (3-5% efficient), the Eritrean mogogo (5-10% efficient) and the rocket elbow (20-30% efficient).
The experimental results were replicated in a computer simulation which was validated for a range of fires. This model was embedded in a CFD package which correctly predicted the flame height, velocity and temperature.
The validated CFD model combined with a genetic algorithm was used to optimise stove design: each stove is defined by a genome describing its dimensions; the various designs are allowed to "mate", each one vying for the attention of the "fittest" or most efficient stove; the offspring inherit a mixture of their parents' features, until an optimum design emerges. Finally the optimised design is to be built and physically tested before being modified to make it suitable for field trials and dissemination to rural communities.

Introduction

Half the world cooks using wood, often on open fires or on inefficient stoves. Collecting firewood is often left to women and children. As well as reducing the time available for education and other activities, there are many cases of women being raped while trying to collect firewood outside of refugee camps in the Darfur region[**].

There have been many attempts to produce fuel-efficient stoves or to replace wood stoves with other fuel sources or alternative means of cooking. Often research is carried out in academic institutions away from where stoves are used and although the resulting stoves can be fuel efficient, the neglect of social factors is a major barrier to successfully introducing improved stoves into the homes of those living in remote communities. In Ethiopia and neighbouring Eritrea, the staple food is injera: a spongy sour delicious flatbread, is cooked on a large griddle on a mogogo stove (see Figure 1). These inefficient, smoky stoves are made

[**] See: www.darfurstoves.org

by individuals from a mixture of mud and clay, whilst the mogogo plates are supplied by the local ceramics industry. Two recently proposed "improved" stoves are not suitable for cooking injera (see Figure 1). The CleanCook alcohol stove [1], made in Sweden from aluminium, has two small burners which are insufficient to heat a mogogo plate. The change of fuel and stove also has adverse economic effects on local mogogo plate manufacturers and firewood sellers. A stove from Aprovecho with a more traditional appearance but made from concrete failed to take into account the even temperature distribution required, so although testing in the USA by boiling pots of water appeared to show improved efficiency, when it came to cooking injira, the results were inedible. Although these laudable attempts have some merit, their use requires Ethiopians to change their eating habits, threatens local economies and could thus be regarded as intrusive and colonialistic.

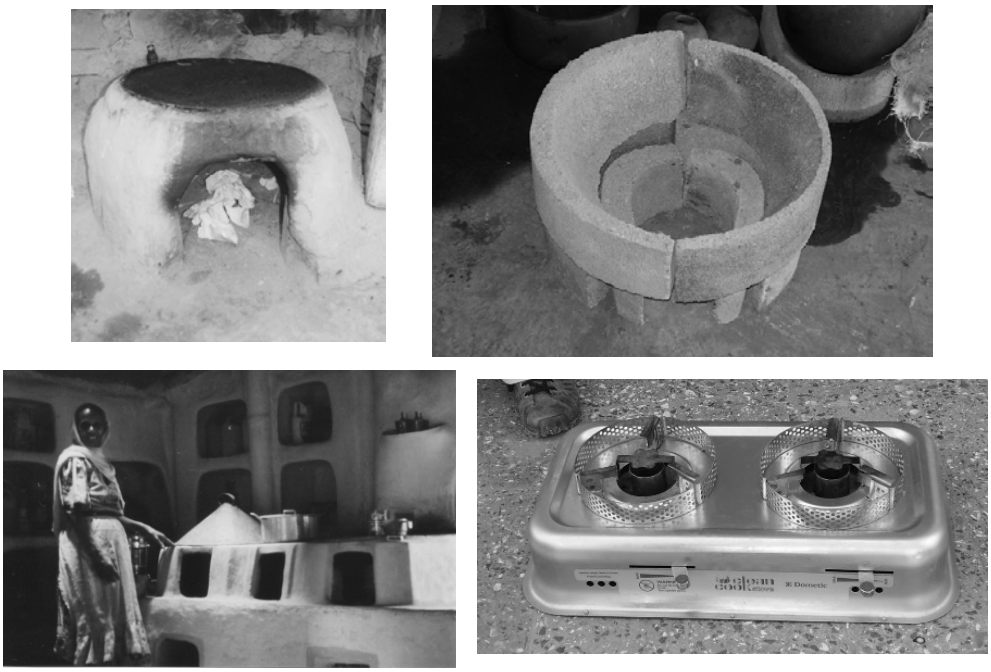


Figure 1: top left: classic mogogo, top right: Aprovecho improved mogogo, bottom left: ERTC design, bottom right: Cleancook stove.

There is also a design of mogogo promoted by the Eritrean government – the ETRC (Energy Research and Training Centre) mogogo, but the cost of US $40 places it out of reach of many Eritreans.

Alternative approaches involving local stakeholders have tended to be successful on a small scale, but are much more labour intensive. For example, on a recent trip with Engineers Without Borders UK in conjunction with FAMUSOD to install wood stoves in a remote village in the Imbabura region of Ecuador, Nottingham University student Rob Quail found that although initially the villagers were rather shy, by involving them in the design and material selection process, they overcame scepticism. After taking a break to go trekking for two weeks, Rob returned to the village to find that the villagers had built two stoves from his design and had begun to experiment with modifying the stoves according to their own ideas [2].

It may be impractical to involve end-users at every stage of the process in the design of improved cook stoves. An alternative approach is to tackle the problems of poor fuel economy and harmful emissions by modifying stoves which are currently in use rather than

starting with a blank sheet of paper. Indigenous stoves will have undergone a natural process of evolution, with good stoves being imitated and bad ones replaced, although we must exercise caution in defining the characteristics of good stoves. A project to replace smoky stoves in Nepal was successful in eliminating harmful indoor air pollution, but after six months, several dwellings collapsed due to termite damage; the previously used smoky stoves had been effect at killing pests whereas the new improved stoves did not fulfil this secondary (but essential) function [3].

A good example of using local knowledge in stove design is the Mirt stove distributed in Ethiopia by GTZ (see Figure 2). The stoves are made of concrete from simple moulds provided to local artisans. They are suitable for cooking injera and are fitted with traditional mogogo plates, protecting another sector of the local economy. However, these stoves are not suitable for use in Eritrea, due to the on-going tension between the neighbouring countries. Eritreans are likely to be suspicious of technology developed in Ethiopia – another factor traditionally ignored by engineers designing stoves.

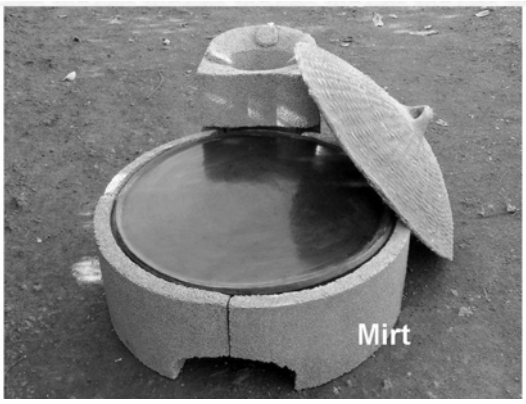


Figure 2: Mirt stove

Whilst the evolutionary approach to stove design is commendable for the way in which it builds up local communities, supports the local economy and fosters a sense of ownership, the process is frustratingly slow and costly in terms of the number of new stoves that have to be built and tested, many of which will not show any improvement on the previous generation. A novel approach is to make use of genetic algorithms and computer modelling. Traditional stoves are allowed to "mate" with stoves with good fuel efficiency, such as the rocket stove depicted in Figure 3. The offspring stoves are modelled using Computational Fluid Dynamics (CFD) and assessed in terms of fitness. Fitness can be defined to include factors such as: fuel efficiency, temperature distribution, volume of material used to construct the stove (indicative of cost) and so on. In this paper we apply the methodology to the Eritrean mogogo. Details of the computational modelling and genetic algorithm (GA) are given in the next two sections, results of the simulations are then presented and discussed before conclusions and considerations for future work are proposed.

Computational Modelling

The computational fluid dynamic model of stoves was developed in Fluent 6.2, with a bespoke user-defined function to describe the rate of fuel combustion in the fuel bed. The model was simplified by assuming steady state conditions and an axi-symmetric domain, divided into three regions: the solid parts of the stove; a porous fluid region to describe the fuel bed and; a non-porous fluid region to describe the rest of the gases in the stove. The

standard axi-symmetric Navier-Stokes equations were solved, coupled with the energy equation, the k-ε model with enhanced wall functions to describe turbulence, the discrete ordinates model to describe radiation heat transfer and the species transport model to describe chemistry with homogenous reactions limits by turbulent mixing as per the eddy dissipation model. No soot model was included, and it will be shown that neglecting the effect of soot on flame radiation has resulted in some significant errors.

Behaviour of solid fuel in the stove was described by a fuel sub-model, written as bespoke C-code and attached to Fluent as a user-defined function. The sub-model avoided the requirement to model each piece of fuel separately, instead applying a non-uniform flow resistance coefficient to the fuel bed, calculated from the Ergun equation. The model only accounted for the active (burning) surfaces of the fuel which were grouped together in lumps throughout the fuel bed: this was necessary in order to make combustion in the resulting flame diffusion limited as volatile matter and oxygen mix, rather than kinetically limited. Within each lump, the rate of volatile release was limited by the transfer of heat through a char layer of assumed thickness to the virgin fuel below. The rate of char combustion was limited by the supply of oxygen from free stream conditions through the species boundary layer to the char surface. The approach is novel, but the numerical model of buoyancy-driven flow was validated against experimental data from the literature [4]; the fuel model was validated against experimental data [5] and convection heat transfer as the plume of hot gases impinge on the cooking surface was also validated against experimental data [6]. Mesh independence of the model was assessed using the Richardson extrapolation.

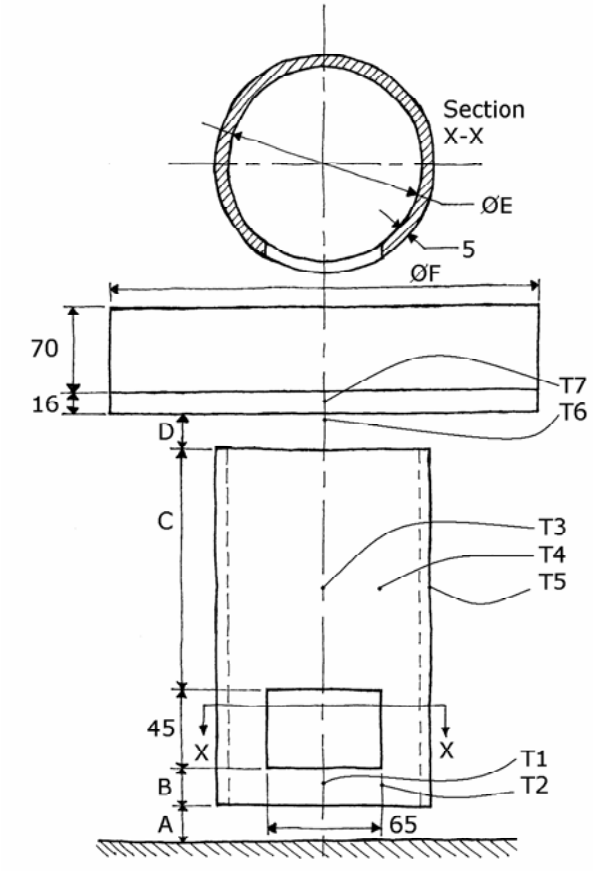


Figure 3: Principal rocket stove dimensions. Variable dimensions are denoted A to F. T1..7 indicates location of thermocouples for experimental testing.

Genetic Algorithm

The genetic algorithm (GA) mimicked Darwinian evolution following the pseudo-code in Figure 4. A generic stove was developed from the Rocket stove [7,8] which had previously been assessed experimentally. This stove was almost axi-symmetric, with an annular air inlet between the stove and the ground, a window to allow fuel to be introduced and a mogogo plate (or similar) atop as a cooking surface. For each stove a gene of single-digits scalars was stored. These were multiplied by a generic set of vectors to yield a unique stove shape for each gene or creature. The GA is an iterative process, and for each stove in each generation, the dimensions of the stove were derived as described above. The GA inserted the new dimensions into a journal file which was executed in the meshing software, Gambit 2.1, to give a coherent mesh. The mesh was then sent to Fluent 6.2 where a second journal file imposed boundary conditions, models and model parameters and set the simulation to solve for 2000 iterations. At the end of the calculation the GA exported data on the fuel burn rate and the local heat flux to the cooking surface. Finally the fitness of each stove in the generation was calculated according to the following objective function:

$$f_2 = g(q'') + \frac{h(q'')}{m_f'} \qquad (1)$$

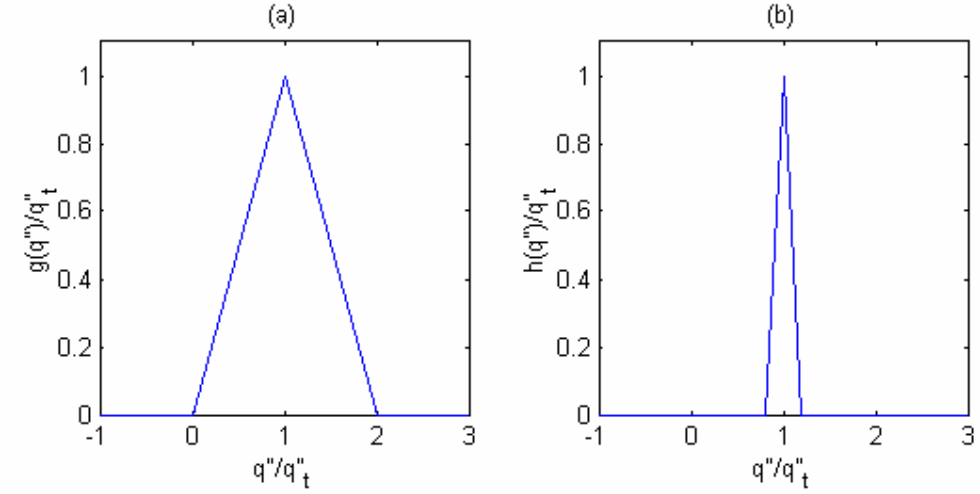
```
initialise random genome of creatures
FOR each generation
     FOR each creature
          transform gene into mesh
          call CFD to calculate fluid flow
          calculate fitness from CFD results
     ENDFOR creature
     select mates
     cross-over to create new generation
     mutation on new generation
     new generation usurps old generation
ENDFOR generation
```

Figure 4: Pseudo-code of Genetic Algorithm.

where q" is the mean heat flux passing through the cooking surface and m'_f is the total fuel burn rate. Functions g(q") and h(q") are described in Figure 5. The objective function primarily rewards stoves which achieve the target heat flux (q''_t) using the first term in

Equation 1, and only when that is achieved does it heap additional fitness on stoves that minimise their fuel consumption, using the second term in Equation 1. Earlier embodiments of the objective function had an additional term to reward a uniform heat flux by monitoring local deviation from the mean flux, but this was found not to be necessary.

Figure 5: Functions g(q") and h(q"), which contribute to the overall objective function



Once the fitness of all stoves had been assessed, the GA moved on to the mating phase, using the roulette wheel selection routine: a virtual roulette wheel was created with sectors sized in proportion to the fitness of each stove. Two roulette balls were set into the wheel to identify two parents. The genetic code of the two parents was mixed using a single cross-over point to produce a child. The child's genetic code was then subject to random mutations. The fittest stove from the previous generation passed automatically to the next, and the rest of the population was generated by random mating events: this encouraged rapid convergence of the results to an optimum stove design. Finally the new generation of stoves usurped the old.

The GA was run with $q"_t$ = 5000 W/m^2, giving 1 kW cooking power over a 0.5m mogogo plate. There were 10 stoves in a population and the GA was run for 50 generations. The GA was run for 10 heats, generating ten champions from random initial genomes. In a second phase, the ten champions were set against each other three separate times to give a champion of champions. The champion of champions (i.e. the best stove) was subject to a sensitivity analysis, whereby all dimensions were subject to small perturbations and the effect on stove performance was assessed to identify critical dimensions.

Results

The champion of champions is illustrated in Figure 6. It features a sharp "turbulator" (at height, z=0.32) and a recirculation region in the combustion chamber, a wide thin virgin fuel region and a tall lower section. Errors in heat flux and fuel burn rate for the optimum stove were estimated to be 2% and 40% respectively using the Richardson extrapolation: results concerning the fuel burn rate should be treated with circumspection.

The turbulator and thin neck (z = 0.34 m) supports a large block of material. It is anticipated that these two features could easily break and render the stove useless, so a further sensitivity analysis was conducted on this region of the stove. Reducing the turbulator size reduces fitness from 6470 to 4220. Removing the turbulator completely results in a further decease to 3980. Clearly the large turbulator is important for mixing and heat transfer: a

smaller version is almost as useless as no turbulator at all, and a final design would have to include an insert in this region to (a) act as the turbulator and (b) strengthen the neck. This is unfortunate as it would increase the price of the resulting stove, and move away from the initial design philosophy that the optimised stove could be manufactured on an ad hoc basis by rural women without specialist training nor recourse to purchasing components.

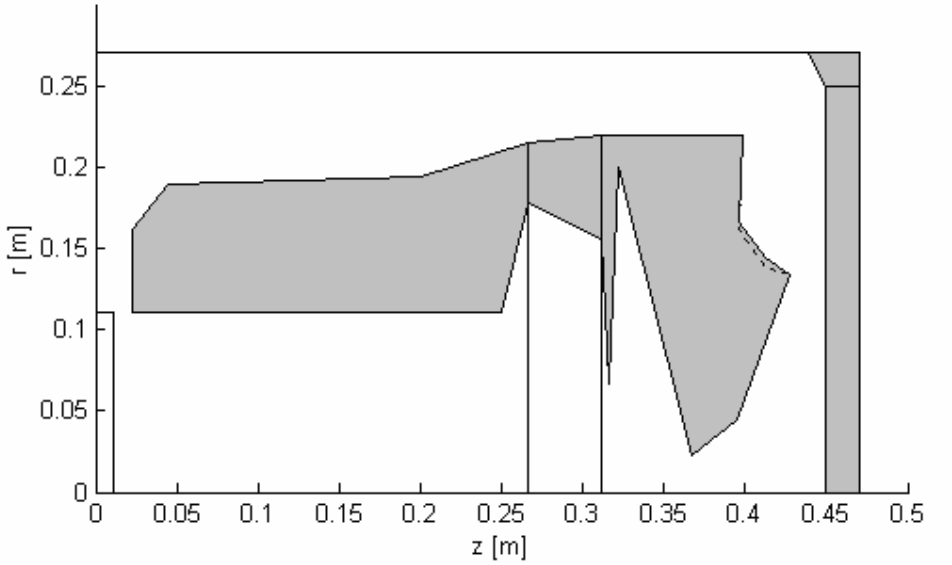


Figure 6: Schematic of the best stove proposed by the GA. The dashed line shows an improvement identified by the sensitivity analysis. The x-axis is the rotation of symmetry, the y-axis is the ground and solid material is shown shaded.

Conclusions

The proposed stove achieved a target cooking heat rate of 997W, using fuel at a rate of 0.6 g/s. This performance is equivalent to 12% efficiency or specific fuel consumption 0.4 kg fuel per kg food, compared to 0.5 for the classic mogogo. This result has not been experimentally verified, and should be viewed with circumspection given the shortcomings of the CFD model. Nonetheless, the proposed stove requires only one bought component, the turbulator, with an estimated cost US$ 1, which compares favourably to the cost of the optimised ERTC mogogo (US$ 40) and the Aprovecho design (US$ 9) and in that respect it has realised the requirements of the project. Considerable further work is required in experimental verification, to adapt the design to manufacturing requirements and to successfully bring it to market in Eritrea.

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Who Will Be the Players in Green Technology and What Will Their Role Be?

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Key words: green technology, alternative energy, solar photovoltaics

Abstract

At long last the general public and businesses have gotten the message. Something must be done about the rising cost of imported oil, and high carbon emissions from it and other fossil fuels that lead to global warming. One solution is to reduce the emissions and energy costs and develop of alternative energy or renewable energy sources/green technologies. The development of alternative energy sources or "green technology" once the focus of small businesses, is now on the radar screen of major corporations. The shift to various alternative energy sources has produced some interesting dynamics. Development of Green Technology is equated with the expansion of the economy and job market. *The development of alternative energy sources has become big business funded by corporate giants in the oil and semiconductors industries. Solar energy companies are now traded publicly on the stock market. The alternative energy sources introduce new players to the energy business, but the financiers are players with the gold and they rule. Farmers, semiconductor technologists and energy innovator , biologists, venture capitalists, politicians, architects, city governments, new energy providers such as integrate solar companies. Community based and development organizations and individual energy producers are among the new players who receive modest benefits. This paper will explore who will play a role in Green Technology, and the dynamics that influence what their role will be. Examples of development of solar and biomass will be provided.*

INTRODUCTION

Recent National Oceanic and Atmospheric Administration (NOAA) studies are pretty convincing that the carbon emissions from energy production and use is leading to global warming [1]. One of the solutions to this problem is to replace the existing energy sources with alternative energy or renewable sources that are cleaner. However, with energy as the driving force behind the US economy, shifting to alternative energy sources can have major implications and potential impact on maintaining the status quo of the economy. Energy is big business, and all indications are that it will stay big business even with renewables. Ninety per cent of renewables are used to produce electricity; therefore, examples of the application of renewables to generate electricity will be focused upon in this paper. The direction of renewable energy development will be covered and the players that make it happen will be described.

Current Status of Renewable Energy

For a century, energy supply, use and demand have been controlled and manipulated by petroleum based(oil) companies that have annual profits that exceed most global

economies. Traditionally, electrical generation for commercial industries and residences has been run by large centralized public utilities. Renewable energy is 7% of the energy supply and 90% is tied to the electric grid (in the USA).

The Role of Renewable in Energy Consumption in the Nation's Energy Supply, 2006

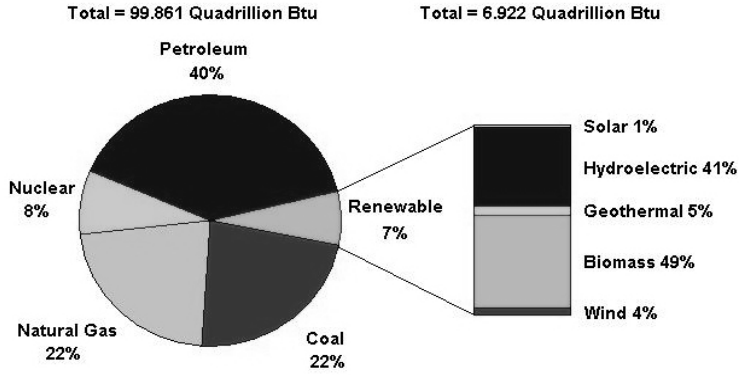

Figure 1. The Role of Renewable Energy Consumption in the Nation's Energy Supply, 2006 [2]. Biomass is the largest source of renewable energy

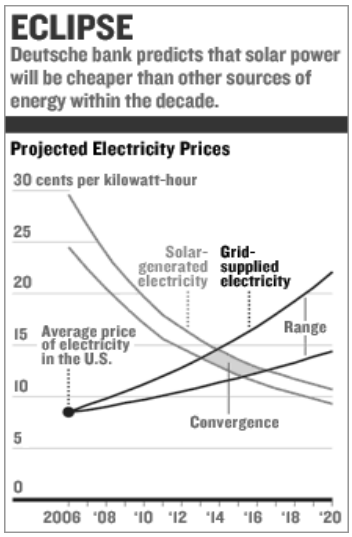

Figure 2. To reach parity Solar must cost less than 10cents per kwh [3]

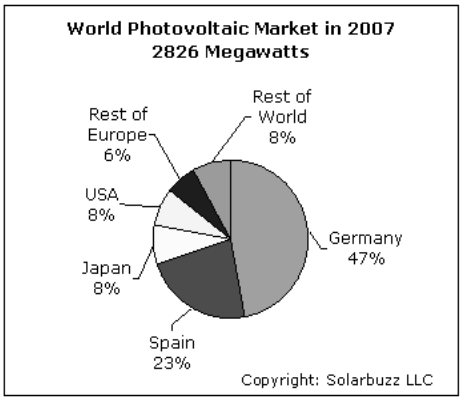

Figure 3. PV market Distribution]

Germany's PV market reached 1,328 MW in 2007 and now accounts for 47% of the world market. Spain soared by over 480% to 640 MW, while the United States increased by 57% to 220 MW. It became the world's fourth largest market behind Japan, once the world leader, which declined 23% to 230 MW. World solar cell production reached a consolidated figure of 3,436 MW in 2007.

Discussion-Players in Solar and Biomass Energy and Their Roles
Solar Energy

To accelerate the pace of the shift to alternative energies, some state governments are now mandating milestones for public utilities to increase the per cent of electricity produced

from renewable energy. California is attempting to pass an initiative, Proposition 7 that requires utilities to produce 20% of their power with renewable energy by 2010, 40% by 2020 and 50% by 2025 [5]. Some cities such as San Francisco are proposing to manage and produce their own electricity. The goal is to shift the electrical production to 100% renewable energy. In each case, the focus is centralization of control of the production of renewable energy. This initiative is modelled after the German approach to solar.

The centralized approach leads to utility scale renewable projects in the 400-600 megawatt range that can only be managed and constructed by capital rich corporations. Utility-scale PV solar projects feature photovoltaic solar modules, which convert sunlight directly into electricity and produce the greatest amounts of power during the afternoons, when electricity demand is high.

For example, PG&E, a California public utility, entered into an agreement with Topaz Solar Farms LLC, a subsidiary of OptiSolar Inc., for a 550 MW of thin-film PV solar power plant and with SunPower for a 250 MW solar power plant. Both plants would be located in San Luis Obispo County, California (100 miles north of Los Angeles). The SunPower plant will deliver an average of 550,000 megawatt-hours of clean electricity annually. The project is expected to begin power delivery in 2010 and be fully operational in 2012. The OptiSolar project would deliver approximately 1,100,000 megawatt-hours annually of renewable electricity and is expected to begin power delivery in 2011 and be fully operational by 2013. It will cover 10 square miles. Combined the two project will produce electricity for the energy needs of 239,000 residents. Both projects are contingent upon the extension of the federal investment tax credit for renewable energy and processes to expedite transmission needs [6].

Over the past six years, PG&E has entered into contracts for more than 3,600 MW of renewable power, including solar contracts that total more than 2,500 MW. PG&E now has contractual commitments for more than 24 percent of its future power deliveries from renewables, including wind, biomass and geothermal [7].

Such projects are ideal for the subsidiaries of oil giants. OptiSolar is backed by private equity firms apparently with oil connections [8]. SunPower is backed by Cypress Seminconductor Corporation which owns 52% of the company [9],

It is deals like this that makes renewable energy attractive to other oil giants like BP, Chevron and Shell and semiconductor companies like Sharp Electronics and Siemens. These are the players that are accelerating the alternative energy market and creating publicly traded renewable energy companies that began to appear in 2004 on the U.S. stock market. They have the gold and continue to rule.

Building solar power plants for utilities and franchised businesses will probably squeeze out the smaller under-capitalized renewable energy companies who are ill equipped to bid on such large scale projects. They probably will be limited to small commercial and residential projects which will dry up as the utilities take over solar energy production. They must also share their profits with suppliers and the customers to make solar affordable on the smaller scale. With utilities as the producers of solar electricity, the need to continue government rebates and tax incentives for the small energy users is significantly reduced.

Environmentalists and small solar energy companies are opposed to Proposition 7 because the initiative was written without input from renewable experts and proposed by a billionaire from another state who is not an expert [10]. Setting milestones for the utilities to become renewable energy producers without adequate studies of impact could result in large scale projects that have adverse and unknown impacts on the environment and economy. Scaling up project sizes that only major corporations can handle marginalizes the participation of small companies and shifts the current market away from the decentralization that provides individual control of energy production. The oil companies have been preparing for the alternative energy shift for more than three decades, evidenced by their investment in biofuels and the establishment of subsidiaries such as BP Solar in the 1970's. BP Solar is one of the largest solar companies in the world.

For decades, the solar energy industry was carried by small businesses with less than 20 employees because it was not very profitable, and the market focus was on small commercial and residential projects. Home installations averaged 3kw of solar power and large commercial installation were only double digit figures. A 3 kW solar power generation system of the type designed for general home use can produce approximately 3,000 kWh of electricity over the course of a year. The effect of this is equivalent to a 540 kg-C equivalent reduction in carbon emissions annually.

The solar market was supported partially by government subsidy programs and tax credits. Most solar systems installed privately were tied to the electrical grid. The solar producer's meters runs backward to credit production. At the end of the year, usage and production are reconciled. No compensation is given for access to electricity produced because of the government subsidies and tax credits given upfront.

Participation in the subsidy programs was on a volunteer basis, and was designed to help expand the solar industry to reduce the cost of solar photovoltaic cells. At the end of 2007, according to preliminary data, cumulative global production was 2,400 megawatts (mw), less than 1% of the global need. It resulted in a small reduction of the amount of electricity that utilities need to produce from conventional sources. Rebates, and tax incentives did not lower costs and the industry grew very slowly. For example, the 120W Kyocera solar cell purchased in 2002 at $ 499 or $ 4.15/w are now $ 614 or $4.99/w (20 per cent more).

Large investments into the industry are making a difference and have created a viable market. Now that it is real, everyone what to be a player. The U.S. Presidential candidates talked about green-collar movements and pledged the creation of millions of new jobs, job training for current and future workers, and the identification of green industries of the future. Community based and development organizations are clamoring for green jobs and a piece of the pie albeit it the crumbs.

> **Republican Sen. John McCain --** "We have the opportunity to apply America's technological supremacy to capture the export markets for advanced energy technologies, reaping the capital investment and good jobs it will provide."
>
> **Democratic Sen. Barack Obama --** "We've also got to do more to create the green jobs that are jobs of the future. My energy plan will put $150 billion over 10 years into establishing a green energy sector that will create up to 5 million new jobs over the next two decades."

The green that matter is money by the billions wrote Fortune Magazine's Marc Gunther. Fortune 500 companies, including BP Solar, SunPower, General Electric, Mitsubishi, Sanyo, Sharp, and Shell, all want to grow their solar businesses.

In Silicon Valley, meanwhile, venture capitalists like John Doerr and Vinod Khosla, entrepreneur Bill Gross, and Google founders Larry Page and Sergey Brin are backing startups that claim they will revolutionize the industry. Chevron Technology Ventures LLC, a subsidiary of Chevron Corporation, identifies, develops and commercializes emerging technologies and new energy systems including hydrogen-related technologies, advanced energy storage technologies, renewable energy and nanotechnology. Chevron, formerly primarily petroleum-based, has expanded into a number of renewable energy technologies.

Solar energy development is definitely a hot item in the stock market. According to John Cavalier, who is chairman of the energy group at Credit Suisse, the market value of the world's publicly traded solar companies stood at about $1 billion in 2004. Now, after a slew of Initial Pubic Offerings (IPOs), they are worth about $71 billion. If the U.S. enacts legislation to counter global warming and it adds to the cost of making electricity from coal, natural gas, and oil, solar energy will be among the winners. "The opportunity for solar companies is absolutely tremendous," Cavalier says.

Major photovoltaics companies include BP Solar, Isofoton, Kyocera, Q-Cells, Sanyo, Sharp Solar, SolarWorld, SunPower, Suntech, and Yingli Green Energy representing the U.S.,Spain, Japan, German, and China. The best-positioned companies are integrated solar players (REC, SolarWorld, SunPower, Suntech representing Norway, Germany, U.S. and China). Integrated companies are those that desgn, manufacture, construct and install utility scale solar systems. In addition, downstream companies with the skills necessary to originate power deals in multiple markets have very strong growth potential (e.g. Conergy and SunEdison)[88] .

Company	Country Of Origin	Cell Technology	Capacity2007 total (in MW)	Capacity2008e _announced	Capacity2009e _announced	Capacity2010e _announced	Capacites_Other
Sharp Electronics	Japan	Crystalline/TF	725	870	870	1250	1001 MW for the future
Q-Cells	Germany	Crystalline/TF	547	834	1055	1135	Plus 1000 MW aft. 2010
Suntech Power Holdings	China	Crystalline/TF	320	590	590	590	
First Solar	USA	Thin film	317	484	1012	1012	
SolarWorld	Germany	Crystalline	280	460	650	671	
Sanyo	Japan	Crystalline/TF	270	365	365	665	
BP Solar	UK	Crystalline	257	480	600	800	
Kyocera (Yohkaichi Plant)	Japan	Crystalline	250	300	300	500	
Motech Industries Inc.	Taiwan	Crystalline	240	330	500	660	1001 MWp by 2012; 2 GWp by 2015
Solarfun Power Holdings	China	Crystalline	240	360	360	360	
SunPower Corp.	USA	Crystalline	214	414	414	1000	
Gintech Energy Corp.	Taiwan	Crystalline	210	300	510	600	
E-TON Solar Tech	Taiwan	Crystalline	200	320	400	500	
Yingli Green Energy	China	Crystalline	200	400	600	600	
CEEG Nanjing PV Tech	China	Crystalline	200	390	550	600	
China Sunergy Co. Ltd	China	Crystalline	192	320	320	390	400 by 2013
Mitsubishi	Japan	Crystalline/TF	190	280	310	430	750 by 2012
Ersol Solar Energy AG	Germany	Crystalline	180	220	300	400	500 by 2012
Jing Ao Solar Co Ltd.	China	Crystalline	175	175	175	175	
Moser Baer Photovoltaic	India	Crystalline/TF	120	120	200	700	
Total (in MW)			5327	8012	10081	13138	
Total for Top 10			3446	5073	6302	7743	

Table 1. Top 20 Global Solar Companies and Energy Capacity from 2007-2010. [11]

Sharp Solar Energy Solutions Group, a group of Sharp Electronics Corporation is the world's oldest and largest (disputed by Q-cells) photovoltaic module and cell manufacturer, produces solar panels in Japan, and near Wrexham, UK. It has been producing solar energy for a half century. SunPower was considered a dead business until Cypress Seminconductor financed it in 2005. The company owns 52% of the business.

Biomass

Biomass is agricultural product specifically grown for conversion to biofuels. These include corn and soybeans. R&D is currently being conducted to improve the conversion of non-grain crops, such as switchgrass and a variety of woody crops, to biofuels.

The energy in biomass can be accessed by turning the raw materials of the feedstock, such as starch and cellulose, into a usable form. Transportation fuels are made from biomass through biochemical or thermochemical processes. Known as biofuels, these include ethanol, methanol, biodiesel, biocrude, and methane. Agriculture and forestry residues, and in particular residues from paper mills, are the most common biomass resources used for generating electricity and power, including industrial process heat and steam, as well as for a variety of biobased products. Use of liquid transportation fuels such as ethanol and biodiesel, however, currently derived primarily from agricultural crops, is increasing dramatically [12].

Currently, a majority of ethanol in the U.S. is made from corn, while Brazil uses primarily sugar cane. New technologies are being developed to make ethanol from other agricultural and forestry resources such as:

- corn stover (stalks and residues left over after harvest);
- grain straw;
- switchgrass;
- quick growing tree varieties, such as poplar or willow; and
- municipal wastes.

The Department of Energy makes funding for research and development related to biofuels available via competitive solicitations. In 2007, BP, now referred to as a Global Energy Company also present in the solar industry, selected UC Berkeley to lead the $500 million energy research consortium with partners Lawrence Berkeley National Lab, and University of Illinois**.** The funding will create the Energy Biosciences Institute (EBI), which initially will focus its research on biotechnology to produce biofuels — that is, turning plants and plant materials, including corn, field waste, switchgrass and algae, into transportation fuels [13]. BP adopted a new slogan in 2000, "Beyond Petroleum" and changed its logo to rebrand itself as a green company.

Biofuels have been commercially successful in several countries. Brazil (ethanol) and Germany (biodiesel) are two examples. In Brazil, "Eighty percent of the 2005 production (ethanol) is anticipated to meet national demands (transportation fuels). In Germany, the last ten years consumption and production of biodiesel has increased several fold. In 2004, 1.18 million tones were produced, up 45 percent from 2003 and an additional 500,000 tonnes were planned for 2005 [14].

Key biomass energy players are already present in the Netherlands and include Biopetrol, which is building a biodiesel plant at Vopak's terminal, and WHEB Biofuels and Argos Oil, which are also building biodiesel plants there.

Conclusion:

Renewable energy is no longer unprofitable and small business. Companies are publicly traded and worth over $71 Billion. The infusion of hundreds of millions of dollars in renewable energy startups by capital rich petroleum-based and semiconductor - based companies behind the scenes has made the renewable energy industry big business and led to real growth. Government incentives have been critical to make these investments.

There are some new faces in energy renewables that have become IPOS, but they are financially backed and often controlled by parent corporations entrenched in conventional energy sources. New comers like farmers, small businesses, and job seekers will benefit modestly from the renewable energy boom. The technical innovators fair a little better, but he who has the gold rules.

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Collection of Useful Data for Sizing a Greywater Treatment Plant at Butare Central Prison

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Key words: wastewater, grey water, flow rate, BOD, fecal coliforms, Waste stabilization ponds, constructed wetland.

Abstract

Rwanda faces serious environmental challenges as do many developing countries. Environmental group from the Institute of Scientific and Technological Research (IRST) has selected Butare Central Prison (BCP) to be the first beneficial of its research activities because this centre has for long been in an alarming wastewater pollution situation. Our goal is to conduct a profound and practical study of wastewater treatment aimed at reversing the current status quo of environment disaster and thereby, protecting and enhancing the public health. At the current stage of the project the group has achieved some results such as the unification of all wastewater streams into one flow and the flow rate measurement, and, the chemical-biological analyses. Results are important as they will serve in the calculation and the designing of the natural system based wastewater treatment plant: BOD_5 measured by iodometric method has an average of 2150 mg/l. From ISO test, fecal coliforms are greater than 10^5. The flow rate measured using triangle spillway and Kindsvater formula had a mean value of 116.64 m^3/day. The design temperature is estimated to be 18.4°C. The results from analyses show that grey water from BCP is highly polluted and must be treated before its disposal. The study and the feasibility of the plant treatment installation continue and the construction activities of the facility itself will be launched as soon as all parameters are determined and funds gathered.

Introduction

Rwanda is a developing country with a remarkable growing population. It is among African countries with the highest density of population and the rural exodus phenomenon increases the population in major cities. The urban population increase is associated with the rise in water consumption and therefore, the increase of wastewater production. The results from a study done in 2003 showed a mushroom increase in wastewater generation especially after the year 1999 [8]. Important quantities of wastewater produced in Rwanda municipalities are not purified before its disposal and yet, inadequate handling of wastewater has serious consequences for human health, the environmental and economic development. It contaminates water supply, increasing the risk of infectious diseases and deteriorating groundwater and other local ecosystems, for instance after flooding [5]. Also, wastewater with phosphorous and nitrates causes eutrophication of receiving water bodies [7]. We can also mention unpleasant smell resulting in organic waste decay. In order to help to solve this growing concern, the Institute of Scientific and Technological Research (IRST) launched this wastewater treatment project that started in Butare city and the experience obtained from here will be reproduced at several sites of the country. The present paper is done in order to report

the results of the first phase of an ongoing project at Butare central prison. The grey water from bathroom, kitchen and sometimes from the medical facilities is our main preoccupation. After the reunification of all wastewater streams, chemical and biological analyses were carried out and flow rate was measured and data obtained will be used in sizing a treatment plant.

Experimental set up

Description of the site

Butare central prison is located in Huye District, Southern Province. This prison of more than 6 thousand inhabitants gets its water from a nearby well. After usage, black water is conducted with faces into a biomethanisation unit to produce biogas that helps in cooking, while grey water is delivered into nearby banana plantation without any treatment. Grey water from BCP is considered to carry organic manure for plantations. Although the soil is an excellent adsorbent for most soluble pollutants, domestic wastewater must be treated before it can be used for crop irrigation to prevent the risk to both public and the environment [4].

Reunification of wastewater flows

The canalization of the grey water from BCP was done using PVC pipes, and collectors. Two existing collectors were repaired and 7 new collectors were built. Those collectors were interconnected with the pipes of 110 and 160 mm of diameter in compliance with the estimated quantity of wastewater to be conducted. Upstream from the first collector, screens and bypasses were installed in order to protect pipes downstream, but also to reduce pollution by grit removal (figure 3):

Figure1: Exit from homes

Figure 2: Solid waste from degritting

Figure 3: Main exit after degritting

Figure 4: Exit from kitchen

It was observed that the composition of solid waste from screening was composed as follows:
-For the grey water from the dormitory site (figure 1 and 2), solid waste are essentially composed of avocado seeds and peeling, worn clothes, packaging waste etc.
- For the grey water from the kitchen (figure 4), they are essentially composed of charcoal pieces, beans and maize seeds, etc.

The screening reduces solid waste in wastewater, therefore, the generation of gases that occurs by solid waste decay in water downstream. At the last collector, a channel was built and a triangle spillway set up for flow rate measurement (figure 6).

Flow rate measurement

The flow rate was measured according to triangle spillway (V-notch) technique as shown on the image below. The spillway was made from a piece of metal sheet that we painted and graduated.

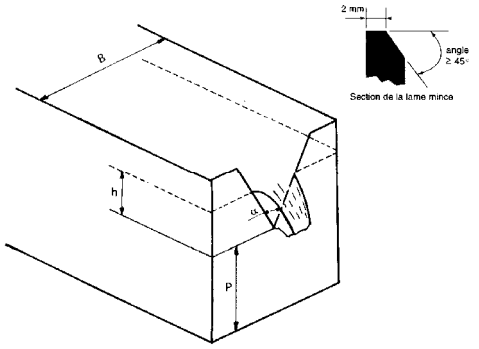

Figure 5: Triangle spillway

Figure 6: Flow rate measurement and sampling

Where: h= level of water above the notch in m
B= channel width in m
P= distance between the notch end the bottom in m
α= angle of the spillway

After measuring the water level above the notch (h), the calculation of the flow rate is done using Kindsvater equation as follows.

$$Q = \mu \frac{8}{15} tg \frac{\alpha}{2} \sqrt{2g} (h_0 + k_h)^{\frac{5}{2}} \quad [1]$$

Where: Q = the flow rate in m^3/s
m = flow rate coefficient
α = angle of spillway
k_h = coefficient taking account of superficial tension and viscosity
g = acceleration of gravity in m/s^2
k_h and m are given in abacus.

In our case of study, different values are B = 29 cm, P = 9 cm, α = 90° and g = 9.81 m/s^2. The channel has 14 m of length. Abacus gives the following values m = 0.592 and k_h = 0.8 mm viz 0.0008 m [1]. Thus, numerical application in international system is calculated as follows, taking the example of the maximum value where ho = 0.11 m.

$$Q = 0.592x \frac{8}{15} xtg \frac{90^\circ}{2} x\sqrt{2x9.81}x(0.11 + 0.0008)^{\frac{5}{2}}$$

Q = 0.005715 m^3/s viz 5.7 l/s

The detail from flow rate calculations is reported in the figure 7.

Chemical and biological analyses

Sampling

The sampling was done at the last collector, manually with latex gloves, polyethylene bottle and cooling boxes to maintain the temperature around 4°C before reaching the laboratory. After we noticed that the changes were important during a day more than between days, multiple samples (6 per day) were taken for few days.

Methods of analysis

Table 1: Measured parameters and methods used

Parameter	Method of analysis
COD	HACH DR-2000 photometer and HACH COD reactor [9].
BOD	Iodometric method [9]
TSS	HACH DR-2000 photometer
Nitrates	Method MgO-DEVARDA [6]
Nitrites	Method MgO-DEVARDA [6]
Total nitrogen	Kjeldahl method [6]
Total phosphorus	Colorimeter method with UV-visible 320 SAFAS Monaco after digestion with perchloric acid [6]
Turbidity	HACH DR-2000 photometer
Alkalinity	Titration by sulfuric acid 0.05 N [9]
Fecal coliforms	Membrane filter techniques, Reference: NF T 90-414-402-1985 ISO 9308-1 1990

Results and discussion

Results from flow rate measurement

The application in Microsoft Soft Excel for flow rate measurement according to Kindsvater equation gave the following chart:

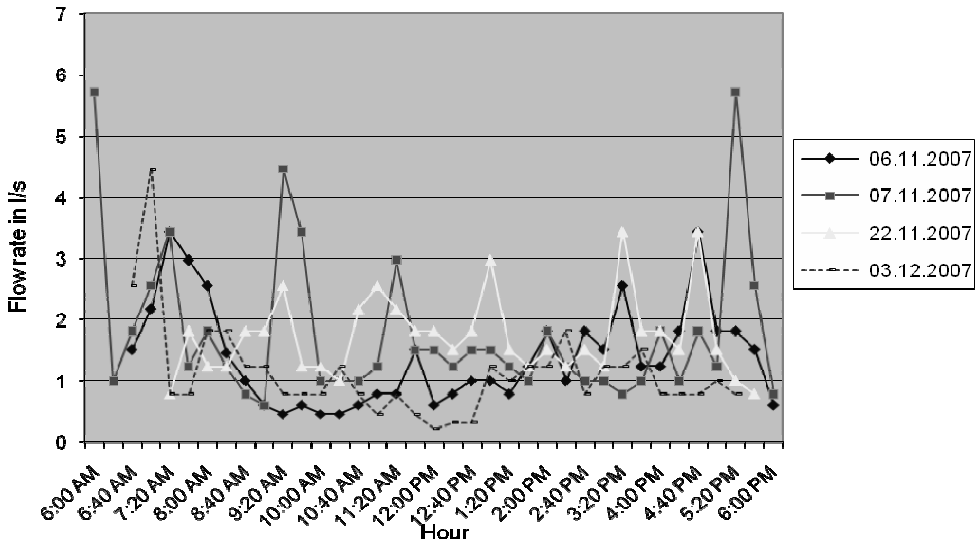

Figure 7: Flow rate variation with time

The flow rate was low on the days 6th November and 3rd December because of the lack of fuel wood that limited culinary activities. Peaks in morning are associated with bath and washings that are also observed around midday; while the evening peaks are related to culinary activities. Thus, the mean flow was calculated using the data from two days 7th and 22nd November. This calculation gave the mean flow of 1.8 l/s, a value that matches the

estimation value using 15 l daily consumed by every prisoner according to prison authorities; given the number of people equal to 7790 at the date of measurement. Assuming that daily activities last 18 hours, the calculations based on measured mean flow rate led to 116.640 m ^{3}/day, while the estimation data led to 15 l per day x 7790 = 116850 l per day videlicet 116.85 m^3/day.

Results from chemical and biological analyses

The quotations --- refer to failed analyses due to technical problems in laboratory like power blackout, while ND refers to non selected samples (not done).

Table 2: Results for sample taken on 07/11/2007

Sample reference 07/11/2007	Parameters					
	Alkalinity ($gCaCO_3$/l)	**NH_4^+ (g/l)**	**NO_2^- (g/l)**	**NO_3^- (g/l)**	**P_{Tot} (g /l)**	**N_{tot} (g/l)**
8:00 AM	4.485	$1.34x10^{-2}$	$1.2x10^{-3}$	$7x10^{-4}$	$6.1x10^{-3}$	$2.2x10^{-3}$
9:00 AM	0.550	$1.02x10^{-2}$	$1.8x10^{-3}$	$4.9x10^{-3}$	$1.2x10^{-2}$	$1.6x10^{-2}$
12:00 PM	0.438	---	---	---	$4.5x10^{-3}$	$5x10^{-3}$
2:12 PM	0.590	---	---	---	$1.1x10^{-2}$	$1.8x10^{-2}$
4:12 PM	---	---	---	---	$1.2x10^{-2}$	$5.3x10^{-2}$

The above parameters are not directly involved in design of treatment facility which is our aim, but they were analyzed in order to give information about others indicators of water pollution. Their analysis was done in the laboratory of High Institute of Farming and Agriculture (ISAE) located at Busogo. The following tables report results for parameters analyzed in National University of Rwanda (NUR) laboratory of water quality located at Kigali.

Table 3: Results for sample taken on 07/11/2007

06/11/07	**7 : 00 AM**	**10 : 06 AM**	**12 : 00 PM**	**1 : 33 PM**	**3 : 09 PM**	**6 : 00 PM**
COD (mg/l)	5820	2920	2220	5940	4230	3690
BOD_5 (mg/l)	---	---	---	---	---	---
Turbidity (NTU)	2100	1325	675	ND	ND	ND
MES (mg/l)	2475	1675	900	ND	ND	ND
Fecal coliforms (Cfu/100 ml)	>1x 10^5	>1 x 10^5	>1 x 10^5	ND	ND	ND

Table 4: Results for sample taken on 07/11/2007

07/11/07	**7 : 00 AM**	**09 : 00 AM**	**12 : 00 PM**	**1 : 30 PM**	**3 : 30 PM**	**6 : 00 PM**
COD (mg/l)	4030	3490	3960	4020	6190	3280
Turbidity (NTU)	1600	1230	1380	ND	ND	ND
TSS (mg/l)	2200	1600	1825	ND	ND	ND
Fecal coliforms (Cfu/100ml)	ND	ND	>1 x 10^4	<1 x 10^0	ND	<1 x 10^0

Fecal coliforms are reported to be greater than 10^5 Cfu/100 ml in the morning while they are reported to decrease in the afternoon. The presence of pathogens in the morning is associated with the body washing that is actually not taking place in the evening. Theoretical values for grey water range between 10^4 and 10^7 [2].

Table 5: Results for sample taken on 07/11/2007

22/11/07	**07 :10 AM**	**09 : 23 AM**	**10 :52 AM**	**12 :50 PM**	**3 : 20 PM**	**4 :50 PM**
BOD_5 (mg/l)	1000	1460	2090	1746	---	---
COD (mg)	---	---	---	3150	11610	3240
Ratio COD / BOD_5	---	---	---	1.8	---	---

Table 6: Results for sample taken on 07/11/2007

Hour	7:15 AM	9:08 AM	10:25 AM	11:40 AM	12:45 PM	2:00 PM	3:45 PM	5:35 PM	Average
DCO (mg/l)	1630	6230	6490	5460	4950	4230	4550	2830	**4546**
DBO_5 (mg/l)	1086	2298	2800	2298	2565	2052	2052	2052	**2150**
BOD_5/ COD	1.5	2.71	2.31	2.37	1.93	2.06	2.22	1.38	**2.11**

BOD of domestic wastewater usually ranges between 50 and 400 mg/l [9]. Grey water from BCP has a mean BOD that overtakes 400 mg/l, characteristic of industrial wastewater. This concentration of pollution is associated with the quantity consumed by each prisoner that was reported to be 15 l/prison per day according to BCP authorities. However, the ratio COD/BOD is one of urban wastewater that is generally around 2 [7]. From the results above, we can calculate the pollution generation per capita as follows: (116.64 m^3/day x 2150 g/m^3 of BOD) / 7790 people that equals to 32.2 g of BOD per capita. Note that this number is only for pollution associated with grey water not to all pollution produced by each prisoner. These results will be used to calculate and design an adequate treatment plant based on natural systems "Waste stabilization ponds and/or constructed wetlands" in compliance with site specifications. Furthermore, these technologies have proven to be effective alternatives for treating wastewater in tropical countries [3].

Conclusion

The study has shown that grey water from Butare Central Prison is highly polluted with mean BOD_5 of 2150 mg/l and more than 10^5 CFU/100 ml of fecal coliforms. The flow rate had a mean value of 116.64 m^3/day. These values indicate that the grey water from BCP needs to be treated before its disposal. In this perspective, a study of feasibility of natural system based treatment plant is ongoing and the final decision will depend on site specifications that are also planned within the current year.

Acknowledgement

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Dug Well Contamination – The Kerala Scenario

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Key words: Septic tank, Soil absorption system, Coliforms, Dug well

Abstract
In Kerala state (India), a substantial portion of the population depends on dug wells or other ground water sources for their drinking water requirements. It is estimated that there are over 6 million dug wells in the state catering to the domestic water demands of more than half of its population. The main sources of dug well contamination are identified as the on site waste treatment systems (OSWTS) like septic tanks. The guidelines laid down by building rules to avoid this contamination were found to be insufficient. The safe distance between well and an onsite sanitation system will vary from location to location. Based on Physiographic classification, sociological data and previous studies a few soil zones were identified as crucial to the study. Out of the various zones identified as important, one zone was considered for the present study. From the current investigation, it is found that the contamination level in dug well depends upon the horizontal distance between the dug well and OSWTS as well as depth of water table. The sufficient horizontal distance for different water table depth values to avoid contamination were thus calculated.

Introduction

Kerala (between longitudes 74°54'E & 77°25'E and latitudes 8°17'N & 12°47'N) - the southern most among the twenty seven states of India- is one of the thickly populated regions in the world, even though the current population increase is only 9.4 % per decade. Unlike other Indian states, Kerala has achieved commendable progress in the social, cultural and public-health sectors. Many of the indicators of social progress for the state are comparable with that of the developed nations.

The state of Kerala is blessed with amazing greenery and water wealth. The state receives an average annual rainfall of over 3000mm. It has many small and large rivers (44), thousands of ponds (1, 35,620), numerous streams (3,200), many lakes (658) and a number of rivulets (187). Apart from these, the State has more than 6 million wells. The State which is supposed to be water rich faces so many water related problems.

The water related problems faced by the state are due to the following reasons

- Lack of serious and concerted efforts in water conservation.
- Increasing water contamination and improper use of water.

In spite of the fact that Government is taking many initiatives for providing fresh water supply in different regions of the State, more than half of the population depends on dug wells or other ground water sources for their drinking water requirements; and very often the well water is consumed without any treatment.

The main sources of dug well contamination are found to be on site sanitation systems like leach pits and septic tanks. Due to the very high density of residential units and dug wells

in the state, most of the wells are subjected to microbial contamination from septic tank effluent. If the distance between the soil absorption system (SAS) and the well is not allowed to fall below a certain limiting value (which is characteristic of a given soil type) for a particular water table depth, the contamination can be greatly reduced, there by saving the large amount of resources spent on the treatment, in terms of energy, man power, money, etc.

Present Scenario

There were many studies in the recent past which investigated into the level of contamination of dug wells in Kerala. A study conducted by Centre for Water Resources Development and Management (CWRDM), a government research institution, reveals that 80 to 85 % of dug wells in Kerala are polluted by faecal contaminants [1]. The study conducted by 'Malayala Manorama', the popular Malayalam daily, in a project named 'Palathulli' reported that majority of the dug wells in Kerala state are contaminated and not safe for drinking. Their findings are shown in fig.1. [2]

A study on the bacterial quality of water in selected wells in Kerala jointly conducted by Kerala Water Authority and Kerala Pollution Control Board (KWA, 1991) showed that water in none of the open wells investigated was safe for drinking.

The Central Pollution Control Board (CPCB) of India specifies the limit of Total Coliforms Organism (MPN/100ml) in drinking water source without conventional treatment but after disinfection, as 50 or less. According to the earlier legislation prevailed in the state, the minimum distance between dug wells and SAS was 15m, which underlines the importance of a sufficient soil-path length in contaminant removal. But as per the revised Kerala Municipality Building Rules 1999(chapter XVI), which states "…No leech pit, sock pit, refuse pit, earth closet or septic tank shall be allowed or made within a distance of 7.5 metres radius from any existing well used for supply of water for human consumption or domestic purpose or within 1.20 metres distance from the plot boundaries…", this distance was reduced to 7.5 m.

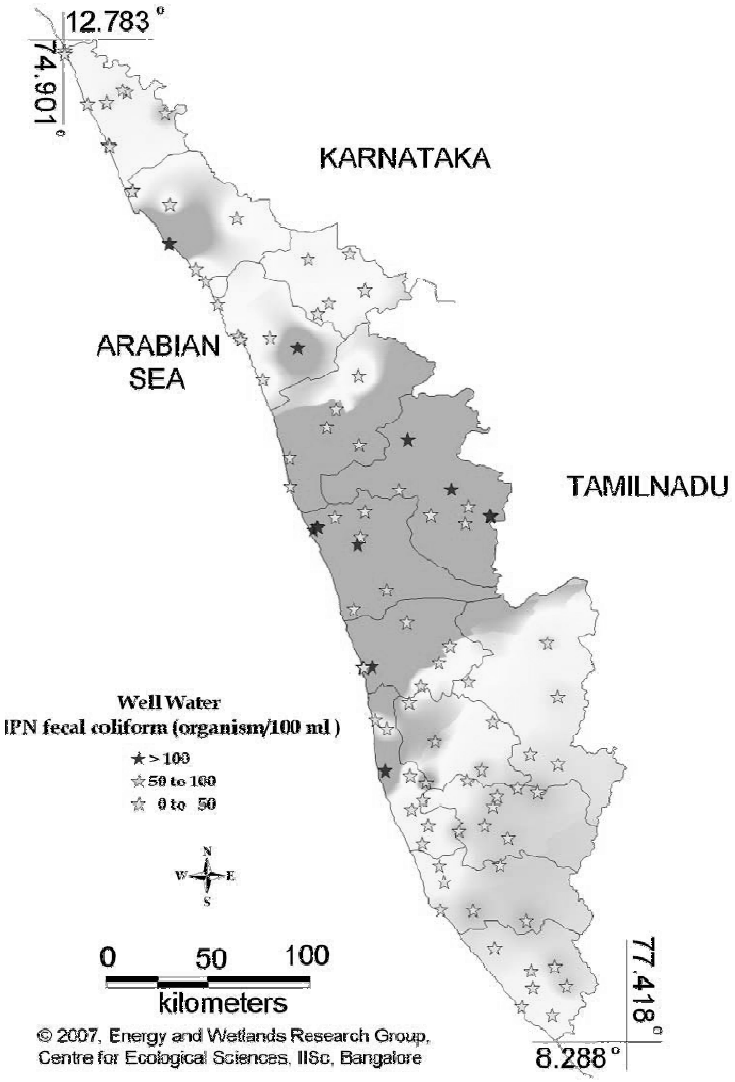

Figure 1: Spatial distribution of Faecal Coliform Bacteria in Kerala well water

Many earlier studies conducted in the state regarding microbial contamination of wells suggested safe distance between well and septic systems and this distance is much above what is given in the Kerala Municipality Building Rules 1999. Thus a critical study of the issue becomes relevant.

Experimental Investigations

The parameters which influences the removal of microorganisms from septage in soil include grain size, Ionic strength, Bacteria sizes, Temperature, Soil Profile, Moisture content, Salt content, pH, Time, Nutrient supply, Hydraulic conductivity and Length of travel. [3], [4], [5] Thus, safe distance between well and an on site sanitation system will vary from location to location. All parameters except the length of travel are assumed same for an area selected. The length of travel depends on two factors, water table depth and horizontal distance between well and soak pit. The flow direction is also a factor but the sample stations are selected visually so that always the flow is towards the well.

'Resource Based Perspective Plan 1997', prepared by Kerala State Land Use Board divided the soil of Kerala state in to 32 types connected to regions. [6] This classification was taken as the basis for the study. As the efficiency of an SAS depends on the ability of the soil to remove contaminants which in turn depend on the soil type, depth and extend, a study conducted on one soil zone can be applied to all regions with similar soil profile. Thus, for each soil zone a safe distance can be recommended. Before selecting a study area it is important to identify the soil zones that are crucial to the study. For this, Physiographic classification, sociological data and previous studies were used as guidelines.

Kakkodi, a place 16 km from the lab where this study was carried out, has 95% of its soil profile falling in a soil zone identified as crucial to the issue of dug well contamination. The selected area, Kakkodi, in Calicut district contains about 1750 houses. There are regions in Kakkodi where the houses are very close to each other and also regions where one can find isolated dwellings. Thus it was an ideal place for getting water samples for an unbiased analysis. The place presented a typical cross section of a Kerala village with people belonging to all social and economic status. The main source of water for the residents of Kakkodi is dug well.

From the previous studies, it is assumed that the sanitation systems which are at a distance of more than 35 metres will not affect the wells. Thus, to avoid influence of more than one septic system, only such wells were considered for study where there was not more than one septic system within a distance of 40m from it. Only the septic tank- soak pit system and wells were considered for the study. Units like a cesspool were not considered as the present regulations do not permit such systems of treatment. The wells considered for study may or may not have been used as sources of drinking water, but were visibly clean. The chances of contamination with animal waste like chicken litter, cow dug were to be avoided since that also can influence the indicator micro organism level in water. This was achieved by carefully selecting the wells.

Guidelines for drinking-water quality given by World Health Organization (WHO) recommend multiple-tube fermentation technique for detection and enumeration of coliform organisms, thermo tolerant coliform organisms and presumptive *Escherichia coli*. Drinking water standards give microbial contamination level in MPN of coliform bacteria per 100ml.Considering these points multiple tube fermentation technique was adopted as the experiment method.

A regression analysis was done by considering water table depth and horizontal distance between well and SAS as independent parameters and microbial concentration in the well water as the dependent.

Results and Discussion

The test results are shown in Fig 2. MPN of coliforms obtained in the laboratory analysis in y-axis is plotted against corresponding path length in x-axis.

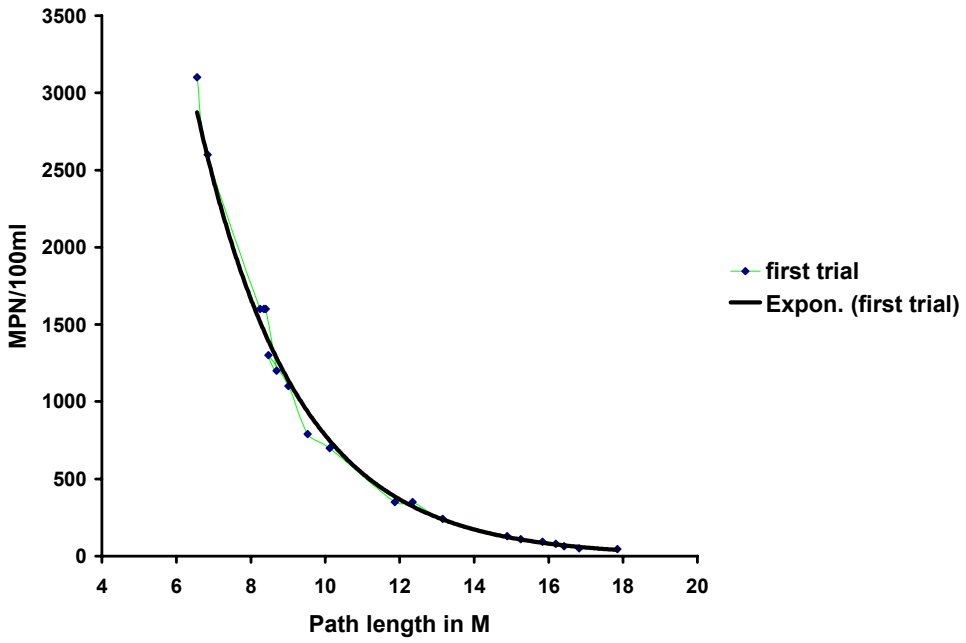

Fig.2. Relation between path length and MPN values

The path length was determined from the horizontal distance and water table depth using a Matlab code. The concentration (as MPN) when Plotted against the calculated path length gave a trend line that had a very low Percentage Root Mean Square Error (PRMSE) value of 0.3. The equation of this curve is used to calculate the safe parabolic path length and corresponding horizontal distance for any given water table depth.

$$x = \frac{1}{-.3781} \ln\left(\frac{C}{34309}\right)$$

From the above equation the safe path length, such that the C value of 50MPN suggested by the CPCB is not exceeded, is calculated as 17.27m, provided, it is the only one SAS contributing coliforms to well water. If there is more than one soak pit situated within the influence zone, the sum of the microbial concentration values contributed by each soak pit individually must be less than the limiting concentration value. So before placing a soak pit near to a well, position of existing soak pits should be considered. Now, if the worst case of having a well under the influence of 4 soak pits is considered, it can be easily shown that the safe distance increases to 21m. Thus, this distance can be suggested as the minimum safe path length for the selected soil zone. Corresponding to this 21 metres of travel distance and different water table depths, the horizontal distance are listed in table 1. The water table depth varies according to the season and the worst case should be considered to get the horizontal distance.

Table 1. Safe horizontal distance for different water table depths

Travel Distance from well to soak pit In metres	Water table depth In metres	Horizontal distance In metres
21	0	21.0
21	2	20.60
21	4	20.00
21	6	19.25
21	8	18.25
21	10	17.00

Conclusion

The study has brought to light that the dug wells of Kerala are subject to considerable bacterial contamination during all seasons. Though the exact sources could not be identified in all cases, the latrines situated close to the wells were found to have great influence on contamination. The guidelines laid down by building rules to avid this contamination were found insufficient .Certain policy guidelines and modifications in building rules might help in improving the present situation. A horizontal distance of 21 meter between well and soak pit will be sufficient to avoid microbial contamination due to this source in Kakkodi a village in Calicut district. The same value can be used for other regions where the soil properties are similar.

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Zinc and Chromium Removal Mechanisms from Industrial Wastewater by Water Hyacinth, *Eichhornia crassipes (Mart.) Solms*

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Key words: Chromium, removal mechanisms, wastewater, water hyacinth, Zinc

Abstract

Zinc and chromium are environmental pollutants toxic even at very low concentrations. Domestic and industrial discharges are probably the two most important sources for chromium and zinc in the water environment. Rwanda is still facing problems of heavy metal discharges into natural ecosystems by factories and households without any prior treatment. The objective is to investigate the major mechanisms responsible for Cr (VI) and Zn (II) removal form industrial wastewater by water hyacinths. pH effects, plant relative growth, trace metal remaining in water samples, translocation ability, bioconcentration factor, adsorption, bioaccumulation and uptake mechanisms were studied. The pH slightly increases from the start time (0 hr, pH= 6.7) to 48 hr (pH= 7.64 to 7.86); but after 48 hr of experiment, the pH decreases due to the saturation of bound sites, so some H^+ are released in water samples. The relative growth significantly decreased ($P \leq 0.05$) from 1, 3 and 6 mg/L in 1 week but it decreased linearly slightly after 1 week, with increasing ($P \leq 0.05$) metal concentrations. 56.7% of Zn (II) was accumulated in petioles, 27.0 % in leaves and 16.3% in roots whereas for Cr (VI) 73.7% was taken up in roots, 14.1% in petioles and 12.2% in leaves. It was seen that 17.6%, 6.1% and 1.1% were adsorbed for 1, 3 and 6 mg/L of Zn (II) concentrations, respectively, by water hyacinth plants. For Cr (VI), 9.0, 36.4 and 54.6% were adsorbed for 1, 3 and 6 mg/L, respectively. The order of translocation ability for Cr (VI) was leaves<petioles<roots in water hyacinth whereas for Zn (II) was leaves<roots<petioles.

INTRODUCTION

Zinc and chromium are environmental pollutants toxic even at very low concentrations. Pollution of the biosphere with toxic metals has accelerated dramatically since the beginning of the industrial revolution [1]. The primary sources of this pollution are the burning of fossil fuels, the mining and smelting of metals, municipal wastes, fertilizers, pesticides and sewage. Heavy metals are of great concern primarily due to their known toxicity to aquatic life and human health at trace levels [2]. It was reported that domestic and industrial discharges are probably the two most important anthropogenic sources for metals in the water environment [3]. However, the lack of a reliable method to predict metals distribution in treatment units is a key weakness in determining metals fate and transport in wastewater treatment processes, and therefore, the development of effective pre-treatment guidelines [4].

The removal of heavy metals from aqueous solutions has therefore received considerable attention in recent years. However, the practical application of physicochemical technology such as chemical precipitation, membrane filtration and ion exchange is

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sometimes restricted due to technical or economical constraints. For example, the ion exchange process is very effective but requires expensive adsorbant materials [5] [6].

The use of low-cost waste materials as adsorbents of dissolved metal ions provides economically viable solutions to this global problem and can be considered an eco-friendly solution [7] [8]. At present, emphasis is given to the utilization of biological adsorbants for the removal and recovery of heavy metal contaminants [9].

In Rwanda, the problem is still critical because there is no appropriate system of heavy metals removal, particularly for zinc and chromium. The development of such a system to remove these toxic contaminats is possible in Rwanda given the availability of water hyacinth. Water hyacinth in the country causes serious problems in many aquatic ecosystems; however, it is possible to use it in wastewater treatment by inoculating wastewater treatment ponds with water hyacinth. This system is inexpensive and can contribute to cleanup in Rwanda with more appropriate technologies.

EXPERIMENTAL SET UP

Sample collection area description

The experiment was performed using free-floating water hyacinth plants. The Water Hyacinth plants *(E. crassipes)* were collected from a natural wetland area called Nyabugogo located in Kigali city and was transferred to the laboratory of National University of Rwanda in big plastic buckets as shown in Figure1and placed under natural sunlight for several days to let them adapt to the new environment in the laboratory. Then plants with similar size, weight and shape were selected, rinsed with distilled water to remove any epiphytes and insect larvae grown on plants and then put in small buckets for experiments as shown in Figure 2.

Fig.1: Water hyacinth plants in big container

Fig.2: Plan view of experimental set up.

All experiments were run in batch mode, using a nutrient solution containing 500 ml of tap water from the valley located at Butare near the Natural Science Centre, 500 ml of wastewater from the Nyabugogo wetland and 20 mg of $Ca(NO_3)_2 .4H_2O$ and NH_4Cl, and 40 mg of K_2HPO_4. Total fresh weight of plants in each bucket was measured before the start of each growing time: 1, 2 and 4 weeks.

Description of the experimental laboratory pilot scale

The experimental laboratory pilot for zinc and chromium removal mechanisms consisted of 12 small buckets as show in Figure 2. Three buckets without water hyacinth plants served as controls (blanks) containing 1, 3 and 6 mg/L of zinc and chromium. Nine (9) small buckets with water hyacinth plants were established with 3 buckets each containing1, 3 and 6 mg/L of zinc ($ZnCl_2$) and chromium (K_2CrO_4). Buckets were maintained for 1, 2 and 4 weeks as the experimental period time. All experiments were performed in the laboratory at a constant temperature (25ºC).

A stock solution (1,000 mg/L) of each metal was prepared in distilled water which was later diluted as required. Individual plants were initially rinsed with distilled water to

remove epiphytes, microbes, and any nutrient that might be transferred and then placed in 2L small plastic buckets containing 1L of solution (0.5Lfrom Nyabugogo wetland + 0.5L from Butare valley). They were maintained in water supplemented by the heavy metals by adding the required volume of zinc and chromium stock solutions to obtain final concentrations of 1, 3 and 6 mg/L of Cr (K_2CrO_4) and Zn ($ZnCl_2$), respectively.

Distilled water was added in order to compensate for water loss through plant transpiration, sampling and evaporation. Water samples and pH measurements were taken every 60 minutes for the first 6 hours and then one sample per day during 1, 2 and 4 weeks of exposure to the metal solution. All samples were filtered using 0.45 µm cellulose acetate filters (wattman papers) and acidified with 5 drops of nitric acid prior to storage of samples. Samples were then analyzed using Perkin Elmer Atomic Absorption Spectrometer.

After each test duration (1, 2 and 4 weeks), final fresh weight for each water hyacinth plant was taken and plants were harvested for other analyses. They were separated into petioles, roots and leaves and were analyzed for relative growth, metals accumulation, translocation ability, bioconcentration factor (BCF) and adsorption on the outer surface of roots. In addition, the metals remaining in the solution were measured to assess the removal potential of water hyacinth plants.

Data analyses

a) Relative Growth (RG)

Relative growth of control and treated plants was calculated to assess the effects of zinc and chromium concentrations on water hyacinth plant growth: $\boldsymbol{RG = FFW/IFW}$**.** Where *RG* denotes the relative growth of the water hyacinth plants during experiment period, it is dimensionless; *FFW* denotes final fresh weight in grams of water hyacinth plants taken at the end of each experiment period and *IFW* denotes the initial fresh weight in grams of water hyacinth plants taken before starting experiment.

b) Bioconcentration Factor(BCF)

The BCF provides an index of the ability of the plant to accumulate the metal with respect to the metal concentration in the substrate. The BCF was calculated as follows: $\mathbf{BCF = (P/E)_I}$ **.** Where $\boldsymbol{i}$ denotes the heavy metals, $\boldsymbol{BCF}$ is the dimensionless bioconcentration factor, $\boldsymbol{P}$ represents the trace element concentration in plant tissues (mgL^{-1}), $\boldsymbol{E}$ represents the initial concentration in the water (mg/L) or in the sediment (mg/kg dry wt). A larger ratio implies better phytoaccumulation capability.

c) Metal Accumulation

Metals accumulation in plant and water samples was measured. Digestion of samples in this study was performed according to the Standard Methods by APHA.7 [10]. Plant biomass samples were decomposed to dry matter by heating at 105°C for 24 hours in a hot air oven and the ash was digested with nitric acid (HNO_3) and hydrogen peroxide (H_2O_2), filtered through a Wattman® paper filter into a volumetric flask before Atomic Absorption Spectrometer analyses. The three following mechanisms were performed in analyses to differentiate the metal adsorbed, bioaccumulated, and translocated by water hyacinth during the experiment period.

Adsorption

The adsorption consists of metal attached to the outer surface of the roots. To quantify the metal adsorbed by water hyacinth; after the plant exposure to different concentrations of chromium and zinc in different periods of times (1week, 2weeks and 4 weeks). After experiment duration, the adsorption was determined by putting roots of water hyacinth plant in nine 100 ml of EDTA-Na_2 3, 24 mmolar respectively for 5, 10, 15, 20, 25, 30, 35, 40 and 45 min for removal of zinc and chromium trace elements on the outer surface of the roots.

Those EDTA-NA_2 solutions were filtered, acidified by 5 drops of Nitric acid (HNO_3) and analyzed by Atomic Absorption Spectrometer (AAS) for zinc and chromium adsorbed by the plants. The most important parameter to consider is the pH [11]. Generally when the pH decreases, the toxicity of metal ions increases because the proportion of the adsorbed ion on the root system decreases [12].

Uptake

The uptake process is a mechanism by which metal ions are transported across the cell membrane and can be used in a building of new biomass or stored in vacuoles. To assess this mechanism during our research; after experiment period, water hyacinth plants were taken out form the small buckets, roots, petioles and leaves were separated, dried in dry oven at 105°C during 24h. Plant samples were transformed in ash, digested and analyzed by AAS to identify the zinc and chromium concentrations in plant biomass (roots, leaves and petioles). The results from AAS analyses show the plant parts which contribute more in metal accumulation. The presence of carboxyl groups at the roots system induces a significant cation exchange capacity and this may be the mechanism of moving heavy metal in the roots system where active absorption takes place.

Translocation ability (TA)

The translocation ability was calculated by dividing the concentration of a trace element accumulated in the root tissues by that accumulated in shoot tissues [13]. *TA* is given by: $\boldsymbol{TA = (Ar / As)_i}$ **.** Where ***i*** denote the heavy metal, ***TA*** is the translocation ability and is dimensionless. ***Ar*** represents the amount of trace element accumulated in the roots (mgL^{-1} dw), and ***As*** represents the amount of trace element accumulated in the shoots (mgL^{-1} dw).

Statistical analysis

In order to detect quantitative differences in the data, statistical analyses were performed.

Standard deviation

It was obtained from the variance by extracting the square root and was expressed in the unit in which the measurements were taken:

$$S = \sqrt{\frac{\sum fd^2}{(n-1)}}$$

Regression analysis

Regression is defined as the determination of statistical relationship between two or more variables. In simple regression one variable (defined as independent) is the cause of the behaviour of another one (defined as dependent variable). The correlation coefficient (r) is expressed by equation:

$$r = \frac{\sum dx.dy}{\sqrt{\sum dx^2 . \sum dy^2}}$$

RESULTS AND DISCUSSIONS

Effects of pH variations

The initial solution pH was adjusted to 6.7 in the small plastic buckets using HCl or NaOH. This is the pH tested in Nyabugogo wetland. The results from experiments are shown in Figure 3 and show that the effects of pH vary considerably in different buckets with water

hyacinth plants over exposure time. Metal will precipitate as hydroxides when the pH of the wastewater is raised to pH 8 to 11 [14].

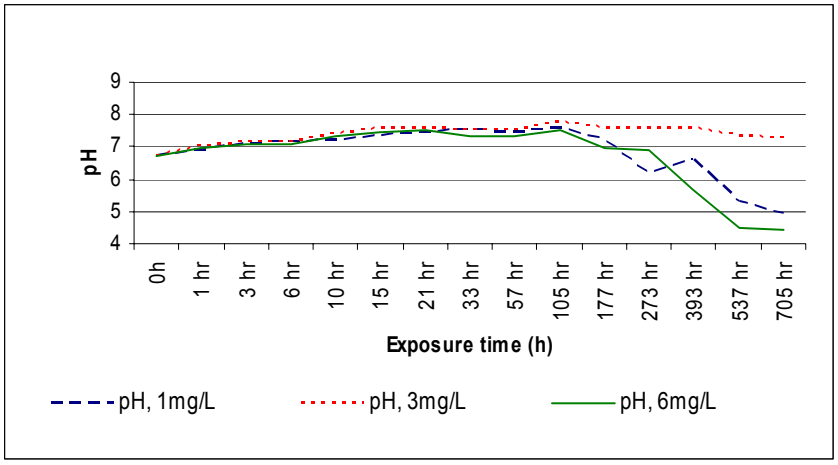

Fig.3: pH variations in plant water samples overtime

As a result, the extent of adsorption was rather low at low pH values. However, in the equilibrium solid phase, Zn (II) and Cr (VI) ion concentrations increased with increasing pH because of increasingly negative charges on the surfaces of the roots at high pH values. This attracted positively charged Zn (II) and Cr (VI) ions more strongly. The ANOVA with replications showed that for 1 mg/L, 3 mg/L and 6 mg/L there was no effect of exposure time but high difference between pH effects and metal remaining in water samples ($P \leq 0.05$). It was seen that the pH effect variations were due to the saturation of binding sites on root systems which affect the pH in water samples with water hyacinth plants by releasing H+ in water samples.

Plants relative growth (RG)

The relative growth of water hyacinth plants at different concentrations of zinc and chromium is shown in Table 1. It can be seen that the relative growth of plants decreases with increasing of zinc and chromium concentrations.

Table1: Relative changes in growth of plants vs. zinc and chromium concentrations

Exposure time (week) with Zn & Cr concentrations	Initial water hyacinth fresh weight (g)	Final water hyacinth fresh weight (g)	Relative growth
1 wk, 1 mg/L	32.33	85.23	2.64
1 wk, 3 mg/L	34.50	96.91	2.81
1 wk, 6 mg/L	26.38	50.07	1.89
2 wks, 1 mg/L	29.75	55.92	1.88
2 wks, 3 mg/L	42.90	80.18	1.87
2 wks, 6 mg/L	16.24	39.96	2.27
4 wks, 1 mg/L	41.15	85.57	2.08
4 wks, 3 mg/L	39.65	98.05	2.47
4 wks, 6 mg/L	34.54	96.16	2.78

For water hyacinth plants treated with Zn and Cr, the relative growth significantly decreased ($P \leq 0.05$) from 1, 3 and 6 mg/L in 1 week but for 2 and 4 weeks, the relative growth decreased only slightly with increasing ($P \leq 0.05$) metal concentrations. The relative growth exhibited a decreasing trend caused by relative increases in toxicity of chromium and zinc.

The analysis of variance showed that for 1 week exposure time, there is a high effect (difference is significant) of initial concentrations (1, 3 and 6 mg/L) to the growth of the plants ($P > 0.05$), but for 2 and 4 weeks related to initial concentrations, the difference is not significant ($P > 0.05$). Xiaomei et *a*l. [15] reported that the relative growth of water hyacinth decreases when metal concentrations increase, confirming what was observed in this investigation.

Bioconcentration Factor (BCF) of zinc and chromium

The bioconcentration factor (BCF) was calculated as the ratio of the trace element concentration in the plant tissues at harvest to the concentration of the element in the external environment [16]. The pattern of the bioconcentration factor of water hyacinth plants is shown in Figures 4 and 5.

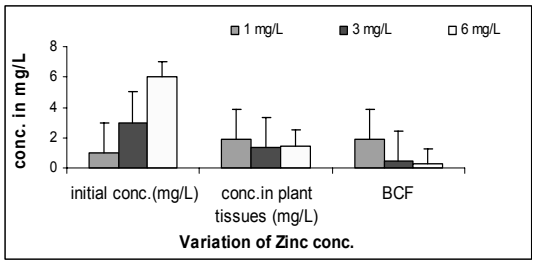

Fig.4: Variations in BCF of zinc

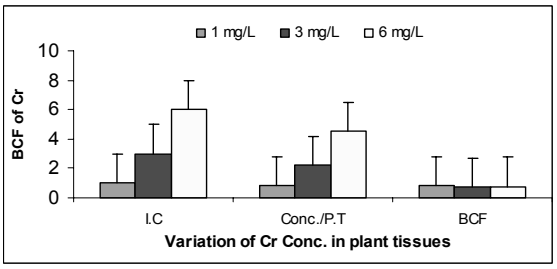

Fig.5: Variations in BCF of chromium

A high competition between zinc and chromium accumulation by the plants and zinc was observed due to kinetics of these metals. The comparison of Zn (II) and Cr (VI) showed that the BCF of zinc was higher than the chromium's BCF for 1 and 3 mg/L, but very low for 6 mg/L for zinc. The plant accumulated more low concentrations than the high ones. It was reported that there is no significant difference both for zinc and chromium when comparing initial concentrations to the concentrations in plant tissues and bioconcentration factors ($P > 0.05$) for zinc and chromium.

Adsorption

More trace elements of zinc and chromium were removed from 5 up to 15 minutes and the high concentration observed for 6 mg/L was around 2 mg/L, for 3 mg/L was around 1.6 mg/L and for 1 mg/L was around 0.3 mg/L. The adsorption ability of water hyacinth plants was seemed to be different when zinc and chromium are compared.

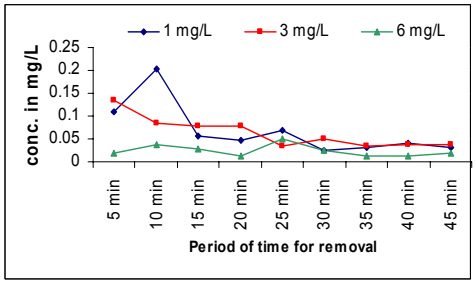

Fig. 6: Desorption of zinc

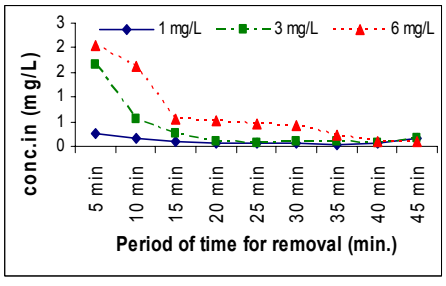

Fig.7: Desorption of chromium.

For zinc, 17.6% of 1 mg/L was adsorbed by the water hyacinth plants, 6.1% of 3 mg/L was adsorbed and the plants adsorbed 1.1% of 6 mg/L. For chromium, 9.0% of 1 mg/L, 36.4% of 3 mg/L and 54.6% of 6 mg/L were adsorbed on the roots of water hyacinth plants. Meggo[17] has confirmed that aquatic plants are able to accumulate metal at low concentrations.

Uptake for zinc and chromium

It was reported that 56.7% of zinc was accumulated in petioles, 27.0% in leaves and 16.3% in roots. The analysis demonstrated no significant difference for different initial concentration and exposure time ($p > 0.05$) in uptake mechanisms of zinc. There was a significant difference observed in plant parts in uptake processes ($p \leq 0.05$). For chromium, 73.7% was taken up in roots, 14.1% in petioles and 12.2% in leaves, demonstrating the preference of plants to store chromium in roots. The trend was the same for zinc; no significant difference existed between plant parts ($p > 0.05$) and also between initial concentrations in uptake processes ($p > 0.05$).

Translocation ability (TA)

The quantities of trace elements accumulated in the petioles exceeded those in the shoots. Roots of water hyacinth accumulated about 3 to 15 times more trace elements than did the shoots. It appears that chromium translocation is compared to zinc as shown in Table 3. The ability of plants to translocate trace elements of chromium increased for roots/leaves (5.3 times for 1 mg/L, 6.5 times for 3 mg/L and 6 times for 6 mg/L). The number of times for roots/petioles decreases (4 times for 1 mg/L, 4 times for 3 mg/L and 7 times for 6 mg/L) because the order of storage was leaves<petioles<roots.

Table 2: TA of zinc

		Zn (II) conc.		
	Roots/ Shoots	1 mg/L	3 mg/L	6 mg/L
1 week	Roots/petioles	0.382[a]	0.255[a]	0.383[a]
	Roots/leaves	1.114[a]	0.732[a]	0.164[a]
2 weeks	Roots/petioles	0.478[a]	0.485[a]	0.439[a]
	Roots/leaves	0.461[a]	0.564[a]	0.993[a]
4 weeks	Roots/petioles	0.171[a]	0.510[a]	0.109[a]
	Roots/leaves	0.241[a]	1.041[a]	0.255[a]

a: times of storage in roots compared to shoots.

Table 3: TA of chromium

	I.C[a] of chromium (VI)		
Roots/shoots	1 mg/L	3 mg/L	6 mg/L
roots/petioles	4.104[b]	3.663[b]	6.831[b]
roots/leaves	5.288[b]	6.487[b]	5.965[b]

a: initial concentration; b: times of storage in roots compared to shoots.

The ANOVA shows the variability in translocation ability. It can be seen that the difference is not significant between metal concentration ($p > 0.05$) and no significant difference between roots and shoots translocation ($p > 0.05$). Stratford and co-workers [18] found that metal accumulations in water hyacinth increased linearly with solution metal concentration in order ***leaves<petioles<roots.*** In this research, the following order was observed: ***leaves<roots<petioles***. When the concentration is high, the water hyacinth plant can only accumulate a low concentration in plant cells. This is in agreement with the results of this study in the case of chromium concentration accumulation in water hyacinth plants, where the high concentration was accumulated in roots followed by petioles and then leaves. Water hyacinth materials were burned after all experiences to avoid the contamination.

CONCLUSIONS

From the above results, it is evident that water hyacinth when grown over wastewaters in controlled environment/closed systems such as constructed wetlands can efficiently remove zinc and chromium in wastewaters, provide fresh water, and possibly clean up the air environment by removing CO_2 and releasing 0_2. The removal mechanisms of zinc and chromium by water hyacinth plants showed that the plant concentrated a high quantity of metals. The aquatic plant water hyacinth have shown promising potential for the removal of

Cr (VI) and Zn (II) from industrial synthetic wastewater of three different concentrations (1, 3 and 6 mg / L).

ACKNOWLEDGEMENTS

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Characterization of Abattoir Wastewater of Kigali, Rwanda

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Abstract
The rapid pace and scale of urbanization in Rwanda represents a considerable challenge for water resources management particularly the delivery of essential water, sanitation services and environmental protection. The main objective of this study was to analyze processes and products at Nyabugogo abattoir in Kigali, and to investigate how they can be optimized for environmental safety. The effluent characteristics of the abattoir were analyzed, with emphasis on nutrients, biologically active constituents, and receiving water impacts. The study focused on establishment of the quantity and quality of different raw materials, by-products and wastewater streams and assessment of potential impacts of the application of cleaner production principles in abattoir processes. The samples were collected fortnightly, preserved and analyzed in each case using Standard Methods. The data were processed for trends and variance using SPSS computer package. The wastewater parameters analyzed are temperature, salinity, conductivity, turbidity, dissolved oxygen pH, TSS, TDS, BOD_5, COD, FOG, NO_3-N, TKN, total phosphorus, chloride, calcium and total coliforms. The capacity of the abattoir is on average 566 cattle and 1512 goats and sheep slaughtered per week. Results show that the current effluent quality is not suitable for discharge into the watercourse. The abattoir wastewater streams' total chemical oxygen demand (TCOD) ranged form 7533 (± 723) from evisceration to 23,778 (± 1,673) mgl^{-1} from slaughtering step and the discharge into Mpazi River increases its TCOD from 213 (± 29) to 852(± 94) mgl^{-1} TSS varied between 2,452 (± 51) from slaughter process and 5,252 (± 174) mgl^{-1}. Results from the bacteriological analysis indicate that abattoir wastewater discharged count (560 ± 81)10^5 cfu/100ml of total coliforms which increases from (2.8 ± 0.58) 10^5 to (8.2 ± 0.86)10^5 cfu /100ml.

Keywords: abattoir effluent, cleaner production, sustainability, wastewater management

Introduction

The rapid pace and scale of urbanization in Rwanda represents a considerable challenge for water resources management particularly the delivery of essential water, sanitation services and environmental protection. In the last ten years, the city of Kigali has experienced a spectacular growth in population leading to large volumes of domestic and industrial wastes.

Nyabugogo Abattoir uses large quantities of water and generates equally large quantities of biodegradable wastewater with a high strength, and complex composition. There is, therefore, an urgent need to develop sustainable management strategies that would control both water and nutrients flows in Kigali city with the added advantages of cost reduction, handling efficiency, increased food production, environmental integrity, and social benefits. This could be achieved by of application of IWRM approach. This entails a holistic approach with waste being seen as resource, and its management linked to that of water resources and nutrients and this could be addressed from a 'cleaner production' angle [1], [2]. The cleaner

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production concept has brought some innovative environmental thinking into the industrial sector, especially in terms of waste avoidance/reduction and use of substitutes [3]. In this framework, this study seeks to:

i. To assess the quantity and quality of the water and wastewater streams at the Nyabugogo Abattoir and their impact r on the receiving Mpazi River;
ii. To explore the relationships between related parameters as a means of reducing monitoring costs for the Abattoir;
iii. To explore ways of improving the abattoir performance for better environmental safety.

Description of the Study Area

The Nyabugogo Abattoir (Figure 1) is located in commercial zone and discharges effluent into the Mpazi River. Adjacent to this area is a highly populated residential zone whilst other industries discharge downstream of the abattoir. Besides the diffuse source of pollution from the population, the main point source polluters of the Mpazi River are Centre Hospitalier Universitaire de Kigali, the central prison of Kigali, Muhima police station, hotels and the Nyabugogo Abattoir. The Mpazi River discharges into Nyabugogo River, a tributary of the Nile River.

Figure1: An aerial view showing the Nyabugogo Abattoir and tannery, and Mpazi River

Figure 2: Abattoir flow chart, by-products and sampling sites

Analytical methods

Samples were analyzed for the following physico-chemical parameters: pH, temperature, electrical conductivity, salinity, turbidity, TDS, TSS, dissolved oxygen measured *in situ* using conductivity meter model HACH sinsion^{TM}5, turbidity meter model wag-WT3020. The analysis of BOD_5, total COD, soluble COD, Oil and Greases, TKN, Nitrate, TP, Calcium, and Chloride were done using standard methods. The bacteriological parameter analysed was total coliforms. The analyses followed APHA's Standard Methods for the Examination of Water and Wastewater [4].

Data analysis and presentation

The means and standard error of the mean were calculated using 5 different samples taken within 5 weeks during the experimental period. The data obtained from sites 7 and 9 respectively upstream and downstream of the discharge into Mpazi River were compared using t-Test. The coefficient of correlation between related physicochemical parameters was calculated by Pearson correlation test using SPSS package. Statistical significance was set at $p < 0.05$ for t-Test (t-Test: Paired Two Sample for Means) analysis in the comparison of means of samples from Mpazi River.

Results and discussion

Tables 1 and 2 summarize the quality of water and different wastewater streams from the Nyabugogo Abattoir for five sampling runs under the monitoring period. The results were split into two tables for clarity.

Table 1: Analysis results for water and various streams of wastewater, Sites 1 – 5

Parameters	***Site 1***	***Site 2***	***Site 3***	***Site 4***	***Site 5***
Temperature (°C)	23.5 ±0.6	24.2 ± 0.5	22.3±0.3	25.8 ± 0.9	22.9 ± 0.2
pH	7.4 ± 0.6	7.7 ± 0.4	8.2 ±0.5	7.2 ± 0.6	8.15± 0.1
Salinity	0.10 ± 0	4.1 ± .36	0.62 ± 0.15	4.0 ±0.65	1.70 ± 0.09
EC (μScm^{-1})	180.3 ±13.9	6,792.4 ±1303	1,890 ± 86.2	5,646 ± 707.9	3,137 ± 130.7
TDS (mgl^{-1})	100 ± 5	3,434 ± 509	603 ± 149	2,657 ± 472	1,800 ± 289
TSS (mgl^{-1})	8.7 ± 0.5	2,452 ± 51	3,492 ± 343	3,504 ± 143	4,412 ± 172
Turbidity (NTU)	NA	NA	NA	NA	NA
D.O (mgl^{-1})	NA	NA	NA	NA	NA
Nitrate(mgl^{-1})	3.2 ± 0.23	648 ± 66.1	208.2 ± 23.1	676.6±53.3	205.8 ± 23.1
TKN (mgl^{-1})	1.1 ± 0.1	714 ± 13	244 ± 24.5	565 ± 43	423 ± 15
TP (mgl^{-1})	0.71± 0.16	693 ± 21	83 ± 7	937 ± 30	396 ± 55
O&G (mgl^{-1})	1	58	56	36	49
Chloride(mgl^{-1})	42 ± 5	190 ± 8	113 ± 4	72 ± 5	520 ± 27
Calcium(mgl^{-1})	7.6 ± 0.9	372 ± 26	54.9 ± 2	40 ± 3	218 ± 10
TCOD(mgl^{-1})	30 ± 7	23,778 ± 1673	17,019 ± 878	7,533 ± 723	13,126 ± 406
SCOD(mgl^{-1})	22 ± 4	7260 ± 1015	5,774 ± 806	1,445 ± 295	5,270 ±1187
SCOD/TCOD(%)	78 ± 6	29 ± 2	33 ± 3	18 ± 2	44 ± 6
BOD_5 (mgl^{-1})	18 ± 3	15,773 ± 847	10,989 ± 814	5,018 ± 180	10,801 ± 456
COD/ BOD_5	1.67	1.51	1.54	1.50	1.21
TC (cfu/100ml)	0 ± 0.00	(9.4 ± 0.92) 10^5	(1.6 ± 0.40) 10^5	(29.6 ± 2.8)10^5	(33 ± 2.39).10^5

In a further step, linear regression of analysis results obtained during the Nyabugogo Abattoir wastewater and the Mpazi River water quality analysis are shown in Table 3. The results are presented together with the corresponding equations and correlation coefficients (R^2).

Table 2: Analysis results for water and various streams of wastewater, Sites 6 – 9

Parameters	***Site 6***	***Site 7***	***Site 8***	***Site 9***

Temperature (°C)	21.0 ± 0.3	20.8 ± 0.6	19.8 ± 0.4	21.3 ± 0.4
pH	8.1 ± 0.1	7.5 ± 0.1	8.9 ± 0.2	8.1 ± 0.1
Salinity	3.54 ± 0.31	0.34 ± 0.02	1.82 ± 0.11	0.54 ± 013
Conductivity (μScm^{-1})	5,761 ± 361	632 ± 33	3,199 ± 66	726 ± 77
TDS (mgl^{-1})	3,231 ± 200.6	328.4 ± 15.2	1,833 ± 131.0	358.6 ± 10.7
TSS (mgl^{-1})	5,252 ± 174	220 ± 16	2,939 ± 71	304 ± 34
Turbidity (NTU)	NA	662.4 ± 37.0	552.2 ± 26.6	707 ± 37.6
D.O (mgl^{-1})	NA	0.053 ± 0.11	-	0.509 ± 0.18
Nitrate (mgl^{-1})	702.4± 101.4	114 ± 10.7	224.0± 37.2	176.6 ± 13.3
TKN (mgl^{-1})	735 ± 30	63 ± 1.9	198 ± 16	82 ± 8
TP (mgl^{-1})	475 ± 73	3.1 ± 0.1	438 ± 19	5 ± 0.4
O&G (mgl^{-1})	61	26	59	31.8
Chloride (mgl^{-1})	275 ± 16	71 ± 5	330 ± 14	130 ± 7
Calcium (mgl^{-1})	139 ± 10	12 ± 0.4	337 ± 16	18 ± 0.6
TCOD (mgl^{-1})	20,271 ± 1552	213 ± 29	14,722 ± 811	852 ± 94
SCOD (mgl^{-1})	7,001 ± 727	133 ± 4	6,100 ± 416	272 ± 24
%SCOD/TCOD	34.2 ± 1.4	67.4 ± 9.6	41.7 ± 3.1	33.5 ± 4.9
BOD_5 (mgl^{-1})	12,786± 1230	161 ± 24	13,157 ± 739	629 ± 27
TCOD/ BOD_5	1.58	1.32	1.11	1.35
Total coliforms (cfu/100ml)	(7.8 ± 0.86)10^5	(2.8 ± 0.58)10^5	(560 ± 81.24)10^5	(8.2 ± 0.86)10^5

Table 3: Relationship between related parameters

Related parameters	***Fitted equations***	***Regression coefficients***
Salinity and conductivity	y = 0.0006x – 0.15	0.97
TDS and Salinity	y = 0.012x – 0.07	0.94
Conductivity and TDS	y = 1.8703x + 125.8	0.97
TCOD and BOD_5	y = 1.411x–36.0	0.95
SCOD and BOD_5	Y = 0.501x – 98.8	0.97
TCOD and SCOD	y = 1.8703x + 125	0.97
TCOD and TSS	y = 3.620 x + 1753	0.61
TCOD and TKN	y = 0.89 x + 29	0.87

The average water consumption was 69 m^3/day for an abattoir of average of 81 cattle and 216 goat and sheep slaughtered per day. Compared to the water used in the USA, UK and Australia, water consumption in Nyabugogo Abattoir is not high [7]. Table 4 presents the quality of Nyabugogo Abattoir wastewater and its comparison with typical literature figures, Environmental Health Safety Guidelines (EHSG) for Meat Processing.

Table 4: Comparison of Nyabugogo Abattoir wastewater quality with different guidelines

Parameters	***Experimental value***	***Typical literature figures (Table 2.1)***	***EHSG for Meat Processing (6)***
pH	8.95 ± 0.26	6.5	6 - 9
COD	14,722 ± 811	9,790	250
BOD	13,157 ± 739	6,433	50
TSS	2,940 ± 71	1,886	50
TP	439 ± 19	128	2
O&G	56	46 ± 9	10
Total coliforms	(560 ± 81) x 10^5	-	MPN 400/ 100 ml

Nitrates are very high in the abattoir wastewater especially at the evisceration and slaughter step where the urine and undigested stomach content concentrated in nitrate was mixed in wastewater streams [7]. This is because wastewater streams for these processes consist of mixed intestinal contents and blood with a high content of nitrates. The levels of

nitrates in the abattoir wastewater show that the wastewater could be treated by biological processes if other inhibiting parameters, such as chloride, are reduced. The BOD_5: N: P ratio was 31: 1: 1, which makes it attractive to reduce the organic matter content first through such technologies as anaerobic decomposition, and then further stabilisation before reuse. Conventional waste stabilisation ponds or other natural treatment systems could be used for further stabilisation and reduction of coliforms.

The concentration of TKN was very high in wastewater streams from slaughtering and evisceration processes because of blood and intestinal contents. In the slaughtering area, nitrogen is mainly in the form of TKN because nitrogen is maintained in organic compound in the form of organic nitrogen and ammonia. For the wastewater from the evisceration process nitrogen was mainly in the nitrate form the end product of nitrification because wastewater was mixed with intestinal content and digested organic materials. The wastewater discharged into impact on Mpazi River was concentrated in nitrogen mainly in the form of nitrate.

The correlation coefficients of the fitted equations between total COD, BOD_5 and soluble COD were generally positive for the results for both Nyabugogo Abattoir and Mpazi River. The high values of R squared (Rsq), and the significant value in the analysis of variance table confirms the strong linear relationship that can be seen on the graph. The following can be deduced:

- The COD and the BOD_5 for the Nyabugogo Abattoir wastewater and Mpazi River showed that the degree of common variation between the two variables was highly positive; thus, the COD and the BOD_5 are said to be highly correlated.
- The correlation coefficients were highly positive hence, they are very strong and indicate a significant relationship between chemical oxygen demand and a five day biochemical oxygen demand. The COD covers virtually all organic compounds, many of which are either partially biodegradable or non-biodegradable. The strong relationship between BOD and COD indicate that COD is could be used as an indicator of the environmental oxygen load.
- The TCOD / BOD_5 ratio was situated between 1 and 2, suggesting that the organic matter of this wastewater is highly biodegradable.

The BOD_5 and the COD values obtained for the analysis of the effluents of the abattoir have been found to be higher than those expected from literature [7]. These levels of BOD_5 and COD could constitute potential pollution problems for the Mpazi River since they contain organic compounds that will require a large quantity of oxygen for degradation. The COD / BOD_5 ratios have been found to be less than 3. This implies that the compound in the wastewater of the abattoir were relatively degradable, thus, a possible depletion of the dissolved oxygen in the receiving rivers and a potential effect on aquatic life. The COD correlates positively with the BOD_5 of the wastewater. The correlation equations could be used to estimate the BOD_5 for reporting and treatment process control. The degree of common variation between the COD and the BOD_5 of the abattoir wastewater from Nyabugogo and Mpazi River was highly positive the strength or magnitude of the relationship is represented by the high values of the R^2 and the significance of the correlation. The correlation coefficient of the fitted equation for the prediction for Nyabugogo Abattoir and Mpazi River may, therefore, be used to facilitate rapid wastewater quality assessment or optimal process control by the abattoir once the chemical oxygen demand (COD) is measured or *vice versa*.

The TCOD of Nyabugogo Abattoir wastewater was mainly in the form of suspended solids as it is shown by the significant correlation between TCOD and TSS (R^2= 0.75). The

high suspended solids concentration in wastewater discharged into the Mpazi River (Site 8) compared to the septic tank influent (Site 5), also suggested some multiplication of biomass. The high level of TDS and TSS values obtained for the wastewater streams support some of the high values obtained for other parameters determined in this study.

Statistical correlation analysis of the data revealed that the wastewater load COD values correlated with values measuring the presence of TSS, BOD_5. This means that a change in one parameter could account for a certain predictable change in other parameter. The abattoir wastewater is characterised by substantial organic matter content, resulting in an average TCOD concentration of 23,778 mgl^{-1} for abattoir wastewater stream from the slaughtering area and 14,722 mgl^{-1} for the mixed wastewater stream discharged into the Mpazi River. The wastewater stream from the evisceration process had a TCOD of 7,533 mgl^{-1}which is low compared to other sources of wastewater streams in the abattoir. The main contributors of organic matter are blood, fat and paunch content from the evisceration step. Results show great variability in the quality of wastewater streams, reflected by high standard error values on the means. Great variability was observed with respect to the wastewater, depending on the type of by-products generated on process, at the time of sampling.

Some useful relationships between parameters were calculated. According to the calculated percentages soluble COD averaged 44.8% (± 6.8 %) and 18.9% (± 2.1%) of TCOD for influent of septic tank and evisceration process respectively, and the significant correlation between TSS and TCOD which is 0.79 indicate that very little amount of COD is soluble. The SCOD of Mpazi River was 67.4 % (± 9.6 %) of TCOD before discharge and becomes 33.5 % (± 4.9 %) of TCOD after discharge. Most of it must be included in the paunch content, coagulated blood and fat which increase particulate COD in downstream of the discharge. The BOD_5/ COD ratio range was 1.1-1.5, which was very high in comparison with domestic wastewater, which has a range of 0.3-0.8 (8). Therefore, the biodegradability of the wastewater was found to be high because the ration was less than 3 [8], [9]. In general, organic contaminants entering the wastewater streams are from slaughtering and evisceration processes. Blood and undigested materials are some of the major sources of organic wastes entering wastewater streams, which end up waterways [7], [10].

Tables 1 and 2 show that the Nyabugogo Abattoir increases the organic pollution of Mpazi River, especially for TCOD and SCOD, which were 213 mg/l and 133 mg/l respectively before discharge, and 852 mg/l and 272 mg/l, respectively, after discharge. The main contributor of that organic material is the wastewater from the slaughtering area especially blood, as it is represented by 23,942 mg/l of TCOD. The nutrients nitrogen and chloride are respectively 130.2 mg/l and 74 mg/l before discharge and 165 mg/l and 123 mg/l respectively after discharge of the Nyabugogo Abattoir effluent. The BOD_5 and the COD values obtained from the analysis of the Nyabugogo processes streams have been found to be higher than expected from Environmental Protection Agency standards guideline for discharge (BOD_5 of 50 mgl^{-1} and the COD of 250 mgl^{-1}) [11]. These levels of BOD_5 and COD could constitute potential pollution problems for the Mpazi River since they contain organic compounds that will require a large quantity of oxygen for degradation.

The volume of the septic tank is 55 m^3 and the wastewater produced per day was about 72 m^3. The hydraulic retention time for anaerobic ponds is 8 day [11]. The quantity of wastewater produced in 8 day is about 8000 m^3.

Conclusions

From this study, it can be concluded that:

i. The effluent from Nyabugogo Abattoir is highly loaded with degradable organics and other pollutant that pose an environmental risk to the receiving Mpazi River. The existing septic tank is no longer sufficient to achieve any meaningful treatment, thus

allowing high loads of pollutants to enter the Mpazi River. Significant pollution of the Mpazi River was observed for COD, BOD_5, nutrients, chloride, calcium, total coliforms and TSS.

ii. The inter-relationship between some parameters monitored could be used to deduce the levels of others through certain equations, as derived in the study. This could greatly reduce the cost of analysis.

iii. There are opportunities for improving the operations and processes at the Nyabugogo Abattoir, thereby reducing environmental impacts and saving on costs. The application of cleaner production concepts: good housekeeping practices, processes optimisation and efficient use of resources by-products recovery and rendering, together with the establishment of appropriate treatment systems, would greatly improve the environmental performance of the Abattoir.

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Using Traditional Knowledge to Cope with Climate Change in Rural Ghana

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Abstract
Indigenous or traditional people often inhabit economically and politically marginal areas. Their livelihoods depend on natural resources which are directly affected by climate change. Such people have immense knowledge of their micro-environment but are usually neglected in academic, policy and public discourses on climate change and adaptation. Coping with increasing climate change/variability is a major challenge in less resourced, natural resource dependent, low technology communities. This paper assesses coping strategies by rural communities in the Offin River basin in Ghana to changing climate. Data was collected in 2007 through questionnaires, focus group discussions, interviews and field observations in 20 rural communities. Key issues examined include observation of changes in local climate, effects of the changes on livelihoods, strategies adopted to live with the changes, viability of and challenges in implementing strategies, and what the people think is the way forward. Identified coping strategies include water rationing, rainwater harvesting, indigenous knowledge in agriculture and water management, and traditional taboo/forbidden days. These strategies are based on traditional norms and practices, less expensive and easy to implement but faces serious challenges due to modernisation. This calls for support and integration of modern scientific and traditional knowledge in coping with effects of climate change.

INTRODUCTION

As calls multiplied for high-tech solutions (installation of early warning systems using cutting-edge satellite and ocean buoy technologies) as a means of preventing similar disastrous occurrences like the 26th December 2004 tsunami off the coast of Indonesia, news began to circulate about how indigenous communities escaped the tsunami's wrath due to their traditional knowledge. Unlike numerous persons who were attracted to the shoreline by the unusual spectacle of fish flopping on a seafloor exposed by the sea's withdrawal, the Moken and Urok Lawai peoples of Thailand's coasts and islands, the Ong of India's Andaman Islands and the Simeulue community of Indonesia all knew to head rapidly inland to avoid the destructive force of the sea. The small villages of the Moken and Ong were completely destroyed, but their inhabitants escaped unscathed. Even more striking was the displacement of more than 80,000 Simeulue peoples beyond the reach of the tsunami. Only 7 persons died. This surprisingly efficient response, striking in its contrast with the frightening losses suffered elsewhere in Indonesia, was acknowledged by the granting of a UN Sasakawa Award for Disaster Reduction to the Simeulue peoples [1]. This drew world attention to the

traditional knowledge of indigenous people and its relevance to the emerging priority domain of natural disaster preparedness and response.

Traditional knowledge, defined by [2] as a changing system, where western knowledge has a place, has over the years played significant roles in solving problems including climate change. Indigenous people, who live close to the natural resources, observe the activities around them and are first to identify any changes and adapt to them. Appearance of certain birds, mating of certain animals, or the flowering of certain plants are all important signals of changes in time and seasons that are well understood by traditional knowledge. Biodiversity have been used as a buffer against variation, change, and catastrophe; in the face of plague, if one crop fails, another will survive [3]. In coping with risk due to excessive rainfall, low rainfall, drought and crop failure, some traditional people grow many different crops and varieties with different susceptibility to droughts and floods and supplement these by hunting, fishing and gathering wild food plants. Diversity of crops and food resources are often matched by a similar diversity in field location, some which are more prone to flooding, others more prone to drought, so that in extreme weather some fields are likely to produce harvestable crops.

Adaptation to climate change includes all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system [4]. This is important when considering climate change and variability because the impacts of climate change, and hence its seriousness, can be modified by adaptations of various kinds (e.g., [5] and [6]). The ability to, and for how long one can adapt, however, depends on the resources available. Africa is clearly the most vulnerable and at the same time very far behind in adaptation to effects of climate change because it is the least resourced to withstand the effects without significant changes to its fundamental structures.

It is estimated that Africa has been warming through the 20th century at a rate of between 0.26 and 0.50^{o}C per century. This trend is expected to continue and even see a significant increase in the rate of warming with its attendant negative effects on livelihoods. According to the IPCC Fourth Assessment Report [7], a medium-high emission scenario would see annual mean surface air temperatures expected to increase between 3^{o}C and 4^{o}C by 2080 (IPCC, 2007). This implies difficult times ahead for the local people who depend directly on the natural resources for their livelihoods and their main and/or only weapon to cope with the changes that are yet to come is their traditional knowledge and practices.

Over the last 40 years, Ghana has recorded temperature rise of over about 1^{o}C as well as reductions in rainfall and runoff of approximately 20 and 30% respectively. For a country which depends mainly on rain-fed agriculture, Ghana's vulnerability to changes in climate variability, seasonal shifts, and precipitation patterns can not be over-emphasised. Over the years, farmers and other natural resource dependent communities in Ghana have found ways of coping with changes in climate as is being observed. Such coping strategies have been based on traditional knowledge and practices and this varies from community to community since the country has no climate change adaptation policy. The coping/adaptation strategies, however, show some similarities among communities within one agro-climatic zone.

The evidence and impacts of climate change may be most felt in Africa than any other continent but this does not mean that the continent sits down, looks on helplessly and waits to be consumed by the changes in climate. Traditional knowledge has played a significant role

in Africa's adaptation efforts, in the face of low technology. This paper critically looks at use of traditional knowledge to cope with climate change in rural Ghana.

METHODOLOGY

Study Area

The study was carried out in 2007 in twenty (20) communities in the Offin River basin in the Ashanti Region of Ghana. This region falls in the moist semi-deciduous forest category with a semi humid tropical climate. The rainfall distribution of the basin is weakly bimodal with a main peak between May and June and a secondary peak in September to October.

Communities covered in the study are rural and predominantly subsistence crop farmers. Some are also into cocoa farming. Agriculture in this region, like most parts of Ghana is rain-dependent and planting seasons are along the two rainy seasons: main season from April-July and the minor season from September-October. Livestock rearing is limited in this region. Economic activity is very low though most of the people engage in petty trading to augment the little income from agriculture. About 90 percent of the communities covered have no pipe-borne water, and depend on the rivers/streams and rainfall for their water needs.

Data Collection

Interviews, questionnaires and focus group discussions (FGD) were used in the data collection. Four (4) focus group discussions were held in four communities to collate their views on climate change and how they are coping with the changes. Semi-structured questionnaires were administered to people in the communities studied, who are forty years and above. The assumption was that younger people may not have observed and experienced enough change in the climate to make good judgement. A maximum of ten (10) questionnaires were administered per community. The questionnaires and FGD helped to identify current observed climate changes and impacts of such changes particularly on local livelihoods; livelihood resources, i.e., natural, physical, social, financial, and human resources of communities in the Offin river basin; and the extents to which these resources help the people to conduct their livelihoods and cope with the impacts of climate change. The responses from the questionnaires were also used to cross-check with each other to get a very good view of the situations prevailing in the communities.

Through the focus group discussions and questionnaire administration, individuals who showed appreciable knowledge in environmental changes around them and their faming operations were selected for in-depth interviews. They were mainly local farmers who were directly affected by climate change and showed remarkable knowledge of the changes and its effects on their farming; traditional leaders and opinion leaders who were usually old, well respected personalities and involved in decision making and administration of the communities.

RESULTS AND DISCUSSION

Local knowledge, perception and effects of climate change in Offin river basin

The indigenous people may not understand the concept of global warming or climate change but they rightly observe and feel its effects: decreasing rainfall, increasing air temperature, increasing sunshine intensity and seasonal changes in rainfall patterns. This is corroborated by a study in 2007 which recorded a remarkable reduction in mean annual rainfall of 22.2% and a gradual rise in average maximum temperatures of 1.3^{o}C or 4.3% rise in temperature from the 1961to 2006, [8]. Gradually, there is increasing realisation that indigenous groups are an important source of information on climate change. Most published reports on indigenous observations of climate changes, however, have come from Arctic regions where the co-operation between scientists and indigenous peoples is strongest [3].

Observed climate changes have resulted in serious effects on natural resources in the Offin river basin. There have been low discharges in all the waterbodies in the Offin basin with some streams becoming extinct. This is mainly in response to the reduction in rainfall since it is the source of water for the streams/rivers in the basin. River Offin which is the biggest river in the basin has been experiencing very low flows in the dry seasons to the extent that the river bed could be seen during recent dry seasons. Generally, from 6.941 m^3/s of discharge in 1957, the discharge of River Offin at 2006 was 3.797m^3/s indicating a 3.144 m^3/s (45.3%) reduction in river discharge [8]. As a measure to ensure availability of water all year round, wells have been dug by the communities but some of theses wells dry up during recent dry periods, indicating a possible reduction in ground waters.

Recent crop failure in the basin has also been attributed to low rainfalls, prolonged rainfall shortages and changes in rainfall patterns. Agriculture in the basin is rain-fed and farmers have over the years perfected the art of predicting the onset of the rainy season. Farmlands are cleared and prepared in anticipation for the rains to start the cropping season. This has, however, become difficult during recent years due to significant changes in the rainfall pattern. The beginning of the rainy season is no longer predictable, and during times that it has started on time, there may be an unexpected long break before the rains resume. This is making it difficult for farmers to plan their cropping seasons to coincide with the rains to ensure maximum crop yield. The result is crop failure and low crop yield. Prolonged rainfall shortages cause a drought situation and a reduction in the water available in the soil for crop growth. This results in crop failure. Due to crop failure/loss, money spent on land preparation and planting, as well as income from the sale of farm produce is lost and household savings are spent to replant farms. People can withstand bad harvests at one time or the other but when it becomes consistent, then things begin to go very wrong.

Another effect of climate change on agriculture in the River Offin basin is the effects of intense sunshine and increasing temperature on crops. These changes coupled with prolonged rainfall shortages causes the wilting of crops. Sunshine is increasingly becoming very intensive and for long hours. Some farmers, notably cocoa growers, narrated incidence of cocoa trees withering as a result of exposure to intense and prolonged sunshine. This situation was also reported by other farmers such as vegetable growers who claim that the high temperatures causes their vegetables to ripen prematurely and as such not getting the expected income from the sale of their produce. This is a major loss to the farmers and puts a big drain on their financial resources.

Heat and water related diseases such as malaria; diarrhoea, bilharzias, shingles and other skin debilitations are becoming common the basin. Malaria has been mainly due to the people sleeping in the open or with windows open due to high temperatures at night. This situation exposes the people to mosquitoes and eventually malaria. During dry seasons and prolonged rainfall shortages, water sources become scarce, stagnant and contaminated. During such periods, cases of diarrhoea and bilharzias are common. Shingles and other skin debilitations are also common during periods of high temperatures. Previously, according to the communities, some skin diseases were rare in the communities but such diseases are becoming predominant in recent years.

Local coping strategies and challenges in the Offin basin

The people realize that water shortages are a major threat to their survival and there are several strategies to adapt to this new phenomenon. One of such strategies is water rationing. For example, "waste water" from washing cloths, utensils and other activities are also used for watering backyard gardens and nurseries. Households also try to reduce the water use per person per day in an attempt to conserve water. This strategy needs to be part of a behavioural change and not during periods of water shortage. Adaptation is not just a climate change issue [9], and education on water conservation should be an on-going process.

Rainwater harvesting, an old traditional way of collecting and storing water where every household had at least two big barrels placed at strategic places in the house where rainwater is directed from the roof of buildings into those barrels for storage, is actively being revived and advocated in most communities. This has become necessary following prolonged rainfall shortages and drying of previously perennial streams that provided water all year round, at a time where more water is needed by the communities due to increase in population. But in all the communities covered under the study, not enough rainfall is harvested because the harvesting technology is not good, i.e. outdated and not inefficient under the current climate regime. The type of houses constructed and the roofing system does not support efficient rainwater harvesting. Only a small percentage of the rains can be harvested with the majority going waste.

The traditional and local authorities identifies clearing of riparian vegetation along their river banks as a major factor affecting their streamflows and are putting on measures to remedy the situation. Some of the measures are creating awareness on the effects of deforestation around water bodies, sensitizing the communities to prevent bush fires, community based management of forests, imposition of fines, etc. These measures by the traditional authorities are not yielding much because the communities, though still rural in terms of development and infrastructure, have become very cosmopolitan or heterogeneous in composition and allegiance to traditional authority is not absolute. There have been settler farmers who have moved into some of these communities and the communal nature of the communities is breaking down and people now think more of themselves than of their collective well-being.

There are also forbidden days or taboo days when nobody is expected to go to the riverside. Previously, the use of taboos was very effective in controlling community behaviour and the traditional leaders see it as an effective alternative in protecting their waterbodies. The question then is, why does it need a re-introduction since such tradition has not at any point been abolished? These taboos have been dormant for several reasons including modernisation, heterogeneity of the communities, and even Christianity. Since

most of the people are now Christians, compared to previous years when almost everyone adhered to traditional way of worship, traditional authority has been undermined and its directives are seen as fetish and not adhered to. Although some do believe in the re-introduction and strict enforcement of taboos and forbidden days, they may not have the desired impacts under the current dispensation. Religion is a very delicate issue in these communities and although re-introduction and enforcement of some of the traditional laws will be very useful, it needs a very cautious.

Indigenous knowledge in agriculture and water management, acquired over many years of practice, has helped the communities to cope very well with water shortage, droughts, and crop damage/losses. The farmers are able to predict, quite well, when the rains will come and plan their planting season to coincide with the rains. This has, however, become difficult in recent years due to changing rainfall pattern. To this, the farmers are adapting by changing the type of crops they used to grow. Crops which thrive well under the current prevailing conditions are increasingly being planted in areas which, hitherto, did not support their cultivation. A case in point is shifting from cocoa cultivation to drought resistant crops such as cassava. Vegetable growers are also gradually moving into the river plains to grow their crops since they do not get enough water in the places they previously grew their vegetables. This is a form of adaptation but obviously not sustainable. The money which they previously earned from the sale of cocoa, for example, was a major source of income which supplemented the upkeep of families and even in buying agricultural inputs and expanding their farms. Clearing of the riparian vegetation and use of chemicals so close to the rivers/streams, as is being done by the vegetable growers has its own hazards.

Farmers, especially cocoa farmers, who complained most about the effects of intense sunshine on their crops see the best way to adapt is to have trees on their farms to provide shade for the crops. Though some farmers already have trees on their farms or are planting trees to provide shade, the practice does not seem appealing to most farmers. In Ghana, all timber trees found on any land belong to the Government and the Government decides when an area of land is given as concession to a timber company for felling. This has resulted in some farmers, having in the past, deliberately killed trees on their farms to prevent timber merchants from coming to fell their trees, destroy their farms and pay little or no compensation. This policy has been a major disincentive to adaptation. Although the Timber Resource Management Amendment Act, (ACT 617), 2002, provides that the right to harvest trees and extract timber from a specified area of land shall not be granted if there are farms on the land unless the consent of the owners of the farms has been obtained or if there is timber already grown or owned by any individual or group of individuals on the land, not much has changed in terms of the relationship between timber merchants and farmers. Due to inability of farmers to show clear proof of ownership of trees on their farms (either planting the tree or tending the tree till maturity), lack of education in forest laws and the financial strength of the timber merchants, the farmers are still being exploited. To stop this exploitation and enhance adaptation of rural farmers, there must be sustained education programmes to get the farmers informed of their rights and empower them to protect their farms and most importantly, plant more trees.

The way forward

The growing importance of traditional knowledge in coping with climate change leads to the conclusion that there must be a healthy relationship between scientific knowledge and traditional or indigenous knowledge especially in developing countries where technology for

prediction and modelling is least developed. Both scientific knowledge and traditional knowledge have their limitations and a good merger will provide the desired results to help cope with climate change. Whereas models and records of precipitation mainly focus on changing amounts of precipitation with climate change indigenous peoples also emphasize changes in the regularity, length, intensity, and timing of precipitation. While scientific explanations of climatic changes have mainly concentrated on anthropogenic greenhouse gas emissions, local interpretations of observed climate changes are often much more varied and encompassing. Whether or not scientific models are incorporated into local explanations, according to [3], depends on the status and accessibility of science within a culture and on the influence of media.

In order to capitalize, develop, expand and mainstream indigenous adaptation measures into global adaptation strategies, attempts by indigenous people to cope with climate change using traditional knowledge should be studied, supported and integrated into scientific research. This is less expensive compared to bringing in aid to salvage catastrophes and disasters or "importing" adaptive measures which are usually introduced in a "top-down" manner — which is difficult to implement due to several factors including financial and institutional constraints. Main findings of the Stern review commissioned by the UK Treasury to assess the economic impacts of climate change as well as the cost of mitigating climate change were that mitigation costs are relatively moderate, while climate change related losses are likely to be much larger than previously thought, [10]. The Stern review was partly an attempt to counter claims that it would be too costly to try to mitigate climate change compared to any damages that might arise from climate change.

The Moken, Urok Lawai, Ong and Simeulue surprised the world with their resourceful and life-saving response to the destructive force of the Indian Ocean tsunami. There is much to learn from indigenous, traditional and community-based approaches to natural disaster preparedness. Indigenous people have been confronted with changing environments for millennia and have developed a wide array of coping strategies, and their traditional knowledge and practice provides an important basis for facing the even greater challenges of climate change. While indigenous communities will undoubtedly need much support to adapt to climate change, they also have much expertise to offer on coping through traditional time-tested mechanisms.

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WiMAX with Wi-Fi: Opening New Frontiers in Education

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Key words: WiMAX, Wi-Fi, Mesh, broadband, HE

Abstract
Connectivity is vital to any country to usher in economic growth, better education and healthcare and improved entertainment services as it has done elsewhere in the world. And the solution must be wireless, to avoid the overwhelming cost and resources that would be required to deploy countrywide fixed-line broadband Internet infrastructure. Some countries, where there is not an established wired communication network, are investigating the potential of broadband wireless technologies to support learning and teaching in remote areas. In order to widen the participation in Higher Education (HE) there is a need for more flexible delivery and study of courses to satisfy the needs of this wider audience. The lack of physical connectivity or telecommunications infrastructure and the cost and lack of broadband technologies are a big hindrance to more widespread participation of people in HE. Broadband wireless technologies like WiMAX with Wi-Fi are beginning to offer reliable alternatives to fixed-line access, offering the potential for widespread, affordable connectivity to every education institutions viz Schools and Colleges, in the rural areas. This paper addresses the potential uses of wireless and mobile technologies and identifies some recent technical developments. It considers how their use might be developed within existing learning and teaching paradigms and it identifies some new models for providing connectivity to rural Educational Institutions.

1. Introduction

The education sector is being accorded top priority by governments in developing countries, as a means of building a reservoir of competent leaders and skilled personnel who will guide and sustain the region's current pace of development. As a result, both the government and private sectors are directing huge technological inputs towards improving educational content and delivery systems and in upgrading infrastructure. Wireless is one of the most important technologies of the century, influencing the nature of business, commerce, education, and society for all time to come. WiMAX with Wi-Fi offer new ways to approach emerging learning environments that holds immense potential like lifelong learning, e-learning, distance learning, home learning, virtual classrooms and mobility between different locations of study in campus based learning. This paper will address in detail: (i) Potential uses of broadband wireless technologies like WiMAX and Wi-Fi and identifies some recent educational developments using these technologies in the world. (ii) How their use might enable education empowerment within existing learning and teaching environments (iii) how it supports connectivity to Educational Institutions in rural areas and provides mobility in campus where connectivity is already available and finally (iv) to generate awareness of the many advantages of wireless connectivity and the mobility it brings to the learning environments.

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2. Technical Overview of Major Wireless technologies

Broadband wireless technology offers a number of concrete benefits over that of wireline. They are as follows [2]:

a. reduced cost as compared to deployment of new wired infrastructure;
b. enhanced operational flexibility, in particular: more freedom in placement of equipment; reduced installation interval; lower barrier to switching or upgrading infrastructure; and ability to move and redeploy equipment as needed with minimal incremental cost.

Moreover, Broadband Wireless technology has built a bridge over some of the education gap. Let us see the technical overview of some of them.

2.1 Wireless Fidelity (Wi-Fi)

802.11 WLAN often called Wi-Fi (Wireless Fidelity) uses the license-free 2.4 GHz frequency band and has become popular for its capability to provide high-speed Internet access at low cost.. The ease of use and low cost are in turn driven by the adoption of the Wi-Fi standard by equipment manufacturers, thus ensuring interoperability among Wi-Fi devices. Wi-Fi is arguably the most ubiquitous form of broadband Internet access in the world [2].

2.2 Worldwide Interoperability of Microwave Access (WiMAX)

WiMAX is a standards-based wireless technology that provides high-throughput broadband connections over long distances and it operates in a licensed spectrum. This is based on a mesh structure and it is capable of delivering broadband Internet and, extending services beyond the physical building constraints encountered with Wi-Fi. WiMAX offers a fast, affordable, convenient solution to Internet access needs [1]. As WiMAX becomes more widely available it could offer opportunities for educational use with groups interacting wirelessly within a much broader virtual classroom [3].

A key characteristic of this standard is a differentiated approach to the Media Access Control (MAC) layer; in contrast to Wi-Fi, the WiMAX MAC can support a range of physical (PHY) physical layer implementations, thus substantially freeing equipment vendors in developing solutions for different applications and vertical markets.

2.3 Wireless Mesh Networking (WMN)

A WMN is a communications network made up of radio nodes organized in a mesh topology. Meshed networks self-configure and self-heal by dynamically sharing information, almost in real-time, between all the access points in a wireless network. If a mesh link becomes obstructed in the event of a device failure, client traffic is dynamically re-routed, ensuring uninterrupted communication through the other available access points. In the mesh network, the core configuration is an array of access points or base stations, all managed by a mesh routing protocol which determines the optimal path across the network at any given time [2]. The advantages of a mesh topology are route diversity and redundancy, thus maximizing the performance of the network. Wi-Fi/WiMAX mesh uses such concepts as cellular-equivalent "picocells" for node proximity and non-line-of-site mesh routing around obstacles.

2.4 UltraWideBand (UWB)

Ultra wideband is a wireless technology for transmitting large amounts of digital data over a wide spectrum of frequency bands with very low power for a short distance. UWB signals are usually very difficult to detect. The amount of spectrum occupied by a UWB signal, i.e. the bandwidth of the UWB signal is at least 25% of the center frequency. Thus, a UWB signal centered at 2 GHz would have a minimum bandwidth of 500 MHz and the minimum bandwidth of a UWB signal centered at 4 GHz would be 1 GHz. High data rate UWB can enable wireless monitors, the efficient transfer of data from digital camcorders, wireless printing of digital pictures from a camera without the need for an intervening personal computer, and the transfer of files among cell phone handsets and other handheld devices like personal digital audio and video players. Intel researchers are working on a variety of UWB technologies, including a platform for next-generation development efforts, and believe it will be a critical step in enabling advanced communications for a wide range of uses in the future [7].

2.5 Free Space Optics (FSO)

FSO is a telecommunication technology that uses light propagating in free space to transmit data between two points. The technology is useful where the physical connection of the transmit and receive locations is difficult, for example in cities where the laying of fibre optic cables is expensive. FSO uses lasers to transmit data, but instead of enclosing the data stream in a glass fiber, it is transmitted through the air. Unlike radio and microwave systems, FSO is an optical technology that operates in invisible parts of the optical spectrum at near-infrared wavelengths and no spectrum licensing or frequency coordination with other users is required, interference from or to other systems or equipment is not a concern, and the point-to-point laser signal is extremely difficult to intercept, and therefore secure. Transmission is highly directional making it far more secure than RF technologies but also requiring that the two points to be connected be within line-of-sight of each other.

2.6 Virtual Fiber

Virtual Fiber Connectivity is a line-of-sight technology that uses lasers to provide optical bandwidth connections [9]. This is a point-to-point wireless system using very high radio frequency (71-76 GHz and 81-86 GHz) to transmit up to 2.5 Gbps of data, voice, and video communications. For example a ninety minute movie will download in one second.

3. Impact of Wireless Technologies in Higher Education

The emergence of wireless technologies and various solutions to extend the capability of the wired world to a mobile secured environment in and out of the classroom is rapidly becoming the norm in providing education programs to students of all ages. At the same time, teaching methodologies have also evolved to encompass concepts such as e-learning, distance learning, home learning, and lifelong learning. To support these different types of learning the modern curriculum has been reformed. Such emerging learning environments and the need for flexible hours in learning environment are driving forces to advocate for wireless networking technologies and hence wireless campuses. This will result in some learners moving between school, workplace and home. Mobile and wireless technologies offer new ways to approach both learning and assessment. They could provide the following: [3]

a. both synchronous and asynchronous communication with peers and teachers
b. collaborative features enabling the sharing of material
c. the facility to access resources, including online communities from local and world-wide repositories via the internet
d. delivery of multimedia content.

The integration of technology in assessment activities has led many universities to use an online Learning Management System (LMS) to present electronic content and control aspects of course management relating to assessments and organization etc. that will facilitate online learning. Wireless is clearly exploding across university campuses as it has in the corporate and consumer sectors and educational applications, IT services and management solutions are growing fast in higher education. Below are some scenarios that how higher education must address the contribution of wireless beyond convenience to its potential impact on teaching, learning and research.

3.1 Conventional networked Campus

Some of the most mobile and connected people in our society can be found in the education community. So broadband wireless technology has become the present and the future of education. It has changed the way instructors teach by relieving them from having to rely on the book and straight lecture as the only tools. It has made learning much quicker than looking for a book or something. Wi-Fi solutions within campus allow the possibility to extend the physical space of the classroom in to other areas while maintaining access to online resources. Wi-Fi goes from buildings to green spaces to the football stadium and other athletic facilities.Thus WLAN solutions provide the necessary functionality, simplicity, and trust to ensure an enriched learning environment.

3.2 Extended networked Campus

Not only within campus connectivity is needed, but extended campus offers more flexibility. This supports both synchronous and asynchronous communication and collaboration. We can build-out an Education Network linking schools and universities with Wi-Fi network. This Inter-campus Wi-Fi network will facilitate students and educators of K-12 and higher education campuses to seamlessly log into any other member campus' educational wireless network. This will allow the educational community to extend their learning experience by leveraging wireless networks of other schools and universities across the country.

Every member campus will become accessible to students, staff, and faculty via this network. This single interconnect will allow the institution's IT department to dedicate scarce resources just once, effectively growing the access available to their students and faculty without having to dedicate additional IT resources and without changing the existing deployed architecture[4].

3.3 Connected Rural Schools

Connectivity is important for the rural schools to participate in the extended campus environment. Some countries where there is not an established wired communication network must find ways to use cost effective hybrid wireless networks for education to the reach the unreached sections of the society. This will increase the opportunities for students to do online learning , to participate in audio/video conferencing, to research by accessing e-resources from other schools and universities etc.. WiMAX plays a major role in providing cost effective access to rural areas.

4. Need for Connectivity and Mobility in Higher Education

In the world today, we have the potential to know and be able to access any kind of information that has ever existed. While students may not want to have all that information every minute, they do want to be able to access it whenever they need. So for colleges and universities to attract the Mobile (M)-generation of students, it is mandatory to provide wireless connectivity and mobility with broadband technologies like WiMAX with Wi-Fi.

Connectivity and mobility in Education is a necessity for the following reasons:

(i) Traditional campus based education often reaps the benefits of the proximity of groups of learners. Even then connectivity and mobility are required in the campus to fulfill student expectations to generate self-help groups, opportunities for informal discussion, and support prescribed group work. Wi-Fi access will provide campus educational wireless network.

(ii) Today's educators and students demand an always-connected, everywhere wireless campus environment [4]. WiMAX provides the backhaul for Wi-Fi access points and provides anytime, anywhere connection.

(iii) Internet services provide a means for students to stay connected with their friends in another campus through e-mail, audio or video chat, and to browse the Internet for job and academic opportunities.

(iv) Over 55 percent of all educational documents are electronic at this point [1] and broadband connectivity is very important to access these educational materials.

(v) Schools and libraries in rural or remote areas without wired infrastructure or broadband services can be cost effectively connected to broadband using WiMAX, so that the students in rural areas could videoconference with educators across the country, and use Internet telephony services, like Voice over Internet Protocol (VoIP) [1].

(vi) Lecture classes from urban schools and top universities can be broadcast to rural students, and the students could use the broadband facilities of WiMAX for communicating with teachers and with their remote classmates. This will allow the educational community to extend their learning experience by leveraging wireless networks of other schools and universities across the country.

(vii)Universities providing distance education is increasing its use of online collaborative activity and content and an online LMS to present electronic content and control aspects of course management relating to assessments and organization etc. With higher bandwidth and faster speeds, broadband Internet can make education more accessible by delivering interactive distance education at a low cost.

(viii) Broadband wireless technologies help to bring our education customers the power of being linked together. This will allow them to provide new services that give their students more educational value while keeping operational costs low.

5. Broadband Hybrid Wireless Network (BHWN)

The potential of wireless communications is to break down traditional wired boundaries, bridge digital divides and stimulate economic growth [2]. Although a range of new technologies have emerged, including WiMAX, Wi-Fi and WMN, each one addresses a specific network segment or application, and that no single technology fits all applications, and also the necessary complementary technologies have differed in terms of stages of development. So it will be critical to use these technologies in tandem to create truly scalable broadband wireless networks. One limitation is that many vendors focus on selected

technologies and applications, thus increasing the complexity of evaluating, procuring, installing, managing and maintaining different parts of the network. However, standards based broadband wireless technologies particularly Wi-Fi, WiMAX, WMN are interoperable and have matured to the point of being deployable in a single, connected network, and furthermore such solutions can now be sourced from a single vendor. This is the concept of a scalable Broadband Hybrid Wireless Network (BHWN).

6. Proposed BHWN for Connectivity to Rural Schools

Schools and libraries in rural or remote areas without wired infrastructure or broadband services can be cost effectively connected to broadband by combining several broadband wireless platforms.

In this proposed hybrid wireless network the traffic from the large fiber optic backbone from the urban area is carried over the last mile via a high speed point-to-multipoint distribution system based on the features of WiMAX that is, enhanced data rate and range. In the point-to-multipoint network, the core configuration is a single access point or base station communicating with one or more clients, and a larger network can be comprised of several such separate cells joined by a common backbone. WiMAX serves as a backhaul for Meshed Wi-Fi Local Area Network. Figure 1 below shows WiMAX connecting to Wi-Fi access points located in rural school buildings. The access points in turn will serve a mesh array LAN which is not shown in the figure. With a robust backhaul system in place, coverage of the network is practically just a function of the number of Wi-Fi access points installed at the edge. The access points reside in a mesh array, with one radio available for access and a second radio connecting into the array. In the figure the customer premise equipment (CPE) serves as the access points.

Thus by combining Wi-Fi mesh and WiMAX could provide the rural population with the most extensive and complete broadband wireless coverage. Though both technologies are distinct, each with unique characteristics, they often are deployed in tandem using WiMAX for backhaul and Wi-Fi mesh to provide access to the growing base of Wi-Fi enabled LANs. Until now, the only solution was to install two separate units, one WiMAX and one Wi-Fi mesh but nowadays companies have come with solutions of integrating these technologies in a single compact outdoor enclosure.

7. Suggestions

(i) National level conferences should be organized to generate awareness of the many advantages of wireless connectivity and the mobility it brings to the learning environment.

(ii) This concept needs to be promoted from the early stages of school, given its importance in achieving better broadband Internet connectivity, and its role in linking homes to virtual classrooms, libraries, campus networks, and Internet labs and in delivering e-learning courses.

(iii) Wireless should not be considered as a replacement for the wired technology, rather it should be considered as a supplement to enhance the effectiveness of the learning environment.

(iv) Research should be done on new methods and new approaches to learning with ICT because ICT is an integrated part of learning process.

(v) Using BHWN with the convergence of multiple wireless services, using different frequencies necessitates the creation of a campus wide spectrum Management group to plan to use any form of wireless and then to work on coordination this with strategic directions of IT, teaching, learning and research.

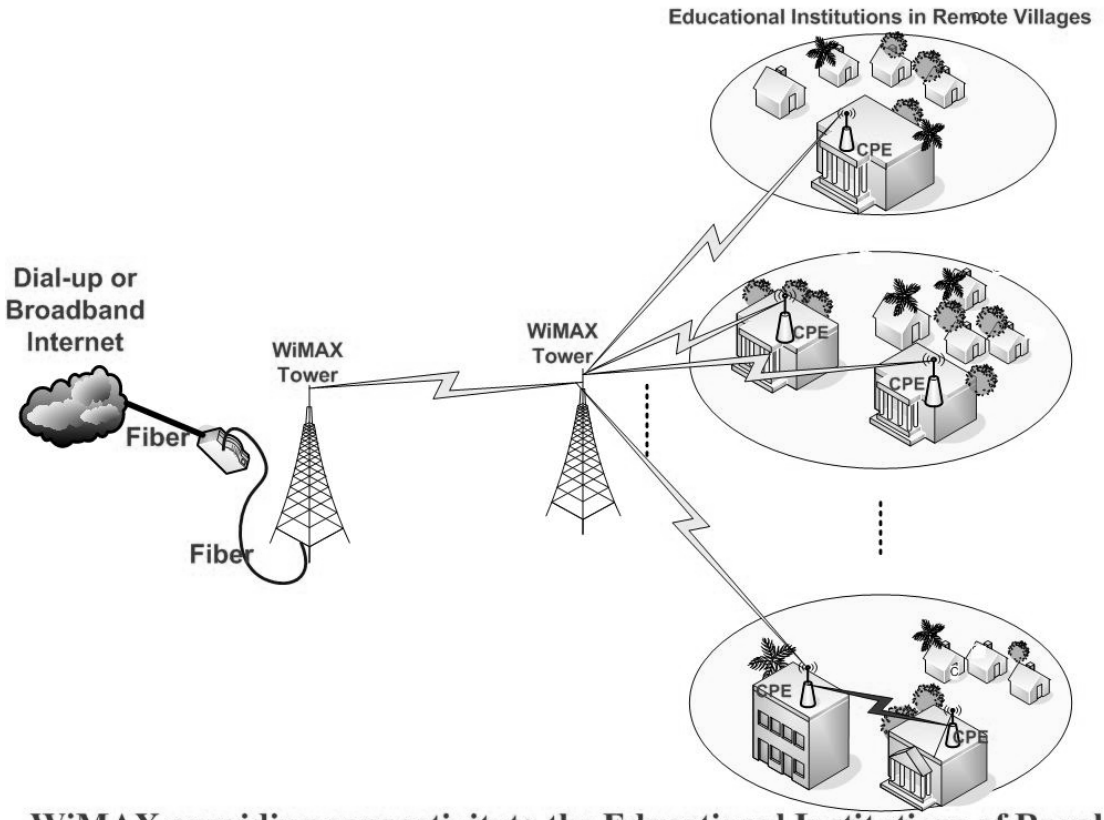

Figure 1: WiMAX with Wi-Fi mesh on the Customer premise side for rural connectivity

8. Challenges in adapting Wireless Technologies

The challenges to adapt to wireless technologies by educators and students, however, is one of understanding and exploring these resources to support teaching and learning.

(i) The most challenging problem facing higher education systems incorporating wireless devices into their classrooms is technical support. Schools must have an in-house support or outsourcing the support for the effective use of the wireless devices [11].
(ii) Speed plays a factor when there are several students competing for the same website and the broadband width is not enough.
(iii) The use of wireless devices in classroom can be a challenge for faculty trying to get the attention of students to a particular lecture when the students are engaged in the World Wide Web [11].
(iv) IT security is still a reality in only a small minority of schools. This is one of the biggest challenges of wireless technologies in classroom. With more data and information transmitting frequently through the airwave, makes transmission of data easily accessible by hackers and intruders.
(v) Allowing outside laptops onto the school network increases the risk of the spread of computer viruses and hacker attacks. Therefore, there is a need for security software updates to protect end-users from viruses and hackers.

9. Conclusion

In conclusion, the opportunities of wireless technologies greatly outweigh the challenges. Wireless is important to higher education for some of the same reasons it is important to other areas of the society. It is believed that using wireless technologies in classrooms not only improves teaching and learning but provides the accessibility of resources to students and teachers. From this paper it is clear that convergence is inevitable, whether on a wireless campus backbone or extended campus connectivity or rural connectivity. Though it is too early to determine the impact of this converged wireless network concept on teaching and learning, but this brief paper argues that in many aspects we are already envisioning the possibility of students' access to information by any device, from anywhere and at any time has become very important in learning environment. The BHWN suggested combining WiMAX with Wi-Fi and Mesh has the potential to provide the rural Educational Institution with widespread Internet access that can usher in, better education, economic growth and health care and improved entertainment services as it has done elsewhere in the world.

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Enhancing Public and Private sector delivery through Rwandan National Smart Card Initiative

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Abstract
This study is based on the ongoing Rwandan National Smart Card Initiative. Drawing parallelism from The Malaysian Smart Card Initiative and similar Global Smart Card Initiatives, the study intends to evaluate the role of smart card technology in enhancing public and private sector delivery. Based on review, the enhancement in public and private sector delivery could potentially be the key to the increment of National productivity and competitiveness. Strategically, the elevation of National productivity and competitiveness has been a strong catalyst for economic development and similarly poverty reduction. In view of the above, the low level of productivity and competiveness are among the factors contributing to the high poverty rate in the low income level nations. Therefore, the study intends to provide a comprehensive overview on common global best practices and methodologies which has led to the enhancement of public and private sector delivery. Strategically, it also evaluates potential economy gains arising from the enhancement of public and private sector delivery. Based on review and analysis, the study provides strategic recommendation and global best practices that could be adopted during the Rwandan National Smart Card program.

INTRODUCTION

Following the success of the National ID program, The Rwandan Government is optimistic in launching the second stage of The National ID and Smart Card program. The second stage is expected to commence as early as August 2008[1] and will involve the introduction of 500,000 smart cards to prospective Rwandan citizens.

A unique feature of the second stage will be the incorporation of a 64 Kb smart chip. Unlike the 2D barcode that has limited data retention capacity and processing capability, the 64 Kb smart chips is designed to incorporate vast amount of data and applications. Initial review suggests that among the application that promises to be incorporated in the National ID and Smart Card scheme are National Registry Information, Driver's License, Immigration and Passport Information, Health Information, Social Security Information, Banking and ATM pin codes and Rwanda Revenue Authority Information [2].

Based on review, the stakeholders are optimistic with the potential success of this initiative. Many stakeholders believe that the Rwandan Smart Card initiative would enhance their quality of service delivery while reducing the lengthy turnaround time [3].Ultimately it could be a catalyst to revolutionize The Rwandan public and private service delivery. In the near future, the entire Rwandan citizen might be carrying a smart card in their pockets or in their wallets.

Overview on Smart Card

Smart Card is a plastic card that contains an embedded integrated circuit, which can process data. This implies that it can receive input which is processed - by way of the ICC applications - and delivered as an output. [4b, 4c,]

Historically it is recorded as a French invention and was first introduced to the European consumers in 1982 in the form of serial memory phone cards. The first commercial manufacturing of smart card dates back to 1977, when 3 commercial manufacturers, Bull CP8, SGS Thomson, and Schlumberger get together to develop an IC based smartcard. The first commercial success of smart card indicates to Motorola with the success of the first secure single chip microcontroller for use in French Banks in 1979 [4a]. The First large-scale smart card application implementation was in the United States in 1987 with the U.S. Department of Agriculture's Nationwide introducing Peanut Marketing Card.

Ever since then, The National Smart Card initiative involving smart cards gained much popularity throughout the world. In 1994, Germany launched the largest Smart Card initiative with the issuance of 80 million serial memory chip cards in the form of National Health Cards. Currently, there are more than 60 Nations reverting to some form of National Smart Card initiative and the number is expected to grow with time. [4]

Overview of Malaysian Government Multipurpose Card - MyKad

Due to cost and complexity factor, all smart cards initiatives have been for a single purpose but all that changed in 1997, when The Malaysian Government introduced the very first Multipurpose Smart Card [5]. The notion of the Malaysian Government is best described by the former Malaysian Prime Minister, Tun Dr. Mahathir Mohammed. In his own words the former premier indicated that "The Malaysian Government is proud to lead the new wave of technology application for a better tomorrow. The transformation of public service and Government machinery is the ultimate achievement for the nation, which is pro-investment and growth-driven. The engine of growth can be propelled further with the world's first Multi-Application Smart Card as we travel into the cyberspace where a growing segment of the economic pie is taking place." [6]

In a nutshell, The Malaysian Government Multipurpose Smart Card or better known as GMPC MyKad is an integration of 9 core public and private service applications under a single technology platform. Among the applications incorporated in the GMPC scheme are identity card, passport information, basic medical data, frequent traveler card, public key infrastructure, ATM application, electronic cash and transit or travel card. Among its primary objectives are to improve The Malaysian public service delivery with the use of technology vis-a-vis to create a pleasant experience for citizen while interacting with Government service providers .To date some 20 Million GMPC cards have been distributed to potential citizens. The large scale roll out operation was segmented into three distinct phases: [6a]

- Phase 1 (1997-2000) – National Population Registration System
- Phase 2 (2000-2002) – Pilot Roll out of 2 Million Cards to Klang Valley and MSC Area.
- Phase 3 (2003-2007) – National Roll out of 18 Million Cards covering all states

Phase I primarily involves the conversion of the National Registry Database to the new GMPC format. A significant amount of digitization and automation exercises was carried out during the first Phase. Among them includes the introduction of the new Automated Finger Identification System (AFIS) and automation of 183 National Registration Department (NRD) branches.

During Phase II, some 2 Million Smart Cards were rolled out to eligible Malaysian citizens in the Klang Valley and Multimedia Super Corridor (MSC) Area. Phase II also witnessed the development of core GMPC Mykad applications. The pilot enabled the Malaysian Government to evaluate and understand the impact and benefit of multipurpose smart card before embarking on the more ambitious Nationwide National Roll Out.
Phase III, some 18 Million cards were rolled out to eligible Malaysian citizens throughout West and East Malaysia. The seven years roll out period not only elevated the service level delivery among public and private sectors but also created the platform for the emergence of Smart card industry in Malaysia. To date, Malaysian Smart Card companies has a global foothold in Card production (Iris), Chip Manufactures (My-MS), Smart Card Application Development (Iris, Heitech). Smart Card Device Manufactures (Tricubes).

Impact and Benefit of The Malaysian Mykad Scheme.
In reference to the following illustration, The Malaysian Mykad Initiative underwent an extensive integration exercise by incorporating nine (9) applications under a single smart card platform. [8]

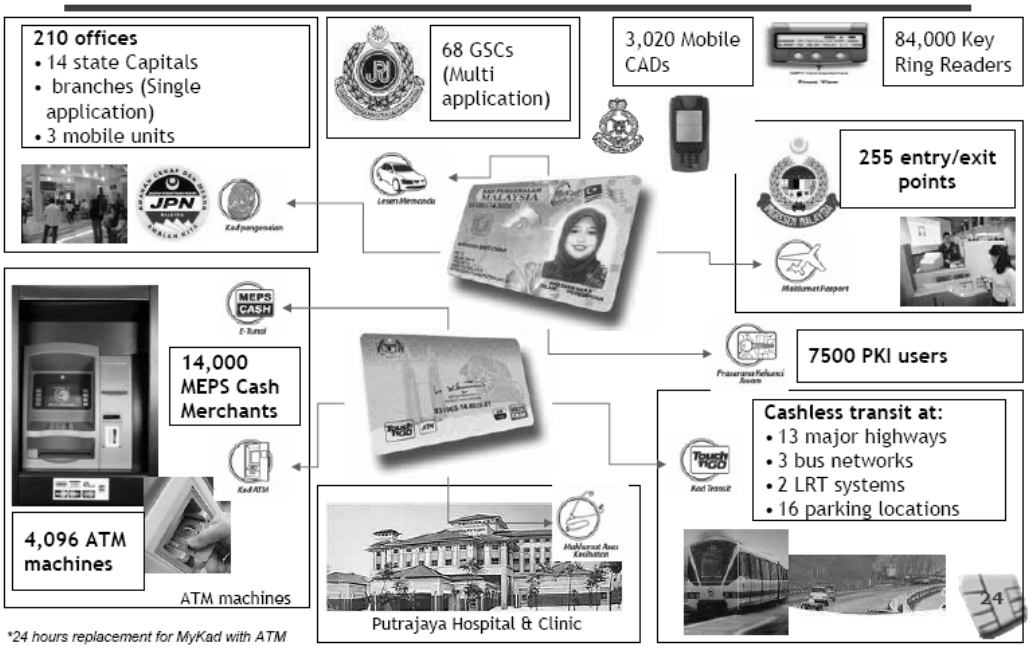

Figure 1a: Integration Model of Malaysian Mykad Initiative.
In doing so, The Malaysian Government advertently integrated the following public and private entities[7]:

- Six (6) Government agencies / ministries - NRD, RTD, Immigration, Police, Ministry of Finance, Ministry of Health.
- Twelve (12) Malaysian Banks and One (1) Micro – electronic payment systems (financial gateway) provider - MEPS
- Two (2) Digital Certificate providers – MSCTrustgate, DigiCert
- One (1) Transit application provider – Touch'n Go

These technology centered integrations elevated the Malaysian public service delivery into a new spectrum. The followings section will briefly explain some of the key Business Process Improvements introduced throughout the implementation of Malaysian Mykad scheme:

Adoption of New Database Format:- The new database format brought a new level of sophistication where it now allows the branches to retrieve more comprehensive informations within a shorter time frame. As a result of this, the yield and the productivity of the branches improved and more business transactions are processed in a day.

Digital Thumbprint:-. The biometric minutiae stored on the cards is an excellent mean of citizen authentication Digital matching of the thumbprints are less prone to errors compared to ink based thumbprints. Due to its nature, it suggests to be a popular adoption in the financial world where it allows faster turnaround time on common financial transactions e.g. opening on account, money transfer, mortgage and loan processing while providing the required security and reliability

The integration coupled with the above mentioned business process improvement revolutionized both the service offering and delivery of public and private sectors. Although there were no empirical evidences indicating the success the Malaysian GMPC initiative but through a series of observations it becomes clear that the initiative has resulted in the following benefits [7a, 7b]:

- The production and delivery of National IDs to citizens have significantly reduced from a few months to a single day.
- Capturing and retrieval of National Registration data could be carried out from any remote and mobile locations thus allowing citizens greater mobility and flexibility.
- Issuance and renewal of driving license have significantly reduced from three days to less than an hour. Similarly, the operation can be carried out throughout nationwide National Registration Departments (NRDs)
- Drivers information together with his/her traffic offences could be verified immediately by traffic police from any remote location through GSM network
- Electronic issuance of traffic summons and payment collection through e-portals, provided the citizens greater flexibility and wider customer interaction points (touch-points).
- The introduction of Auto gate by Malaysian Immigration at the nation's entry and exit succeeded in eliminating the long queue at these points and subsequently reducing the wait time to an approximate three minutes.
- Patient Registration at selected hospitals is carried out by reading the information stored in Mykad thus significantly reducing the amount of time required for manual entry.
- Opening of accounts and customer verification are carried out by reading the information and biometric minutiae thus significantly reducing the time required for data entry and customer verification.
- Automated Fare collection through the Touch'n go application stored in Mykad has significantly reduced traffic queues at toll booths.
- Automated Fare collection through the Touch'n go application stored in Mykad has streamlined passenger movement at both light rail transit (LRT) and public buses.
- Incorporation of Public Key Infrastructure (PKIs) on Mykad has provided the necessary security needed for electronic filling of income taxes. The PKI together

with electronic filling resulted in greater flexibility on tax filing for Inland Revenue Authority's (IRA) customers.

In a nutshell, the Malaysian GMPC- Mykad not only revolutionized the Malaysian public service delivery but it also provided the necessary cataclysm to enhance the productivity and competiveness of Malaysian public sectors. Malaysia is not the only example where the Government has enhanced the public and private sector delivery through National ID and Smart Card Initiative. Similar achievements could be also credited to the Hong Kong Government Initiative on "Octopus Smart Card" and Finland on "Fin-ID" initiative.

Parallelism between Malaysian MyKad Initiative with Rwandan National ID and Smart Card Program

Therefore and by virtue of parallelism to other global initiatives, one should expect that an efficient implementation of Rwandan National ID and Smart Scheme would harvest similar impact and benefits.

Review suggests that the Rwandan Smart card Scheme is already progressing through similar tracks. Among the first agencies to be integrated are the Police Departments which are to be integrated with financial institutions and the National Registry. The following illustration depicts of the proposed integration model. [9]

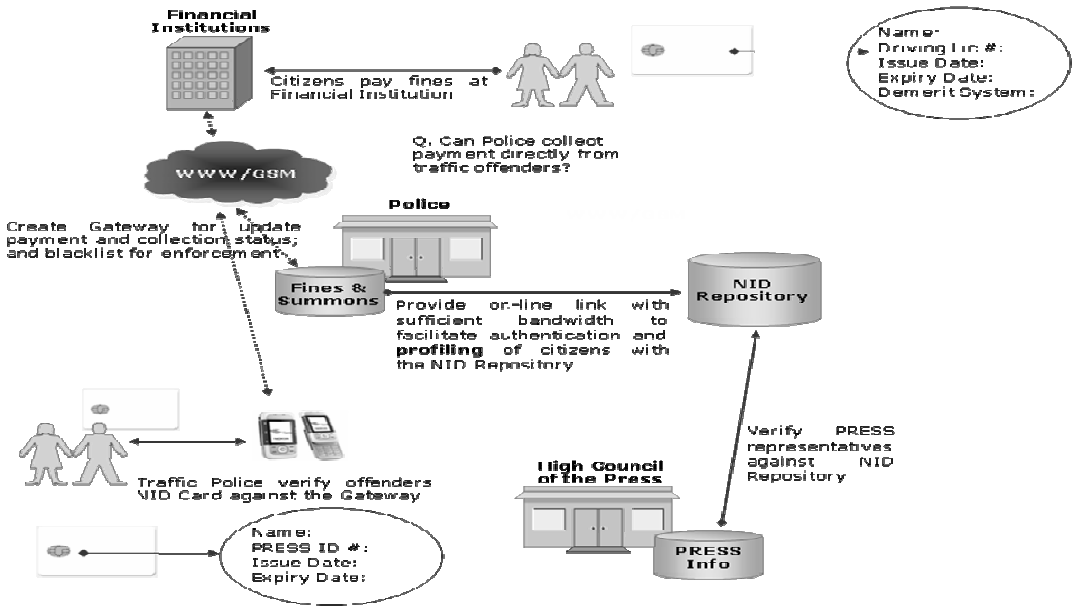

Figure 2a: Suggested Integration of Rwandan National Smart Card Scheme

Subsequently the scheme intends to integrate the National Health Services, Financial Institutions, Social Security, Medical Insurance and Immigration Services. The immediate benefits expected for the implementation of the Rwandan National Smart Card program are:

- Establishment of a Central National Registry; which will act as an official reference point thus reducing the amount of time and processes required to authenticate and verify citizen related information.

- Retention of data on digital media e.g. on Smart Chip and database would eliminate the need of paper records thus reducing the cost involved in generating and maintaining paper records.

- Retrieval of stored user data from Smart Card will minimize the need to capture them through human data entry. Potentially, it could reduce the time required for data capture and minimize the errors resulting from human data entry.

- The ability to rewrite or update digital records on smart chip could potentially reduce the need to reproduce new ID cards whenever a change on user record occurs

- The ability to store multiple applications and data in a single smart card reduces the need for users to carry multiple cards.

- The biometric minutiae stored on the card are an excellent mean of customer authentication. Enabling, the banks and micro financiers a reliable means to authenticate and verify potential customers.

- Integration of Government agencies and financial institutions is among the key requirements of this phase. Based on review, integration could potentially enhance information flow and automate the common business processes and workflows. Therefore, reducing the time required to process common business transactions.

In view of the above Rwandan National ID and Smart Card initiative is poised to revolutionize both public and private service delivery and similarly to catalyze Rwanda's National productivity and competitiveness.

Conclusion

A comprehensive overview of The Malaysian and other Global National Smart Card initiative does indeed suggest that the project has a potential to enhance public and private service delivery. By drawing parallelism, to the Malaysian GMPC – MyKad initiative it becomes evident that the Rwandan National ID and Smart Card Initiative could indeed be an efficient vehicle to revolutionize both the public and private service delivery. In view of the above, the Rwandan National ID and Smart Card Scheme are in the right path to evaluate the Government entities and components to be integrated. The Malaysian and Global best experience, case studies and best practices are indeed valuable tools to under see the success of this initiative. Modernization of Government through the use of technology could ultimately result in the enhancement of Rwanda's National productivity and competitiveness.

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A Systems Approach to Determining Critical Infrastructure and Appropriate Technology

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ABSTRACT

The Systems thinking approach to problem solving has been used to address strategic questions in determining process choice and supporting infrastructures, including optimisation of resources and project management.

This study is based on the need for an approach to determine critical infrastructures and appropriate technologies to be deployed in underdeveloped and developing countries and focuses on the dairy industry. The study is informed by our current work of developing a productivity model for knowledge- based systems to be applied in the dairy industry in Rwanda. The benefits of systems thinking approach in deriving a supply chain model is examined against the constraints and goals of an individual organisation in the supply chain attempting to maximise profit.

This paper provides an approach that uses a discrete simulation method at the factory level and systems dynamics for simulation of the supply chain in determining alternative choices, and links key characteristics of system dynamics and modeling to process choice for organisational excellence and competitiveness. We close with some guidance on factors to consider when selecting an analysis approach that is appropriate to the problem under study.

INTRODUCTION

The major constraints facing the dairy industry in Rwanda are the low level of productivity, seasonal fluctuations in supply and demand, and inadequate infrastructures to support the competitiveness of the industry. The lack of important services compounded by the relatively high interest rates impact gravely not only on the competitiveness but also on the sustainability of the industry. This paper suggests how these industry challenges can be analyzed by using systems dynamics and discrete simulation models. The purpose of the modelling is to gain insights into supply chain factors that contribute to the low productivity and to explore strategies to minimise these effects. Changes to infrastructures are recommended to support the process choice.

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LITERATURE REVIEW

Society is a complex system with many interacting constituents that influence each other. These constituents include critical infrastructures whose availability and reliability determine to a considerable extent the productivity, and hence the well being, of the particular society. This is because for goal attainment, a process choice is made and the process choice has to be supported by critical infrastructures.

A current definition of a "critical infrastructure" is a large scale infrastructure which if degraded, disrupted or destroyed, would have a serious impact on the health, safety, security or well-being of citizens or the effective functioning of the government and/or the economy [2]. These infrastructures can be divided into physical and soft infrastructures. Examples of physical (tangible) infrastructures include transportation networks, telecommunication systems, and energy supply systems while the soft (intangible) infrastructures include trade credit procedures and policies, regulatory systems, skills availability, and the easiness of the business environment. It is deduced that an increase in availability of critical infrastructures positively impacts productivity.

However, researchers have extensively highlighted the impact of knowledge on growth and productivity during the last two decades. This discussion has put in focus the importance of knowledge-based productivity and important measurement problems. It also highlights potentially important conceptual challenges in the conventional ways of measuring growth and productivity in the knowledge-driven society [9].

Ilka Tuomi [9] argues that these challenges are particularly visible in developing countries as they try to increase competitiveness in the face of globalisation but that they also require new approaches for understanding productivity and growth. The famous "Solow paradox" can be interpreted as an indication of a need for a new productivity paradigm [9]. A conceptualization of productivity that would allow substantial analysis of the impact of knowledge seems [9] to require reconsideration of the links between growth and development to innovation, creativity and the degree of openness of the system as well as its degree of stability.

Within the supply chain, knowledge-based systems consist of hardware, software, skills, systems integration, operational support, and infrastructure that support decision making. They are what may be considered decision support technologies chosen from existing ICTs and combined with research, modelling and optimisation applications. However, a multidimensional and holistic conceptualization of application of knowledge bases in a supply chain allows the researchers to address the different complementary elements that are needed to make decisions affecting choices of appropriate infrastructures to support total productivity goals.

Supply chains in rural areas are the next big issue for businesses in the dairy industry in developing countries. The reasons are simple: the urban areas are congested with markets, and more than 70% of Rwanda's population lives in rural areas. Thus, there is a need for transforming rural areas into a group of sophisticated vibrant activity centers. Innovations in every layer – products, processes, business models, and service models are fundamental for this transformation process to happen. Businesses need to be reinvented with appropriate technology tools that can provide employment and services for millions of rural dwellers at an affordable cost. Increased productivity of supply chains is needed.

WHY DOES PRODUCTIVITY MATTER?

The main purpose of improving productivity would be to improve service delivery and increase availability of basic infrastructural facilities. It would also improve quality and quantity of goods and services, increase both the quality and quantity of employment opportunities, reduce poverty, increase self reliance and develop a well motivated, dynamic and productive workforce.

Whereas policymakers use productivity outcomes to plan how productivity and economic growth could be increased [9], managers relate productivity to increased operational efficiency and reduced waste. If productivity increases, other things equal, aggregate economic welfare increases. In the dairy industry, this means reducing losses and increasing gains per invested input (labour, capital, information, energy, and raw materials).

Productivity measurement is also important for monetary and fiscal policy. Productivity trends are used to forecast potential economic growth and, for example, tax revenues. If labour income grows faster than labour productivity, the expected result is inflation. Productivity measurement, therefore, is used in the difficult act of balancing unemployment and inflation. Long–term productivity growth is commonly viewed as the speed limit for sustainable economic growth [9].

A SYSTEMS APPROACH TO SUPPLY CHAIN PROCESSES

The different firms in the supply chain should not work individually to achieve an optimum, as the goal is not to achieve local optimums but to achieve the highest global performance level. Therefore an organisation should take a systems approach to designing a supply chain or making decisions in the organisation [16]. In a supply chain, business processes can be considered the basic units of organisations. Thus, they are the means by which an organisation, whatever the economic sector, survives and thrives by processing products or services for a customer.

Due to specialisation in the dairy industry and the fact that factories [in Rwanda] tend to structure themselves around tasks, there is a tendency to design and operate business processes within a specific department or group of internal departments. This leads the company not employing a systems (global) approach to carrying out operations. Today's need for specialisation stems from the rapidly growing body of knowledge and information [15]. Specialisation should not be blamed, nor is it wrong to specialise in a specific field. Specialists can still play an important role in any organisation, but the organisations ought to structure themselves around outcomes [7]. Processes generate outcomes by linking functions across the entire organisation (systems approach).

The same holds true for the entire supply chain. Specialist organisations still play an important role within the supply chain, but organisations ought to structure the processes so that the entire supply chain can achieve an optimum.

How are business processes designed to achieve global optimums for the entire supply chain? There are no specific steps for this purpose, but business processes should be designed so that each link in the supply chain would share in the risk of the entire chain [8].

THE IMPORTANCE OF THE PROBLEM

Improving the productivity of knowledge work is a significant societal problem. Peter Drucker identified that:

> *To make knowledge work productive will be the great management task of this century, just as to make manual work productive was the great management task of the last century*. [14]

He argued that unless managers undertake serious and effective approaches to improving the productivity of knowledge workers, now the fastest growing sector in industrial societies, nothing like the gains in prosperity of the 20th century will materialize in this century [13]. The significance of Drucker's observation is that if non-trivial gains could be made in the productivity of knowledge work [if integrated in a supply chain] the value to the economy could be dramatic [especially for developing countries that lack both the knowledge and organized supply chains].

APPROACH TO THE PROBLEM

A Lean Supply Chain could be of greatest importance in determining appropriate technologies and infrastructures. A lean supply chain is characterized by as a set of organizations and processes that are linked in a continuous flow of products and services, finances and information, and that interact collaboratively to reduce cost and waste.

Knowledge [of opportunities to continual improvement] gives the competitive edge.

If a lean approach to managing the supply chain is to succeed, the entire organization has to focus on removing waste and adding value. The organisation has to focus beyond its boundaries and adapt change to focus on the entire chain.

- Product value has to be defined from the customer's point of view, not the company's; to eliminating waste caused by making the wrong product (one that nobody wants), making the product at an unsuitable quality level, making too much or too little of it, or delivering it too slowly or through the wrong channel.
- Avoiding delays and discontinuities in the supply chain process is the second principle. The supply chain should flow continuously, and so should the information that supports it.
- Product should be pulled by the customer, not pushed by the company.
- Finally, continual improvement is critical, concentrating on the elimination of waste and the addition of value in all of its supply chain processes.

THE MODELS

In choosing the appropriate model, it is recognized that business operations can be formally described in business process models that capture activities, information, and flow embedded in business operation. System dynamics modeling enables business process designers to build computer simulations of complex business process behaviors.

System dynamics (SD) models provide an accurate description of system behavior along the time dimension. It gives a convenient tool to conduct what if analysis though dynamics points of view. The SD model in figure I below illustrates how 'infrastructure quality'; 'farming practices & extension services quality' and 'milk products demand' drive the productivity in the Dairy Supply chain.

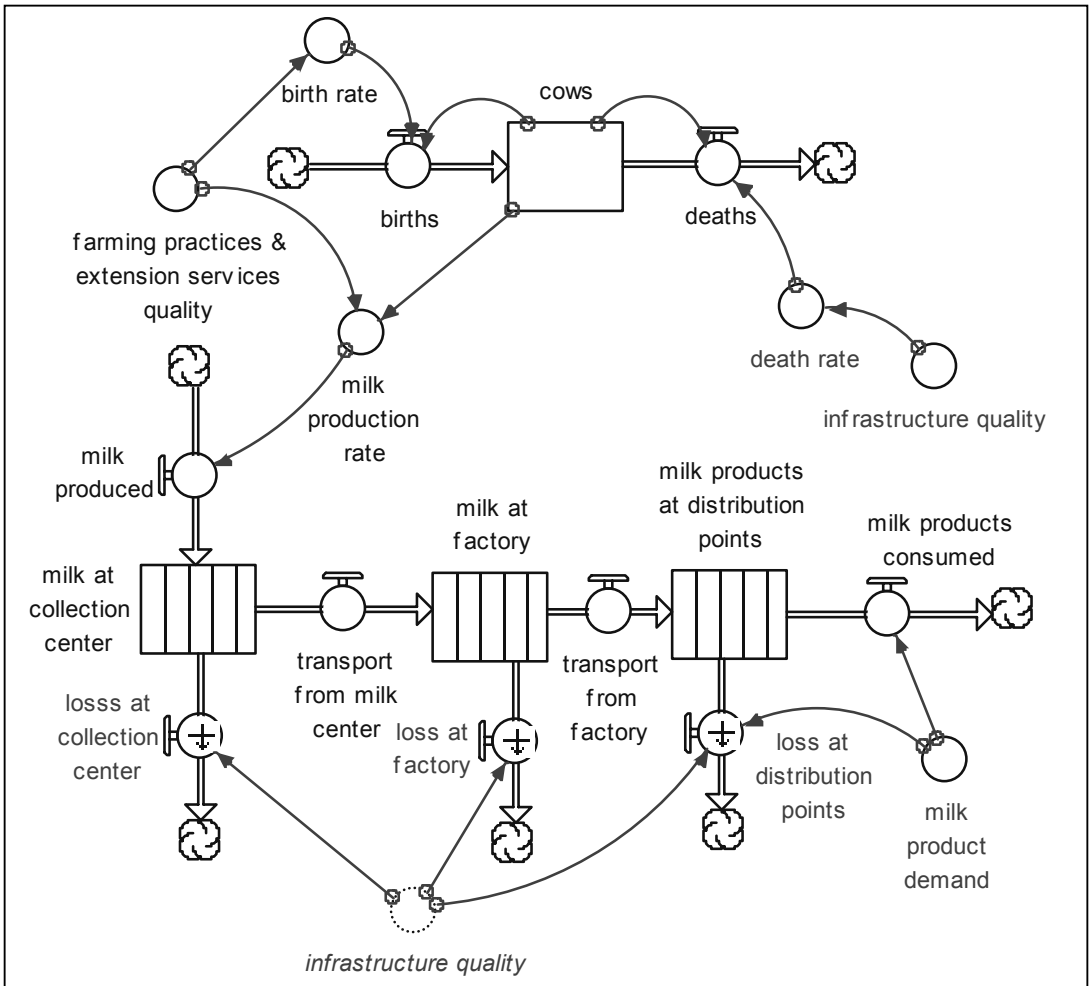

Figure I: An SD model for the supply chain

Strategies for organisational excellence: Applying knowledge for productivity

The individual organisations in the supply chain will have a value chain as demonstrated in Figure II [12]. Primary activities are those involved in the physical creation of the product or service – its marketing and delivery to buyers, and support and servicing after sale. Supporting activities provide the input and infrastructure that allow the primary activities to take place. Each activity in the organisational value chain employs purchased input products, human resources and a combination of technologies. The organisation's infrastructure, such as legal work, accounting and general management, supports the whole chain [12]. A **competitive advantage** is gained when all activities (primary and supporting) in the chain are improved or managed on system principles [14]

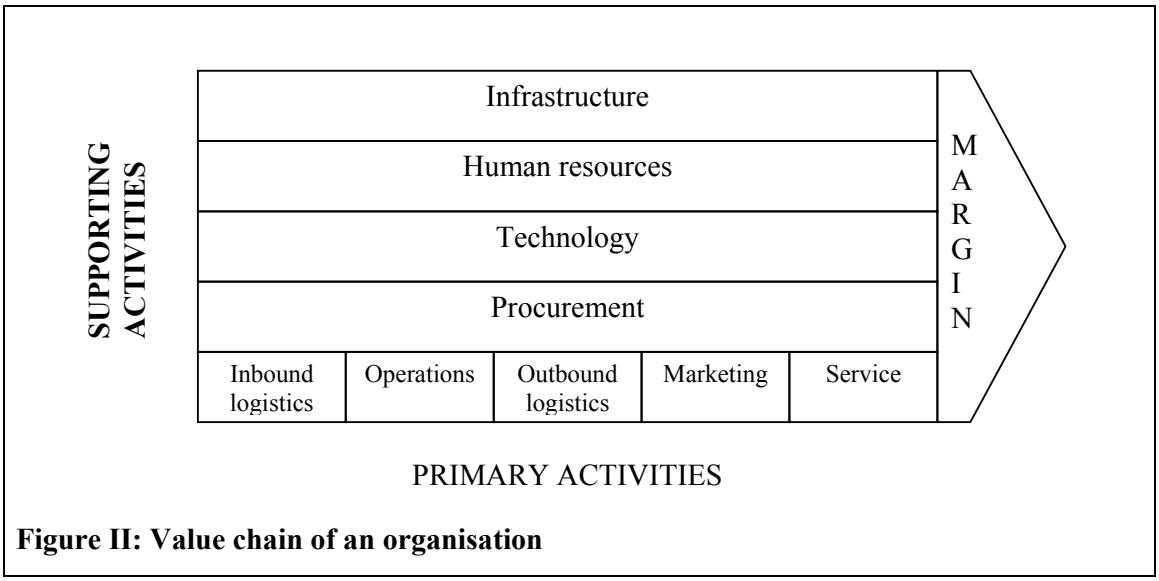

Figure II: Value chain of an organisation

Porter [12] shows the importance of linkages within the value chain as a competitive advantage and its valuable role in designing organisational structure and Goldratt &Cox [5], [6] indicate how the same applies for the supply chain [16]. If a supply chain is considered as a network of individual organisations, an individual organisation can be regarded as a constraint that limits the output of the whole supply chain. A constraint within the individual organisation limits the throughput of the organisation and has to be improved. The process of continuous improvement by improving the constraint organisation within the supply chain increases the throughput of the entire value chain [16]. Therefore, in order to improve the output of the whole supply chain the *constraint organisation* has to improve. This means that the other organisations in the supply chain have to work according to the *constraint organisation*. In this way the entire chain will reach its full potential [4].

Supply chain lead-time is the time it takes information to travel from the market to the raw material supplier (total supply chain information lead-time) plus the time it takes *a single* product to travel through the different transformation processes (total supply chain production lead-time) back to the market. By shortening the lead-time, sales will be made more often. If more sales are made, more money is generated for the supply chain. To shorten the total supply chain lead-time, the inventory levels have to be reduced [6] and/or additional capacity be created within the system [5]

The effective flow of information, from a knowledge base, through a supply chain plays a crucial role in ensuring that all organisations have the necessary information to make global decisions regarding the productivity of the whole supply chain.

Some Factors to Consider When Selecting an Analysis approach

While this discussion has focused on Systems Dynamics, there are other approaches, including the use of spreadsheets, discrete simulation, and various types of optimization algorithms, that are often a better choice for addressing particular types of transport, supply chain and logistics issues [10] [3]. Selecting the right approach or collection of approaches will be guided by the problem to be solved [1] [3].

One example is provided by to use the SD model to link the quality of farming practices, extension services and infrastructure to production through the supply chain. This will be used to assist in the design of operations. The application of optimization techniques

to identify the ideal mix of infrastructure (number of sites, locations, functions, links between these, etc.), use of a discrete event simulation model to test and develop the operational rules that will govern the new operations (e.g. replenishment rules, production priorities, transport policies, etc.), and creation of a spreadsheet model to combine and present the modeling results in financial terms (e.g. calculate total costs and analyze cash flow, etc.) are also key components. It is observed that in practice, using a mix of models is an iterative process whereby results from one model may inform the inputs to another and vice versa [3] [1]. In using systems approach to determine critical infrastructures and appropriate technology utilizing systems dynamics and other approaches use of major assumptions that inform models like perfect competition in which sellers are price takers and the quantities sold are driven by supply and demand regulate the appropriate allocation of resources and push for productivity improvement in the supply chain.

Collaboration in the supply chain is driven by information technology infrastructure (interface/presentation devices, communications, Databases, and system architecture) as well as applications like ERP (enterprise resource planning) ability to support SOA (service-oriented architecture) and BPM (business process management) technology [17]. However, the same factors associated with analysis of productivity, from considering the overall system cost and perfect competition as a baseline, expands beyond the scope of this paper but highlights the basis of analysis. The challenge of what information to share and what not to share given the advantage of sharing information weighed against the competition challenge remains the discretion of the organisation within the supply chain and is beyond the scope of this paper.

CONCLUSION

In this paper, it has been highlighted that it is feasible for a process to strive to achieve a global optimum in the enterprise instead of a local optimum for an organization if all parts of the organization touched by the process can be taken into consideration as a whole. This requires a systems approach to supply chain optimization. That in turn generates choices of infrastructures that lead to global results that increase total productivity. A SD model allows the impact of these choices to be modeled. This is combined with the use of other tools like discrete event simulation, spreadsheets and optimization are employed using a systems thinking approach.

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A National Framework for Infusing Information Technology in the Decision Support Process

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Key Words: Knowledge management, decision support systems, e-governance, web portals, ICT educational strategy

ABSTRACT

This study is based on an examination of the decision support needs of underdeveloped and developing countries and draws largely on our current work in Rwanda. This effort centers on a comprehensive framework for an information technology based decision support system (ITDSS). It addresses decision support at the national and local levels. The strategies and benefits of informed decision making at the central level are contrasted with the strategies and benefits of involving the broader population in decentralized decision making. Particular detail is provided on the strategy to infuse the necessary training and education in the national education process. The focus of this education strategy is on the tertiary level, but extends to recommendations to K-12 and community based education. The intent of this work is to draw on previous studies, as well as an examination of current conditions to detail a framework for IT-based decision support that national policymakers can consider as a guideline for developing, enhancing and assessing their knowledge-based decision support process.

INTRODUCTION

Every day the world becomes more globally connected. As a result our daily economic and social lives are becoming more and more knowledge-driven. The challenge is for individuals, organizations and nations to plan for more effective knowledge management to aid in decision making at all levels. Computing researchers and academics will play a role in the organization and development of decision support software and techniques to facilitate all levels of decision-making. E-governance and e-government have unique roles in this knowledge management decision support system partnership. They have the ability to contribute significantly to more effective governmental administration on all levels and more effective efforts by governments to empower the people. Academics have a particular task to further curriculum development at all levels to better prepare future participants in this scenario of: knowledge management – computer based decision support systems – more effective e-governance. The collaborative, distributed nature of this scenario makes using content management systems to develop web portal based Knowledge and decision support systems a meaningful alternative.

METHODOLOGY

This effort starts by clarifying what is knowledge, knowledge management and a decision support system (DSS), based on current work. This follows with a close examination of DSS's role in e-governance. Based on the work and future plans of Information Decision support Centers (IDSCs) in Egypt and Rwanda we propose 1) a framework for DSS development to enhance e-governance and 2) an educational strategy to complement that framework.

KNOWLEDGE

In projecting the role of knowledge management, a concise definition of knowledge must be forwarded. This definition must distinguish knowledge from information and data. These three terms are often used interchangeably and in many instances inconsistently and contradictorily. "Knowledge is understanding gained through experience or study. It is "know-how" or a familiarity with the way to do something that enables a person to perform a task. It may also be an accumulation of facts, procedural rules, or heuristics."[1] This broader definition of knowledge includes 'facts' which in many instances are classified as information. "Knowledge is a more subjective way of knowing and is typically based on experiential or individual values, perceptions, and experience."[2] This narrow definition of knowledge excludes much of what is classified as explicit knowledge. A middle ground is more appropriate.

Knowledge is 'information about information'. Knowledge can be concisely defined as rules, guidelines, decisions, algorithms or processes that act on information. Knowledge is distinguished from information in that knowledge implies real or potential action. In contrast data is a string of signals with no assigned meaning. Information is data with an assigned meaning. Information can be simple facts such as my weight = 180 pounds or more complex information structures such as a database of student information that includes names, addresses, id numbers, courses, grades, etc..

Part of the confusion on distinguishing information and knowledge is the fact that most information implies knowledge. For example the 'class average = 74.5' implies the knowledge on how to calculate the mean from a set of individual grades. The equations and the action of the calculations represent the knowledge and the practice of the knowledge. However the individual grades and the class average are simply information.

KNOWLEDGE STRUCTURES

Knowledge can be captured in a wide range of knowledge structures. Knowledge structures can be placed in four broad categories: graphical representations, logic, prose, and mixed approaches. Examples of graphical representations are decision trees, causal diagrams, semantic networks and 'stock and flow diagrams'. Logic knowledge structures are grounded in proposition logic and predicate calculus. The most widely used logic knowledge structures are 'rule based systems' popularized by expert system development. Prose is by far the most widely used category of knowledge structures used in knowledge management systems. Prose structures can take many forms such as: scripts, recipes, scenarios, cases, guidelines and reports. These prose structures follow particular formatting rules that facilitate their utilization.

KNOWLEDGE MANAGEMENT (KM)

The definitions of knowledge management range from the simple and straightforward "doing what is needed to get the most out of knowledge resources"[3] to Dalkir's set of contextual definitions captured in table 1 below.

Business Perspective	Cognitive Science Perspective	Process/technology perspective
KM is a business activity with 2 primary aspects: treating the knowledge component of business activities as an explicit concern of business and making a direct connection between an organization's intellectual assets and positive business results.	Managing Knowledge (the insights, understandings and practical know-how), the fundamental resource that allows us to function intelligently. Knowledge is one, if not THE, principal factor that makes personal, organizational, and societal intelligent behavior possible	KM is the concept under which information is turned into actionable knowledge and made available effortlessly in a usable form to the people who can apply it. A virtual repository for relevant information critical to tasks performed daily.

Table 1 Contextual Definitions of Knowledge Management (adapted from Dalkir)

As the world becomes more globally connected our daily economic and social lives are becoming more and more knowledge-driven. Individuals, organizations and nations must be more conscious of this and plan for effective knowledge management. The task of knowledge engineering practitioners and researchers is to advance the science and art of knowledge management to keep pace with advances in information and communication technology (ICT). The definition and intent of knowledge management may vary given the context. However, all knowledge management systems must be concerned with best practices, rare expertise and complex knowledge practice.

LINKING KNOWLEDGE TO DECISION SUPPORT

Generally a knowledge management system is based on a particular 'domain of knowledge'. This domain can reflect a scientific discipline such as Botany or an organizational structure such as Umutara Polytechnic University. Knowledge outside of the principal domain can be used to manipulate the domain knowledge to assist in the decision making process. This assisting knowledge is classified as 'decision support techniques' and decision support software'. The relationship is evident in figure 1 below.

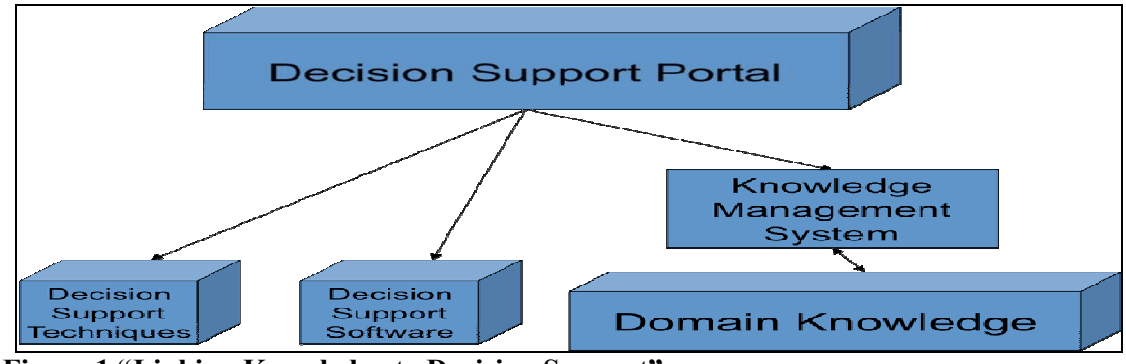

Figure 1 "Linking Knowledge to Decision Support"

DECISION SUPPORT SYSTEMS

A Decision support system combines intellectual resources (information and knowledge) of individuals and organizations with computing and communication technology to improve the quality and timeliness of decisions. It uses a computer-based system to support decision-making. Early decision support computing environments were isolated dedicated systems.

The most recent wikipedia definition of DSS "A properly-designed DSS is an interactive software-based system intended to help decision makers compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems and make decisions" [4] shows the shift to interactive collaborative decision making.

The decision support process should cover 1) approaches to decision-making, 2) techniques for decision-making and 3) technologies for decision-making. In addressing approaches to decision making the concerns are philosophical and ideological perspectives, critical, scientific and system thinking, and the role of collective decision-making versus individual decision-making. There is a wide range of decision-making techniques that can be considered such as: group meeting where consensus is required, individual and group ranking techniques and the nominal group technique.

Decision support technologies automate communication and management techniques where relations of production are key. Decision making technologies are built using a variety of software approaches such as 1) intelligent systems (software agents, particularly search agents; expert systems; case-based reasoning); 2) Operation research / Decision Science - (math programming, inventory theory and supply chain mgmt, discrete simulation (grounded in queueing theory and Markov decision processes)); and 3) system dynamics (based on continuous simulation, grounded in closed feedback loop).

DECISION SUPPORT AND E-GOVERNANCE

"e-Governance is a growing phenomenon within public sector institutions around the world and is emerging as a significant discipline within the field of public administration and management in general. … The concept of e-Governance is evolving and efforts to stabilize and clarify its operational implications must be made."[5] The combination of knowledge repositories and decision support tools and techniques combined under a e-governance agenda can provide a powerful environment for empowering the public in the governance process.

However "the debate regarding e-Governance is most often polarized between those who feel that ICTs will enhance the participation of citizens in the government policy decision-making process, and those who feel that it will simply be business as usual via a new medium."[5] Government, ICT practitioners, and academics all have a role in assuring that it is not 'business as usual' by working to assure that the design and implementation of e-governance is 'appropriate technology'. "The National Center for Digital Government seeks to apply and extend the social sciences in research at the intersection of governance, institutions and information technologies."[6] This effort should promote a people centered e-governance development.

The public awareness, in general, of the potentials of the advances in ICT has led to increased expectations of government efficiency and access. This will serve to increase pressure on policy makers to make e-governance more people-centered. "Recent advances in information and communication technologies (ICTs) have redefined citizens' expectations of the government and its services".[7] Punia focuses on communication and coordination between departments in the workflow and concludes "To facilitate coordination between independent and autonomous government departments, public private process structure with an independent third party monitoring may provide a feasible solution."[7]

Misuraca examines the implementation of e-governance strategies in Ghana, Senegal, South Africa and Uganda; and concludes "there is no single way of introducing ICTs " in the governance process. Their study recognizes that "local languages and illiteracy constitute a barrier to access of information as well as lack of available skills to operate and maintain the physical infrastructure, as well as develop and maintain software".[5] Our personal experience in Rwanda confirms this reality. Most of Africa lacks the ICT personnel to develop and maintain an ICT-based governance process. One solution is orienting the educational process to address this shortage and developing a national 'information, knowledge and decision support center' to implement a long-range national and continental strategy of e-governance.

INFORMATION DECISION SUPPORT CENTERS

As part of their ICT plan 2005-2010, Rwanda intends to establish a National Information, Knowledge and Decision support center.[8] They indicate the purpose of the center will be to provide "valid and robust information for use in decision-making by key central authorities." I will focus on the analysis of data and information required by such agencies as the Presidency, the Cabinet, the Parliament, various Ministries and Agencies. Rwanda identified Egypt's IDSC as a model. Egypt's IDSC Center identified five national projects categories that are to reflect their objectives listed in table 2 below: 1) decision support in strategic issues; 2) technological infrastructure; 3) information provision; 4) human resources development and 5) development of the administrative environment.[9]

Egypt's 'Information and Decision Support Center (IDSC) Objectives
To Strategically identify opportunities and challenges confronting the Egyptian Government in implementing its programs.
To Support implementation of public policies and decisions through carrying out state-of-the-art policy research leading to solutions to the reform and development challenges facing Egypt.
To disseminate our findings and views through a regular flow of publications and public events.
To develop regional and international networks/ partnerships, to exchange know-how and research, which will result in the integration of international best practices in government

Table 2 IDSC Objectives

ROLE OF WEB PORTAL DEVELOPMENT

Web portals provide a Content Management Framework System that also 1) Builds connections with outside resources; 2) Brings many tools to one convenient Location and 3) Supports Dynamic Customization and Personalization. The private sector has seen extensive use of web portal development. In recent years non-profit and government

organizations have begun to build sites using portal development tools. Kastel identifies four layers of an Enterprise Portal, from top to bottom: business layer, functional layer, administration layer and portal platform layer. Key components of the functional layer are single sign-on, workflow and collaboration. Much of our concern in constructing an e-governance portal lies with the administrative layer that handles: user management, content management and document management.[10] The importance of content management is apparent in that many of the portal development tools are classified as 'content management systems'. While major computing companies, such as IBM Microsoft, Oracle and SAP are portal vendors, the open source community has developed several high quality content management systems that can be used to develop and maintain a substantial web portal. Bonfeld compares the three leading open source contenders: Joomla, Drupal and Plone. The article concludes "For simpler requirements or lower budgets, Joomla, or possibly Drupal, should suit your needs. If you need something powerful and proven, and are willing to commit the resources to make it happen, Plone is likely to meet your need, but Drupal is also worth a look".[11] Look for the open source portal tool set to continue to develop. New tool features and additional support (online videos, user groups, books and conferences) will make it even easier to quickly develop and maintain decision support portals.

FRAMEWORK FOR IT BASED NATIONAL DSS

"While organizational leaders and managers must manage as knowledge leaders, they must be aware of the relationship between knowledge and those who possess it. Obtaining individual cooperation and motivation to be part of teams and groups is essential in making knowledge sharing the core of effective knowledge management."[12] Not only do all government workers possess and use knowledge, but all citizens possess and use knowledge. A comprehensive framework for decision support development must address knowledge development and sharing from the highest leadership to the common citizen. The table below serves as a starting framework for this process.

PARTICIPANTS	TOOLS / STRATEGIES	BENEFITS
National leadership: President, Prime Minister, Cabinet, etc.	-Operation Research Models, -Simulation, -System Dynamics, -Statistical analysis	-Better central planning -Better national assessment -Better international linkage
Local leadership and technical workers: Secretary generals, sector, district and provisional leaders	-Collaboration tools, -Operation Research models, -E-learning tools, -Document sharing on portal	-Decentralized work plans -Larger segment of trained e-ready government workers -More collaboration across organizations and regions
Citizens	-Regular update of content -Diverse 'how to do' content -Elicit citizen inputs (i.e. surveys, petitions)	-Increase democracy -More satisfied population -Channel more creativity -EMPOWER THE PEOPLE

Table 3: Framework for Decision Support Processes

The implementation of this framework requires governmental support at all levels. However, it requires a strong commitment on the part of central or national government leaders to involve the general citizenry and commit to the necessary training to make e-governance a reality.

ADDRESSING EDUCATIONAL NEEDS

The implementation of any effective e-governance strategy requires the trained personnel. In the case of most of Africa, the extreme shortage of personnel capable of implementing and maintaining information and knowledge-based systems requires a comprehensive, aggressive educational strategy.

The educational strategy is divided into two parts. The first addresses the general needs – preparation at secondary school level, general education at university level for all students, and community based education. Table 4 below addresses these needs. The 2nd part deals with training ICT students at the university level to play a leading role in the future of knowledge-based decision support systems. This curriculum is contained in Table 5. It assumes a student has completed the secondary curriculum and general university curriculum listed in Table 4.

SECONDARY	UNIVERSITY	COMMUNITY
-Critical thinking -Computer skills -Student centered learning -Scientific inquiry -Introduction to systems	-Computer Skills -Development Studies -Web utilization -Appropriate Technology -Critical Thinking	-Computer Skills -Web utilization -Introduction to Systems -Appropriate Technology -Critical Thinking -Development Studies

Table 4: General Educational needs for Knowledge society

ICT CORE COURSES	ADVANCED COURSES
-Problem solving and programming -Web development -Introduction to modeling and simulation -Database design -Data structures and algorithms -Data communications and networks -Probability and Statistics	-Operation Research -Statistical analysis and data mining -System Dynamics -Knowledge management -AI and expert systems -Web services -Portal development

Table 5: Curriculum for university degree in Knowledge systems.

CONCLUSIONS

A national strategy to achieve more effective use of computer-based decision support processes should start with clarification on what knowledge is. A knowledge management system that focuses on decision support is not only a knowledge repository of a given domain knowledge, but must include techniques and technologies that assist in decision-making. The inclusion of this decision-making component in an e-governance strategy requires 1) a comprehensive evolving national decision support system strategy and 2) and aggressive educational strategy. The educational strategy must be all inclusive – addressing students at secondary and tertiary level as well as community members that are not students. The decision support strategy must address training and tools for the highest administration (national leadership) to the general citizen.

A comprehensive strategy of this type will serve to set and monitor a strong national development agenda, as well as channeling the creativity of the broad citizenry. Most importantly it will empower the people, thereby contributing to appropriate technology.

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A Case Study of Software Procurement Strategies in Sudanese Organizations

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Key words: Software Procurement, software acquisition, COTS software products, software quality and measurement

Abstract
Generic software components that can be procured off-the-shelf (COTS) are now available to perform most of the functions that in the past required bespoke development. The use of commercial software products in organizations is being driven by its potential for reducing the cost and time to develop software systems. A number of COTS-based development methods and standards have been proposed in the literature, however, many organizations struggle in their attempts to select appropriate software products for use in systems. This paper examines procurement activities carried out in three organizations with the aim of identifying their risks and potentials. The outcome of the work highlighted areas of improvement, e.g. business requirements analysis, risk assessment, and documentation of procurement projects. The authors argue that availability of products because of language, cost, embargo add a further set of complexities to procurement in developing countries. The paper concludes by making recommendations to foster the informal networks of information exchange on products that exist among IT staff in similar (also across) organizations, as a possible medium for wider participation in the development of national standards, as well as outlining final thoughts on some of the imperative tasks and challenges that remain to be addressed in country efforts on software procurement and development.

INTRODUCTION

Generic software components that can be procured off- the-shelf (COTS) are now available to perform most of the functions that in the past required bespoke development. The use of commercial software products (or COTS) in organizations is being driven by its potential for reducing the cost and time to develop software systems. A number of COTS-based development methods and standards have been proposed in the literature, however, many organizations struggle in their attempts to select appropriate software products for use in systems. Given the complexities of today's software systems, the cost and risk of procuring/purchasing wrong package due to inadequate requirements acquisition and product selection is large.

Central to COTS evaluation for suitability is the process of establishing the context of procurement such as functional, technical, business, etc. that determine the criteria for evaluation criteria to assess the product. [1] While some of the challenges come from limited access to internal design of products and scope for evaluation of fitness [10], other challenges come from the dynamic nature of COTS market and rapid change in technology. Software products procurement in developing countries have additional sets of challenges that come from being at our infancy as software consumers, and hence have little effect on its market and the development of standards. As part of local efforts by government to regulate and develop standards for software procurement, this paper compares and evaluates processes

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employed at three local organizations with the aim of identifying their risks and potentials, and propose a set of guidelines that can support organizations in making carefully reasoned and sound product decisions, as well as improve their process models.

The paper is structured to give in section 2 an overview of the concepts that are knitted in the procurement process and common procurement activities and steps proposed in the literature. Section 3 presents procurement processes from the case study which is followed by comparative and critical analyses in section 4. Section 5 concludes with highlighting some of the questions and thoughts on product evaluation, process improvement, and challenges in procurement processes that arose from the study.

Software Procurement Concepts and Processes

The development of systems using COTS products bring fundamental changes to the way organizations do their work [4]. The central cause of change is that the organization becomes a consumer with less or no control over the product implementation and adopts standard interfaces based on COTS market. Some familiar software engineering activities are altered. Requirements analysis may have to consider standard implementations, architecture design must be performed together with package evaluation; and new activities will become significant parts of development process, for example product adaptation and integration. These changes require organizations to have an understanding of the capabilities and limitations of COTS products and standards in their domain, conduct market research and product evaluation to select products, and involve different kinds of expertise such as business analysts and legal consultants in the procurement process.

There are two types of standards that an organization must deal with. The first are the standards used in implementations to be able to balance requirements with available product features. The second are standards and recommended practice for conducting procurement processes. For example, IEEE 1062 suggests a number of major phases, steps and milestones for acquiring COTS products, and its variant MOTS (Modified-off-the-shelf), as well as provides checklists to assist organizations in developing their own processes [6]. Another standard that is not specifically geared for COTS but offer related guidelines is the ISO 9126 for software quality. A number of COTS-based development methods have also been proposed, for example OTSO (Off-the-Shelf Option) and PORE (Procurement-Oriented Requirements Engineering). The OTSO method starts with a specified set of requirements and provides techniques to define evaluation criteria and to compare the costs and benefits of alternative products [7], while PORE [13] integrates the process of requirement specification and product evaluation using techniques from requirements acquisition and engineering such as card sorting and laddering, and provides guidelines to design evaluation test cases.

Investigating current procurement practice in Sudanese Organizations

This section will consider how three very different organizations deal with the problem of procuring an appropriate COTS product. One organization, ("A") is a major telecommunication company that is privately owned. The second organization, ("B") is a government owned bank and the last organization ("C"), is a large industrial corporation that is a public/private partnership. While the three use very different approaches to COTS evaluation, still it was observed that the abstract process ideas underlying are similar. The procurement project consists of three major steps to initiate, select, install and integrate of the COTS product in the system. And the authors also learn that differences in approaches support the notion that whatever the actual process used, it is driven by context. The subsections below highlight the main features of the organizations and their COTS software procurement processes (depicted in Figures 1, 2 and 3 – in the Appendix).

Organization "A"

This is an international telecommunication company that bought a public owned company and has more than 20 branches worldwide. Software is fundamental to the operation of the organization which procures from different ranges of COTS products, e.g. Antivirus, Billing System. The company is frequently engaged in multiple procurement projects and technology upgrades. Procurement projects are initiated at middle management level and the decision to procure is taken in consultation and approval of higher management. Selection of products considers vendors of existing running components of the system, for example the Reporting system solution used the same vendor of the Billing system. A main feature of the procurement process is the existence of end-of-project evaluation.

Organization "B"

This organization is a large government owned bank with 35 national branches, and one branch outside Sudan. Although software is an integral part of the bank system and improves its performance, failure of the computer system is not as catastrophic as for "A", because the bank can revert to its established manual system. The current core system the bank uses is a Jordanian COTS product that is implemented in COBOL and runs under DOS on Novell system. The rate of change of computer systems is slow in this organization and undergoes various government regularity measures on spending and on procedures followed from the Central Bank. The organization uses a tender system to select products and involves representatives from different stakeholder groups in the organization in the procurement team.

Organization "C"

This is an industrial corporation that is owned by government, and private national and international investors. The company's sites of management and production are located in Sudan, with one office abroad. The main type of COTS the company deals with is CRM (Customer-Relationship Management) systems. A continuous business and needs analysis (using external consultants for large projects) is conducted in the organization that can initiate a procurement project, and yield a list of requirements as well as possible solutions. The procurement process in this organization is characterized by an early identification of a suitable product and that it performs initial testing before signing the contract. This is followed by customization and a second round of testing before the system is launched.

Analysis and Discussion

The information obtained from organizations is organized according to the software acquisition life-cycle process model proposed in the IEEE 1062 which includes planning, contracting, implementation, acceptance and follow-on activities. The activities considered during information gathering are based on acquisition management and technical activities associated with the use of COTS products and standards proposed in [11] and on other

generic processes of the PORE method that are specifically proposed for requirement engineering and product selection. Table 1 lists the phases and related activities and state how they are considered or occur in each organization.

Phases	**Organization "A"**	**Organization "B"**	**Organization "C"**
Planning (business strategy, risk analysis, standards use, software requirements)	• Considers immediate performance needs. • No risk analysis • Choice of product is based on quality and short schedules. • Use own standards. There are no evaluations of standards used. • Requirements are determined by beneficiary department. They are expressed in different forms by different departments.	• Considers change in domain requirements. • Risks are mainly defined in terms of old data. • Products judged on cost and quality. • Select products from a set of national standards and participate in their development. • Requirements are determined from outside organization. They are expressed in standardized language used nationally by similar organizations.	• Considers output of business analysis. • Evaluates business and technical risks. • Product quality is prime factor in selection. • Extensive search and evaluation of international standards. • Requirement are gathered during business analysis and expressed in standard used by business department.
Contracting (vendor and product selection, suitability assessment, contract development)	• Supplier is selected based on personal knowledge of staff. The product is selected after supplier selection. • No suitability tests conducted. • Legal advisor part of procurement team from the start of project.	• Supplier and product selected using a tender system. • Tests are performed outside the organization by national regulatory bodies. • Legal advisor is part of the procurement from the start of project.	• Supplier is selected based on business analysis. Products are selected from proposed solutions by internal staff assisted by external consultants. • Conducts a set of suitability tests set by organization. • Legal advisor joins team after product selection.
Implementation (configuration management)	• Configuration starts after contract signing led by vendors and internal technical staff.	• Configuration starts after contract signing led by vendors and internal technical staff.	• Some initial configuration management and testing is done by internal staff prior to contract signing.
Acceptance (conformance testing)	• System installed by vendor and technical staff, testing performed by internal staff in real environment.	• Training of technical staff is carried out, then system set up and testing (also by national bodies) before launch.	• Training of technical staff is carried out before second round of testing. The system is then fully installed and deployed.
Follow-on (evaluation)	• Projects and software are evaluated.	• Evaluations are conducted at national level.	• Continuous evaluations.

Table 1: Procurement Activities carried out in Organizations surveyed

It can be observed that organization "C" has a more robust process compared with organizations "A" and "B". This may be due to the fact that "C" has a business analysis department as part of the IT Section. This department was important during the initiation and requirements analysis activities and is engaged in a continuous process of assessing the

business needs of the organization. When these analyses suggest the need for a software, this department ensures that the software product is in line the organization's business objectives and performance goals. This wide view of need/impact assessment of the proposed computer system serve as a quality assurance mechanism for decisions made with regard to investments, as well as ensures coverage of needs and compatibility of requirements from different departments or sections in the organizations.

The tendering procedure used by Organization "B" is considered a strength as it facilitates identification of suitable products based on tender criteria which reduces the search space. The organization benefits from being under the judiciary of National Central Bank that regulates and evaluates processes for government owned banks. However, this can also prolong the procurement process as decision making is required at senior management level and becomes focused on product cost more than quality.

In organization "A", project and product evaluation – strength, are conducted at the end of procurement. These evaluations are used to update information on vendor, user satisfaction, or to improve procurement processes. More recently (after this study), the organization set up a business/IT section to be responsible for procurement projects. Another characteristic of this model is its emphasis on short schedules of procurement projects which may be necessary in their context because new requirements are introduced at high rates.

Conclusion

The outcome of the work highlighted some areas of improvement to the organizations procurement processes. For example, decision to procure must be based on business analysis; use of organizations surveys and market research during product search; and risks to projects must be identified. A number of COTS assessment attributes such as availability, ease of use, maturity, vendor support are proposed Bohem in [2] to use in determining the time that should be spent on product evaluation. Also, teams should include a number of fixed staff assigned to procurement projects management, and evaluations of product in use and procurement process must be carried out at end of projects. These are considered as some of the enabling factors to improvement continuity and process maturity.

The context of the organization was found to significantly influence the procurement activities carried out and their sequence. For example, the lengthy tendering system employed by organization "B" is required for government procurement, while short project schedules was an important criteria for organization "A" where change in requirements and developments in the domain are faster. Alternatively, in organization "C" time was not a factor as software is not a fundamental part of their business process.

The paper also identified that language, cost and availability of COTS products for economic or political reasons, add a further set of complexities to known procurement problems and cause some organizations to use unstable or "middle-vendors". In these cases, serious problems of quality and support types are reported to arise. Very few organizations outside academia are currently using Open Source software (OSS), alone or within their COTS-based systems. Lowering procurement costs, availability of source code and the freedom to modify according to need present some of the benefits of this type of COTS. Quality and support are major concerns in using OSS although this is not the case where OSS has been developing e.g. operating systems and web servers [12]. Collaborative activities and social networks of IT personnel working in related organizations in identifying products, selecting vendors, fixing compatibility problems, is a particularly interesting finding in terms of its potential for

an organized local standards development efforts, user community set up, skills transfer, information sharing, and in that it encourages wider participation in the development of national standards.

Final remarks and thoughts

More recently in Sudan, specialized government agencies in information and telecommunication technologies moved towards promoting an indigenous software industry by funding the establishment of research centers in a number of universities as well government owned ones. The impact of this initiative is yet to be seen however it is worth noting that the importance of OSS is highlighted. For instance, the newly established Information Technology Research & Development Center (ITRDC) in the Department of Computer Science at the University of Khartoum, in collaboration with the National Telecommunication Corporation, has a dedicated OSS research group and all research staff currently being trained in Linux.

Some of the imperative tasks and challenges that remain to be addressed in the local context of software procurement and development include: First, developing national standards or guidelines that can be tailored for use by different sized organizations, to regulate and support the purchase of products and services. This requires a broader situation analysis similar to the study reported in this paper, as well as examining other country experiences e.g. ChileCompra [5]; Second, resolving the paradox of the need for government support to local (especially growing) industries and how that may infringe global free trade rules. [3] In addition, developing countries gains from OSS is discussed and demonstrated by non-governmental organizations like UNDP and UNCTAD and by researchers worldwide. The slow uptake of OSS in Africa, behind that of South East Asia and Latin America, can be understood in the context of inadequate telecommunication infrastructure, but it also begs the necessity of political will as well as the examination and perpetuation of national interests, e.g. Peru's Bill for Free Software in Public Administration [9] and the recommendations of South Africa's National Advisory Council on Innovation [8]. Finally and crucially, centering the issues of economic and social development into the heart of country software use and development efforts would foster relevant indigenous industry and boost our critical minds – to address pressing problems and seek appropriate solutions.

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Appendix: COTS Procurement Activities of Organizations in Sample

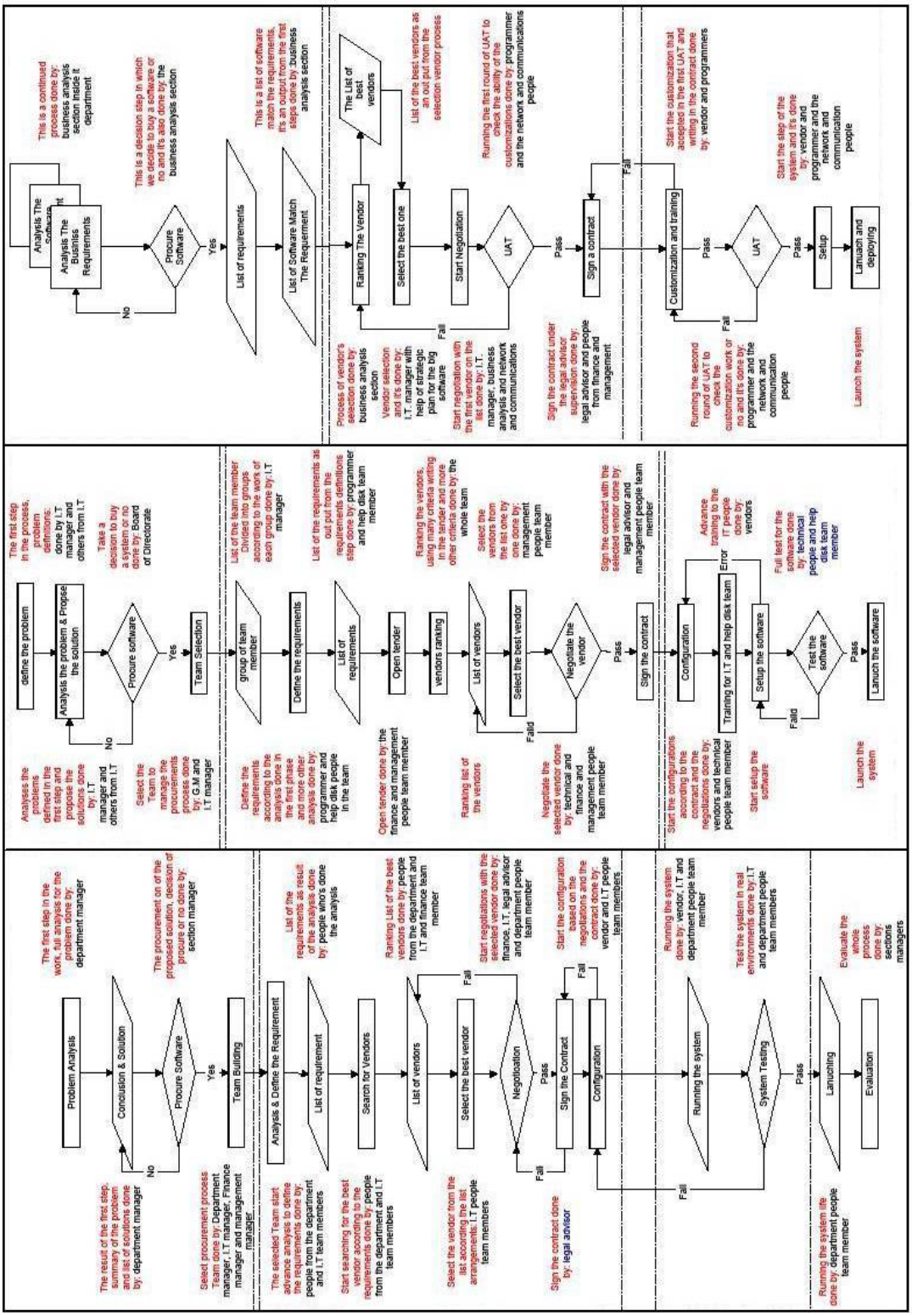

Figure 1: Organization "A"

Figure 2: Organization "B"

Figure 3: Organization "C"

Promoting Virtual Schooling in the environment of the Least Developed Countries using LoColms

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Key words: Virtual Schooling, LoColms, Proxy Cache Server, PSTN, PPP, Video-Stream Server

Abstract
We have been witnessing sharp increases in evening classes in many LDCs' Institutions of Higher Learning where enthusiastic learners have been converging to very few and heavily crowded Institutions, sometimes many coming from as far as the ends of the country (in the case of Rwanda). In these situations ICT becomes an appropriate technology, providing a timely solution in this regard. It is becoming both possible and easy to establish virtual schooling environments to make learning and teaching cheaply and easily accessible from anywhere and at anytime; the movements in search of schools and teachers is no longer a must to learning. LoColms (Local College Management Learning System) is a learning management system that has been designed with the purpose of making virtual schooling, especially in the LDCs environment, a viable option [8]. It is designed to deliver multimedia contents, especially the rich full-motion video contents, over the PSTN (which in most of the LDCs is being upgraded to digital system, and with sufficient bandwidth by means of ADSL or fiber optical infrastructure used on the subscriber loop). The LoColms lowers learning costs by employing the combination of Proxy Cache & Multimedia Stream storage Servers and Point-to-Point communication Protocol (PPP) Technologies. The learners can access the few tertiary institutions and the limited expert staff any time and from anywhere, and the use of learning and teaching materials is greatly reduced.

1. Introduction

The LDCs represent the poorest and weakest segment of the International community [1]. These countries are characterized by their exposure to a series of constraints such as limited human, institutional and productive capacity; and lack of access to information and communication technologies. Adequate tertiary education places a significant role in national development, which the traditional mode of educational system is not able to meet in the light of the current demand against the disproportionate population growth rates and budget constraints in most of the LDCs.

Virtual schooling system can be a feasible and relieving alternative; the enrolment figures and teaching/learning resources of each institution can virtually expand exponentially, and the limited resources such as qualified teaching personnel and reference materials can virtually be shared without a major extra stretch. Generally, the barriers to distance education in these countries have been the: 1) lack of resources needed for meaningful development and sustenance of technology-based learning; 2) lack of infrastructures (which includes information and communication hardware systems) to support modern technologies in least developed and/or low-technology countries, and; 3) the lack of recurrent funding necessary to acquire or develop appropriate software and courseware on a continuous basis, and maintain, service and replace the equipment [2]. This paper discusses a prototype of LoColms, a system designed to support Virtual Schools. The Virtual Schools in distance education can make the education a "*must for*

all" [3], especially in the LDCs, a realizable dream. One of the major objectives of distance education is to help widen access to education, raise the quality of education by training and making resources available to the classrooms, and to bring new methods and approaches into schools, [4].

2. The LoColms Based Virtual Schools

2.1 The Concept of Virtual Schools

A Virtual Organization is defined as a "dynamic collection of individuals and institutions which are required to share resources to achieve certain goals" [5] and as "a temporary or permanent coalition of geographically dispersed individuals, groups, organizational units or entire organizations that pool resources, capabilities and information to achieve common objectives" [6].

As pointed out [7] the related terms "virtual", "virtually" and "virtuality" imply that something exists having a potential effect but this something is not tangible. In classical organizations the boundaries are clearly defined, while virtual organizations are characterized by fuzzy boundaries, flexible structure and the ability to include new partners as the need arises. In a nutshell, virtuality can be defined as a temporary or permanent coalition of geographically dispersed individuals, groups, organizational units or entire organizations that pool resources, capabilities and information to achieve common objectives, while decisively relying on information technology (IT). A virtual school is also extended to cover different alternatives of symbiosis with physical school. A virtual school can work as a virtual extension of ordinary school or classroom activity. The concept of virtual school does not emphasize teaching; it focuses on individualism and the independent initiative to study. The Virtual Schools concept allows a great deal of flexibility for learners and educators.

2.2 LoColms General Architecture

The LoColms relies solely on the local resources, namely the local universities and the local telecommunication facilities, a characteristic that makes it highly sustainable. The rationale is to utilize what exists locally; every country has a well-established PSTN infrastructure, and presumably that is already being digitally upgraded (for the ease of data communication).

The key technologies supporting the LoColms virtual schools comprise **PSTN**, **PPP,** and **ProCa**. The choice of the PSTN eliminates the duplication of communication networks (especially Internet, a packet-switched network, that has been the main infrastructure for the Web), or dedicated private virtual networks (PVN) usually required in similar situations.and the choice to utilize the local educational institutions (LEI) is to empower the local educational institutions. The PPP is used to provide a direct TCP/IP link between the Local Educational Institutions (LEIs) and the Virtual School Centers (VSCs), while the ProCas are to minimize communication traffic and costs. The choice of the optical fiber cable or Digital Subscriber Link (xDSL) is to provide a broadband environment over the ordinary telephone subscriber lines. The architecture is as in fig. 1.

The Video-Streaming technology is also employed to solve the downloading time. The basic idea of video streaming is to split the video into parts, transmit these parts in succession, and enable the receiver to decode and playback the video as these parts are received without having to wait for the entire video to be delivered. Video streaming allows the students to start studying even before the downloading has completed with a short delay (usually on the order of 5-15 seconds) between the start of delivery and the beginning of playback. For most users of the web (56k), streaming video appears as a small video window, usually 160x120 pixels in size and 5-15 frames per second. For those

with intermediate Internet connections (DSL, Cable), that picture might be 320x240 pixels and 15 frames per second. Those on institutional networks (T1, T3) are capable of viewing 640x480; full motion video. However, this is not required after the contents have been saved on the ProCa. They are downloaded locally and played from the ProCa server.

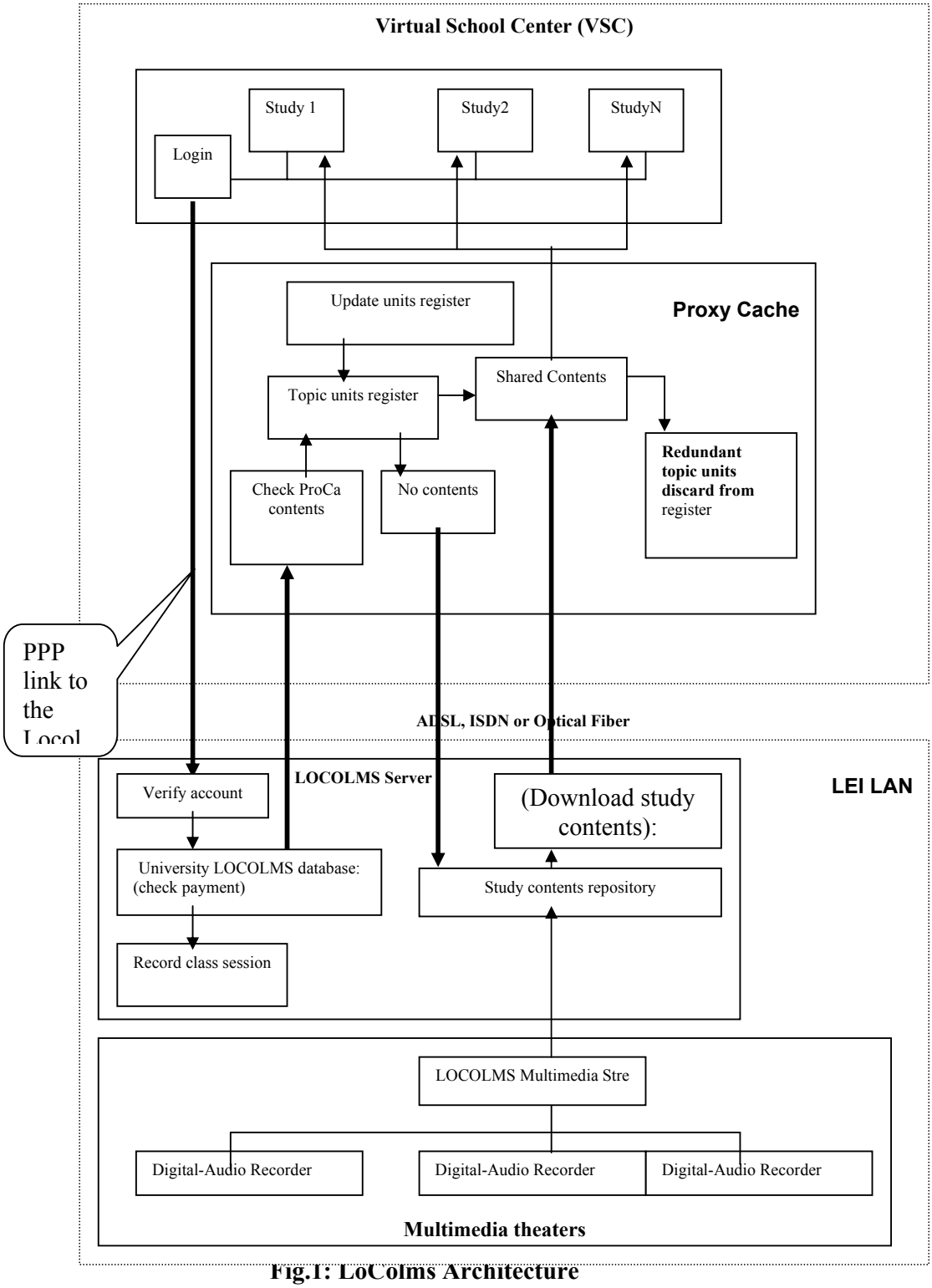


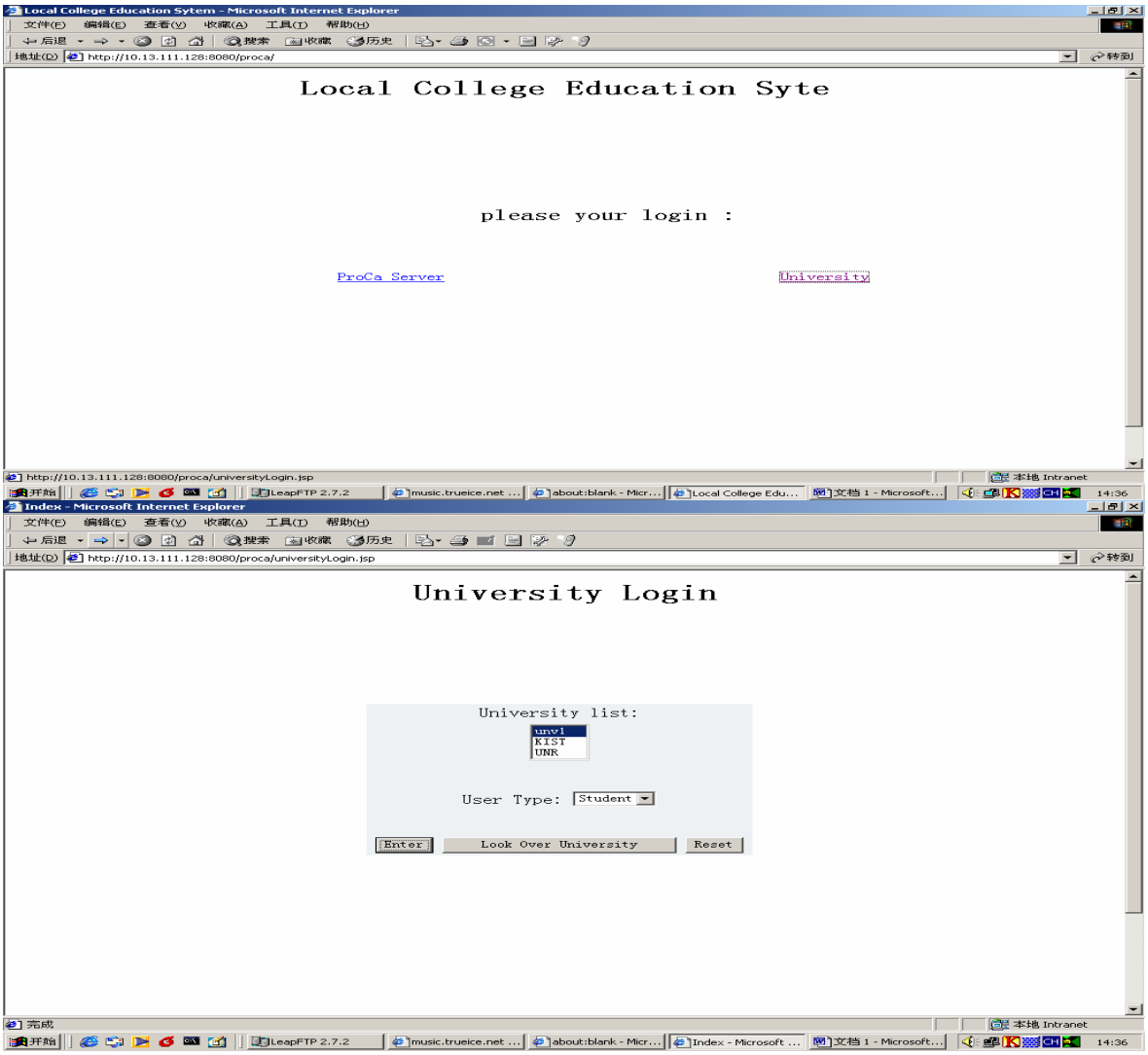
Fig.1: LoColms Architecture

2.3 **LoColms Description**

The LoColms, an asynchronous interactive educational system, is built on the Java technology, and is based on the Client/Server paradigm. The objective of LoColms Application is to provide both a sustainable and an economical solution, suitable for the educational situation in the LDCs. Its economicability comes from the fact that it is supported by locally existing resources. Its local feature comes from the fact all the subscribing parties, namely the local universities offering the courses, the private companies operating the *LoColms based virtual school* study centers, the local telecommunication firms, and the remote students are all local resources and operating purely on business terms. On LoColms the same lecturers can serve both the residential and the remotely learning students with a minimum extra effort.

The LoColms deployed over PSTN, the VSCs and the LEI LANs are each linked to the PSTN central office by bandwidth of either 128 kbps (using ISDNs) or higher (using ADSL, or Optic fiber technologies) and the PPP technology, a link layer protocol to transport datagrams across a serial point-to-point links. The system supports video recorded class sessions that were saved in the *LoColms* servers, to be downloaded by remotely learning students in VSCs over broadband links such as SONET/SDH on the PSTN backbone and over ISDN or xDSL over subscriber links the; the learners on the LoColms are organized in VSCs in order to provide sufficient bandwidth to the VSCs. On making a PPP dialup connection to the respective LEIs, the users of the system must first go through the login process for authentication, and the server keeps the record of the number of times the online learner turned up for classes. At the client side the remote learner is guided through the information about the college, the level, the course (or major), and subject of study. First, the system must check whether the contents have not been previously downloaded, because the study resources downloaded by previous learners are temporarily saved in the VSC's ProCa Server for the subsequent learners, until they are replaced by successive course packages; either by automatic *prefetch* or by more frequently shared resources, according to the *Course Sequencing Prerequisites* and *Completion Requirements*. It is highly hoped that many courses would be shared, although different remote learners may be studying different Assignment Units (*Aus)* of a same course, according to the Course *Structure Format* (CSF) of each course. It is highly hoped that many courses would be shared, although different remote learners may be studying different Assignment Units (*Aus)* of a same course, according to the Course *Structure Format* (CSF) of each course.

The Course Structure Format (CSF) and Course "Packaging" in the LoColms is emulated in the ProCa. It requires contents of 45 minutes block units of a topic plus 15 minutes of *Assignment Unit,* (*au) exercise* of the subjects being studied at a time. The learners from the VSCs will be served with Topic Assignment Units (Tau) according to the prerequisites and completionReq procedure, (Tau_1&Tau_2 &...&Tau_x); studied sequentially according to the sequence these units were taught at the LEI with an after Tau exercises to mark the completion of the Tau if attempted after a period of 60 minutes. A finished Tau is recorded in the LoColms. The LoColms application screens (figures. 2 and 3).



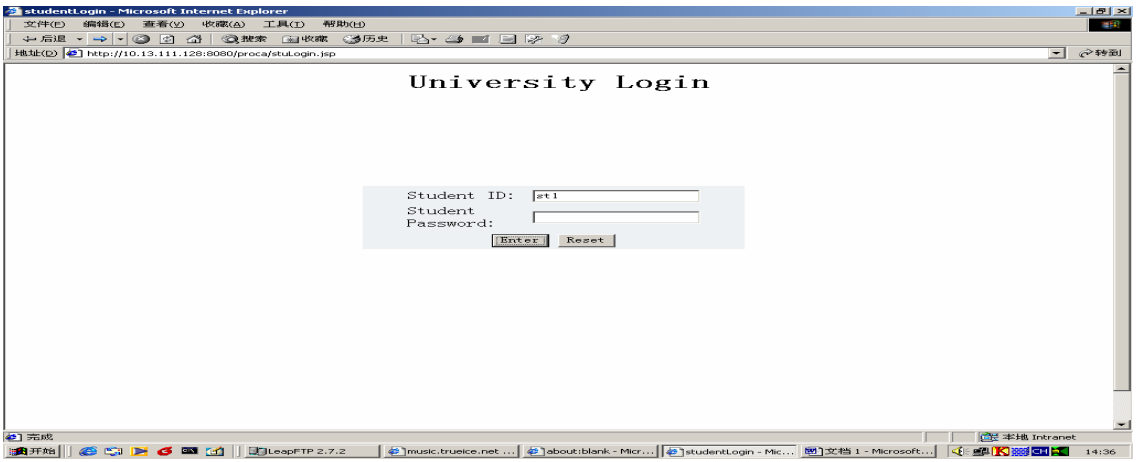
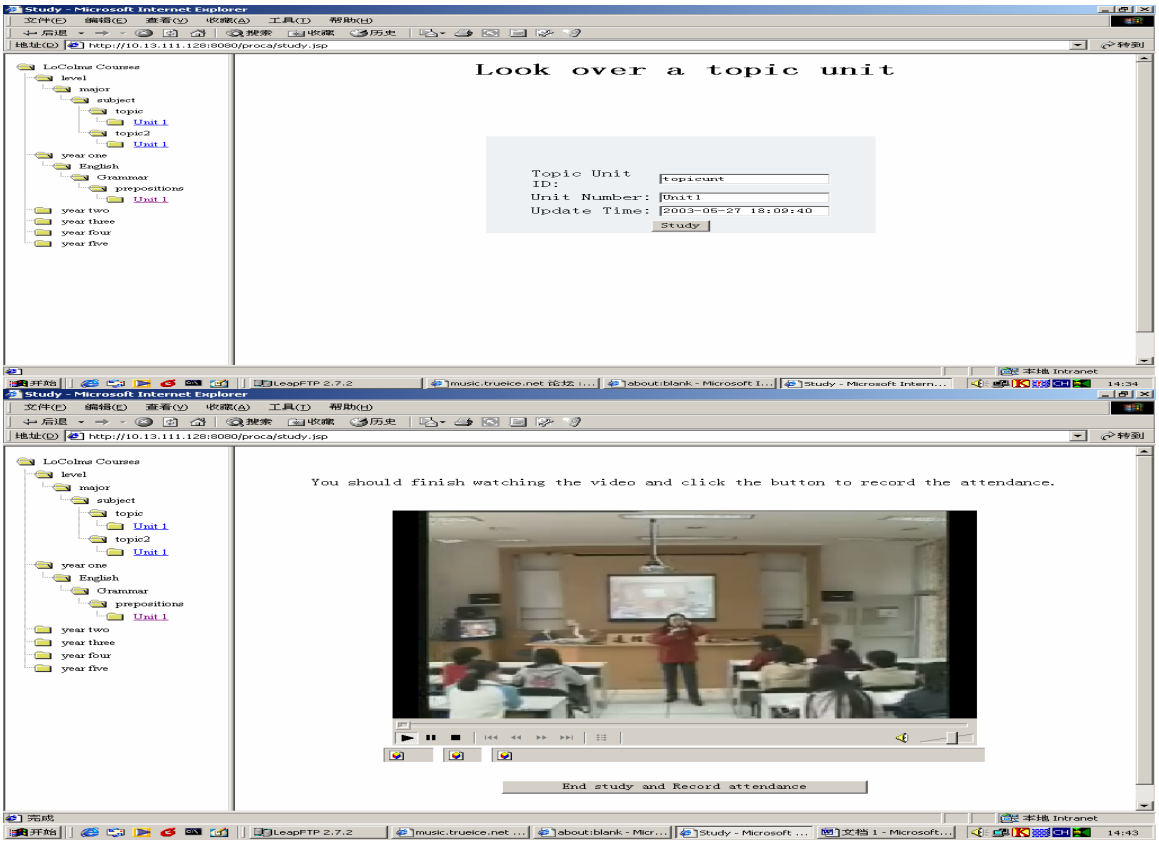


Fig. 2: selecting study content screens

Fig.3: downloaded content screen



2.4 ProCa storage optimisation

To optimize the ProCa storage capacity, the system will only be concerned with the contents regardless of the LEI or colleges the contents were obtained from. In other words, it doesn't matter from which university the contents were downloaded, the learners studying with different universities but studying the same courses will have to share the contents. This is illustrated as follows. Since the basic purpose of caches is to encourage sharing of contents, consider a subject, SubjectA (SA), having several *Tau*s:

$SA = \{Tau_1, Tau_2, ---, Tau_N\}$ ----------(1)

For, a Tau_j, an Na_i (number of students sharing a copy). The bigger the Na_i for Tau_j, the fewer the copies of contents residing on the ProCa. By definition thus;

$(Tau_j) =$ $Na_i = 1$ (*unshared contents*)
$Na_i > 1$ (*shared contents*) ----------(2)
$Na_i = 0$ (*no contents in cache*)

The overall contents in the ProCa would be;

$\sum Tau_j = \sum(Na_i > 1) + \sum(Na_i = 1)$ ----------(3)

Since the $\sum(Na_i = 1)$ contents would be removed from the ProCa, the net content will approximately be;

$\sum Tau_j \approx \sum(Na_i > 1)$ ----------(4)

For instance, if the video contents of say 45MB files were arranged in units of 45 minutes consisting and the end text file, *Tau* exercises, the proxy cache storage capacity of, say, 100 GB used to the full capacity would support about 2000 units, (or 2000 different subject topics hosted) on the ProCa. In other words, ProCa would support 2000 students simultaneously studying from a single VSC LAN. If the size of one LAN had, say, 20 PCs, and all the 20 computers were busy throughout the day (from 8.00 to 22:00 hours), it would accommodate nearly 300 learners; that is 1/6 of the capacity or 13 GB per day, for the worst-case scenario.

According to the Zipf's law, the popularity of a course will determine the frequency of sharing the content. Since the number of LEIs and the volume of the expected courses offered on line would also be small among the LDCs, we can expect a very high hit ratio for most of the popular SA_i in the ProCa.

3. Conclusion

In this paper we discussed the prototype of the Local College Learning Management System (LoColms) we are using to support virtual schooling, a system used to provide a sustainable and economical solution suitable for educational situation in the LDCs. The application is supported by traditional communication technology, the public switching telephone network system (PSTN) formerly regarded a voice communication system, which already exists in all of the LDC countries to avoid the costs that would be involved in deploying packet switched networks or dedicated private virtual networks (PVN) usually required in similar situations, and is aimed at improving the traditional form of education through empowering the local educational institutions. The work discussed is an innovation, whereby different technologies are combined to provide, cheaply, an easy access to higher education in the least developed countries. By this approach a lot can be achieved: 1) the virtual infrastructure would be economically established and with ease; 2) individual colleges' enrollment would, virtually, increase; 3) the local resources would be helped to develop; 4) the e-learning educational system that is sustainable.

We hope that this work will stimulate further research in appropriate technologies, especially the web-based ones, that will be more applicable in the LDCs' situations, for the interest of education in the LDCs in particular and any other socio-economic aspects in an effort to bridge the digital divide in general, relying on the locally available resources with an aim of strengthening them. Although the mastery of IT related technologies should become a priority, it shouldn't be a precondition for these countries to engage in the technology-based education systems, especially if there already exists a minimum technological capacity with which to start.

We are planning to improve the application by including an online examinations aspect, where the set of examination sessions would be randomly selected for candidates in such a way that no two papers would have same questions, to make the application more or less a complete educational application.

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Success and Failure Factors of Management Information Systems in the Livestock Industry of Developing Countries

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Key Words: Livestock, MIS, Success, Failure

Abstract
Management Information Systems (MIS) enable commerce and industry to collate and manipulate their data in a methodical manner and use the records, facts and figures to generate quality intelligent information. Information generated is knowledge which is used in making timely decisions. There is an increase in the interest of MIS in the Agro-Industry, especially the livestock production and animal products processing operations. MIS projects in the Livestock Industry are quite different from each other from the technology standpoint, but we can reach similar conclusions about the factors that enable each of them to succeed in the implementation process and in putting the systems into operation. This paper seeks to appraise the importance of MIS in the Livestock Industry by elucidating real factors of success and failure that developing nations needs to pay attention to if livestock is to play a bigger role in economic development. The paper recognizes that some key factors in the success and failure of any implementation MIS project have hinges more on telecommunications infrastructure. This article therefore supports the idea that it is important to have the right policies, then infrastructure and have clear processes in place for data collection, processing and generation of quality information.

Introduction

Management Information Systems in the livestock industry means the employment of a record systems that create databases from which information can be retrieved, processed, batch or real time, to generate quality information that is usable in decision making. MIS in the livestock system can be applied in the following areas (departments):

1. Animal production and management (milk, meat, eggs, wool),
2. Nutrition (Feed analysis, fabrication, and feeding),
3. Animal Herd Health (epidemiology, prevention and treatment),
4. Breeding and genetics (artificial insemination, multiple ovulation and embryo transfer, gene banks),
5. Animal products processing and
6. Marketing (on the hoof:- electronic auction system), on the hook (meat grading schemes).

Many experts have talked of sustainable livestock production, integrated crop-livestock systems and organic livestock farming methods for many years and yet their real impact is very small especially in the developed world. Information is power, they say but are we distributing it enough and using it to make decisions! If developing countries can take the known, good MIS technologies to another level of magnitude then they can contribute significantly to the supply of 300 million tones of meat (by the year 2020) from

non-industrial systems that the world so need [1]. It is a major challenge that relies on the success or failure of the promotion, implementation, and sustenance of an MIS in each country and within regional groupings like Southern African Development Community (SADC), Common Market for East and Southern Africa (COMESA), Economic Community of West African States (ECOWAS), to mention a few.

Critical Success or failure factors of a Livestock MIS

MIS Livestock Policy

The first factor is the presence of a policy statement within countries spelling out the importance hence the need for the implementation of a Livestock centered MIS. Policies with set milestones are critical but there must be a system in place to monitor and evaluate progress, benefits, difficulties, experiences, effectiveness and efficiency of the system. This will allow either change of course or fine tuning where necessary. At the policy, producer and processor level, the provision of safe and wholesome animal products as human food must be recognized as the cornerstone to sustainable livestock and product development. At the end of the day, policy decisions must be made. At least these policies should remove the obstacles for small producers and, in some cases, restrain the big companies. Policies directly promoting MIS in the livestock industry in the developing countries are not explicitly pronounced. One can only make inferences from the national livestock strategies which consistently aim to commercialize animal production. Commercialization of livestock production succeeds if relevant and current information is used in decision making. For the developing countries, this can only be possible through facilitation backed by specific policy statement that encourages a deliberate attempt to promote distribution and hence intelligent use of data and information.

The central role of Telecommunications Infrastructure

One problem that directly hinders success or cause the failure of an MIS in the livestock sector is infrastructure. This is in terms of telecommunication infrastructure to enable transfer of data and information via telephones (fixed and or mobile), internet or VOIP. How can small producers (who are usually the ones applying the more sustainable technologies and integration of farming activities) have access to the livestock information market? The answer probably lies in governments developing elaborate communications technology infrastructure. A case in point is the NEPAD initiative of laying an optical fiber from Cape to Cairo by committing member countries to an ICT protocol. This will allow livestock farmers to participate in telemarketing, and telecommuting. A case in point is the mobile phone, being used as a village communication tool in Bangladesh (Grameen Bank) and Venezuela, which has had a positive impact on marketing from small producers [2].

A functioning telecommunications infrastructure allows all classes of livestock farmers (smallholder farmers, large scale commercial farmers, and specialist animal breeders), agro dealers, middle men, veterinarians and other animal science practitioners to access information about, animal breeds, feeds, veterinary drugs and medicines. There is also a need and demand for low cost and simple processing technologies for livestock products whose supply and demand can be assessed and accessed for the benefit of livestock resource development.

In many situations, the middle-men or traders take the lion's share of the profit in the livestock industry because they have the means, the knowledge and the access to the consumer market. Emphasis needs to be given to the development of an inclusive Livestock MIS that collects data and feed back information to the small-scale and village-level livestock cooperatives, livestock products processors, including information on equipment, training, distributions network and marketing channels.

Availability of information on suitable equipment, which can make small-scale processing competitive, can easily make livestock development advance significantly. There are examples on the African continent for example there is a successful project in Uganda to develop value-added meat products by village women and young people. An information system has been put in place to equip the same group of farmers, promoting a method of milk preservation (the Lactoperoxidase System or LPS) which keeps milk fresh for 7-8 hours longer [3]. The widespread adoption of the low-cost system stems from a sustained inflow of technical information. This means increased income for farmers who rely on livestock, enabling them to sell their fresh milk beyond the village and supply the growing urban centers. The farmers use the information about supply from primary production levels as well as demand trends from the market.

Sustained communication infrastructure has recently helped to prop up activities in meat preservation in Ghana [4]. This has resulted in the development of highly effective solar meat drying equipment.

Fulfillment of consumer demand is not only quantitative but also qualitative. Livestock producers need timely systematic information for example that livestock products must be produced from disease-free animals and under hygienic conditions. They must have readily available information about the question on the use of additives that 'improve' production but are unacceptable to the consumer if they are to create opportunities for export markets.

The best way to stimulate livestock production is to allow producers easy access to information on good return for their products. This provides real incentive for livestock production at farm level as farmers can make correct decisions on adjusting the scale of their operations.

There is progress in some places, like Bangladesh where women farmers have been assisted with both microcredit and training. There has also been effective training of technicians in farm and village work and information technologies. A Livestock MIS that combine new communications methods and greater focus on village-level action seems to be the only way to expand and sustain livestock production.

There is a global 'knowledge base' that FAO is developing (through its World Agricultural Information Centre (WAICENT)) which can provide solutions to production, health and processing so as to enable small producers worldwide to meet food security challenges of the future [5]. This must get through the system, via the technicians, to the village level and telecommunications infrastructure holds the key to the success or failure of these endeavors.

As production and consumption of meat and other animal products increase, the problems will become even more pressing and acute making the need for improved

communications infrastructure more critical. Individual livestock farmers and livestock cooperatives can not develop this kind of infrastructure due to the huge capital outlay needed. As a result it is up the national governments to create an enabling environment by making necessary investments in telecommunications now not later.

Examples of Information Communication Technologies (ICT) that have a potential for working under Developing Country constraints

In the crop agricultural industry, there has been adoption of commodity indexing system in countries like South Africa through Agricultural Marketing authorities. This information exchange system captures data on supply, demand and price trends. It has helped small holder farmers to take part in formal markets to their advantage. If such a system is put in place in the livestock sector, it will make a big difference in allowing farmers to participate in competitive market. The advantage is significant as the cattle farmers can be able to cut off middlemen who are currently exploiting them.

Another tool that has been adopted completely by commercial farmers in South Africa, Zimbabwe, Botswana, Namibia and Kenya is the LIVESTOCK IDENTIFICATION SCHEME. In this scheme, only beef animals that are registered by a national trust qualify for exports to European markets. The scheme captures a lot of data from producers and feed back useful information which help the farmers to improve their production levels. Wide adoption of such a scheme by smallholder farmers who have the majority of beef animals can place them into the main stream of their national economies and contribute meaningfully to wealth creation.

Dairy herd management data capture systems used in the developed world presents an opportunity to improve milk production so as to match demand and supply. The scheme exists only for big commercial milk producers in some developing countries and it is possible to extend this to small scale dairy producers.

Computer aided feed formulation and computer based record keeping at the production level has a potential of modernizing livestock production in the developing countries. Use of correct and accurate data is critical for decision making. Individual farmers may find these packages expensive, but there is an opportunity for government extension staff to do it on the behalf of the farmers. Most extension staff in the developing countries are computer literate and they can easily be organized into information agents.

Requirements for successful Livestock MIS

Empowered and enabled livestock-keepers

In order to achieve buy-in by the users of information of a Livestock MIS and achieve pro-poor economic growth, it is imperative that resource-poor livestock-keepers are involved right from the start of any livestock MIS intervention. Large scale farmers operate from a business stand point and usually buy-in easily due to the desire to remain profitable. But for the majority of the smallholder livestock farmers, resources must be allocated to identifying them, targeting them and planning, with them, appropriate interventions. There is no MIS system that is applicable to all levels of information consumers. So targeting and wealth ranking is always necessary so that relevant information channeling creates effective communication. In each country or regional

grouping, there is need to first obtain information on where resource poor livestock-keepers live, i.e. at province and district level [6], and on their systems of production. This information helps direct investment into the most appropriate geographical locations. Care should be taken in the process so that the local elite do not bias decisions at the expense of poorer farmers.

The expectations are that a local Livestock MIS facilitates all the activities in livestock farming e.g. herd management, feed management, inventory management, herd breeding and genetics, interaction with centralized feed centers, pasture management and fattening feedlots. A database is created that would provide the national herd management services with information on management of each herd as a profit center, cost accounting and economic analysis and the economic assessment of the animal husbandry aspects, knowledge mining from the data sets, logical deviations, algorithms,, reports, knowledge feedback from researchers and scientists. This system also allows for connectivity to all providers and recipients of services, automatic report generation and dissemination.

Participatory Livestock MIS planning and management

The development of a Livestock MIS must make it clear to all stakeholders and address the fundamental questions about the situation to be improved and what constitutes an improvement. It may be necessary that the existing situation is assessed by livestock-keepers themselves and that they actively participate in defining their problems and developing realistic solutions [7]. For long-term sustainability of any Livestock MIS, stakeholders must see clearly into the future, what roles each one of them individually or collectively will perform, as well as the roles of government and the private sector. This is critical for the farmers to understand because they will sustain the Livestock MIS with relevant data on say livestock numbers, breeds and breed structure, disease morbidity, take off rate etc. which the government and private sector will use to make decisions that benefits all.

Role and Potential of Farmer Organizations and Groups

It has been proved the world over that farmers acting as a group are stronger than when they act as individuals. Groups, commodity associations and cooperatives can serve a variety of purposes including, mutual support and encouragement through comfort in numbers and sharing of experiences and novel ideas, provision of non-formal micro-finance (through savings and credit schemes), animal breeding services (e.g. sire services, Artificial Insemination (AI), registration, livestock identification schemes), veterinary services (e.g. vaccinations, clinical procedures, diagnostic services, herd health management calendars), feed and forage analysis, feed formulation, cost-effective input supply through economies of scale (e.g. bulk procurement of feed, drugs, forage planting material), technical support and training, product collection, bulking and processing (e.g. bulk milk collection), improve access to markets, increase bargaining power and effective lobbying. So, how organized the farmers and animal products processors are, has a huge bearing on the success or failure of a Livestock MIS. For example, the Israel Cattle Breeders Association (ICBA) represents all dairy cattle farmers in Israel. For the past 8 decades the organization has been the sole representative of all milk producers in the country, taking care of all their professional needs and sustaining a vibrant and modern industry [8]. The organization supplies essential assistance to its members and the satellite organizations connected (through a Livestock MIS) to the industry. As a representative

organization the ICBA is involved in national milk pricing and milk production quota policy, milk quality assurance, information dissemination, bull certification and more [8]. This Dairy Management Information System (MIS) was developed by the Israeli Cattle Breeders Association (ICBA) to oversee the professional management of the National Dairy Herd. Its main function is to give the individual and national herd managers updated relevant and quality information regarding all aspects of dairy activity, addressing all aspects of dairy farming. This Livestock MIS has been successful because it represents a concept of optimizing each individual cow's performance as the basis for dairy management rather than using "averages". This concept in turn is aggregated to practicing dairy herd management at the local, regional and national levels. Infrastructure on Information and Communication Technologies (ICT) are critical success factors enabling implementation and sustenance of this concept.

Marketing Livestock MIS

It is important to end this paper by reviewing success factors linked to the process of innovation especially in the introduction of an electronic auction system for livestock. While this might suit big livestock producers, small producers are part of it as they often constitute the catchment area of most animals that are taken for fattening. The growth and development of the system takes a number of years to implement and requires substantial seed capital. Models of the innovation process implemented in the developed world provide useful and powerful frameworks for the developing countries to emulate were possible, resources and technical expertise allowing. The growth of 'trust' in the system (where it has been implemented) was found to be an important additional factor in determining successful innovation [9]. Since electronic auctioning is high-tech, appropriateness, defined in terms of the ability of the system to benefit the stakeholders, is used to determine the competitive advantage over simpler marketing channels and hence success. The gains accrued to stakeholders and the long-term changes in the appropriateness have been found elsewhere to determine the long-run sustainability of this kind of Livestock MIS.

Conclusion

The main support that the Livestock MIS provides is data updating and refinement – mainly correcting current management programming issues. This exposes the users of information so generated by the system to new management applications and supports the integration of the various animal husbandry systems involved in all aspects of the livestock industry. The critical point is that for the Livestock MIS to succeed, it must be adopted, creating in the process, capabilities among information users so that they make decisions that are compatible with the expected animal husbandry and market developments over time. Apart from telecommunication infrastructure, it is necessary to emphasize the importance of good leadership and putting in place enabling policies. It is also vital to recognize the importance of stakeholder involvement to insure that participants will make a good transition from implementation to maintenance. Livestock businesses are spread out in different regions within a country and it is always important for constant contact hence networking technologies are a big challenge to the success of Livestock MIS.

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A Model for Turning African Stories into Creative Content

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Key Words: New Media, Creative Economy, Intellectual Property, Crowd-Sourcing

Abstract
Producers and consumers interested in content reflecting various manifestations of the African world face a problem. For the producers, the pain is finding an economically sustainable way to create work, such as music and film that present various narratives of the global African community. The hurdles of traditional production, marketing and distribution systems often prevent good storytellers from bringing their visions to a wide audience. If their stories do reach a wide audience, it is usually at a severe trade-off for equity in the ownership of the story. Thus, the content creator must either sell to a small audience and risk not recouping their expense or sell to larger audiences and never receive a sustainable share of the income. In either scenario the storyteller is left without the financial resources which could have later assisted them to become financially independent.
This paper evaluates examples of new technologies that have created an opportunity for low cost high quality content production. Specifically, it examines strategies for organizing the appropriate human and technical resources to leverage present and emerging Information and Communication Technology (ICT) infrastructure to foster new ventures that commercialize Africa's abundant stories. The paper then addresses, from a market perspective, the technological resources currently available, or within reach, of most African countries to begin creating, packaging and exporting its stories. This new export is sustainable and can lead to both job creation and economic growth.

Introduction

The African storytelling tradition and its many forms of artistic expression have been a critical aspect of communication within the African tradition. From the composition of music to the performance of dances, African artistic expression conveys messages of identity, history and shared value systems that have sustained cultures throughout dislocation and "development". Professor Harold Scheub once wrote "The African oral tradition distills the essences of human experiences, shaping them into [re]memorable, readily retrievable images of broad applicability with an extraordinary potential for eliciting emotional response."[10] People continue to seek out and connect with African cultural expression. In many cases producers as well as consumers must often overcome resource and product scarcity along with higher costs in order to fulfill that need. This is the case due to both micro and macro issues with regard to content creation, distribution and marketing on the continent and abroad. The emergence and growth of ICT on the continent[11] and abroad has reduced some of these obstacles. The creation process is now cheaper for producers who have improved access to global

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audiences[12].

There are other resources that discuss policy issues in depth, namely the recently published UN Report on the Creative Economy (UNRCE). This paper however, focuses on the market and builds a case for a new digital media marketplace. A marketplace that taps into the latent demand and nascent commercial potential of content built on the multitude of identities and stories of the African experience. Further, differing from the UNRCE that uses the linear United Nation's(UN) classification[13] of creative industries, we propose a model that allows storytellers to convert the vast stores of cultural IP (Intellectual Property) into what the UN classifies as functional creations.

Taking into account the various strata of African societies, the writers considered both those with and without the means of organizing the necessary resources for low cost content creation. Given the level of constraints faced by the vast majority of African storytellers a market intermediary is required to:

1. Define a set of resource independent guidelines that convert ideas into fundable projects.
2. Provide an open marketplace where micro-producer and niche content consumer can exchange value.
3. Provide a compendium of resources that assist in the above two items and can be accessed at little or no cost.

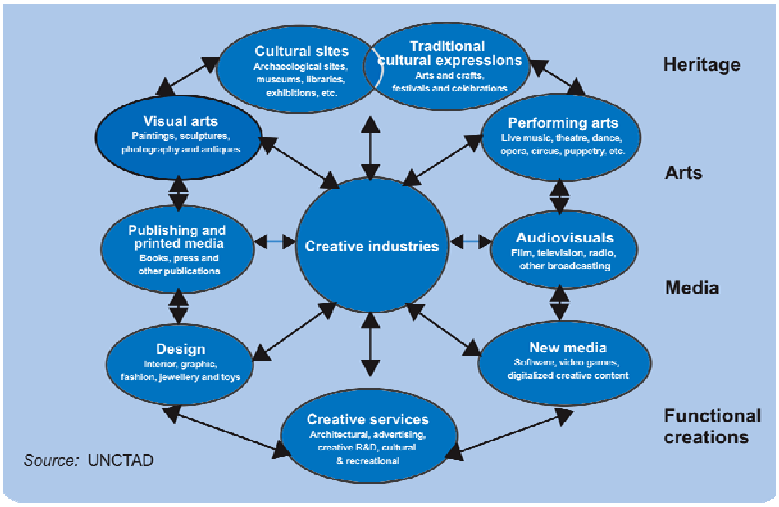
Examples of Culturally Compelling Content

In this section we outline a number of examples of culturally compelling content that can be mined for heuristics around building niche content accessible to mass audiences. Recurring themes in the content offerings we examined where not related to subjective visions of quality or technical sophistication but rather identity and

[12] UNCTAD E-Commerce and Development Report 2004 has an excellent discussion of ICT as a growth engine for developing countries (see chapter 3, "Creative industries and digital and Internet technologies: The case of music", pp. 61-94). The report is available at: http://www.unctad.org/ecommerce/ecommerce_en/edr04_en.htm.

[13] UNCTAD and the UNDP Special Unit for South-South Cooperation. The Challenge of Assessing the Creative Economy Towards Informed Policy-making, UN Creative Economy Report 2008, page 38. 2008.

Figure 1.3 UNCTAD classification of creative industries



accessibility.

Identity

Identity in this context is used as a showcasing of ones self, or a reflecting of ones self. The success of Bollywood and Nollywood film industries reflect this in today's media landscape. They have shown that local and Diaspora audiences, if given the choice, will consume media products that are reflective of their cultural identity. Bollywood, currently the largest film making industry in the world, has not only been able to win over audiences in South Asia but also reaches the South Asian Diaspora worldwide and attracts many non-Asians. The same can be said about Nollywood's products that are now favorites of Nigerians and non-Nigerians across the African continent and in the Caribbean.

One of the ultimate examples of the concept of differentiation or content diversity is the Hip Hop musical form. An art form born in the New York in the early 70's[14], Hip Hop has provided a platform for young people worldwide to both represent their local conditions, styles, and realities through mc'ing, dancing, dj'ing, beat boxing and street art. Through the songs of Run-DMC, NAS, Notorious B.I.G. and many others, youth across the world learned about and sometimes emulated life in the Queensbridge and Brooklyn boroughs of New York City. Despite its current image in certain quarters, Hip-hop is one of the best modern examples of low-cost cultural content crossing boarders to globally showcase one's identity.

Differentiation/Diversity - Showcasing Individuality Amongst Global Identity

To stand out in a world where media and content crowd your television, computer, and personal space one has to be different. The continent has a natural advantage in gaining attention in the content marketplace with settings and sounds that are not widely known by global audiences. In addition, though certain plots and themes may be universal, the potency of the African storytelling tradition is as unique as it is old.

Diversity marks one cultural resource available to relate Africa's contemporary identity. This diversity is present on tribal and regional levels and is further extended by the divergent experiences of urban and rural populations. The urban/rural iteration of the identity provides an opportunity to access perspectives that incorporate traditional messages with modern realities. Bollywood's movies, though not always reflective of India's diverse population, has successfully crafted its unique music, dance, and visual preferences into cultural artifacts that have won over audiences Indian and Non-Indian alike. Delivering the storyline amongst traditional, modern and magical settings, as well as in a unique format, Bollywood created fans with an affinity for the individual movies, the culture, and the country.

Accessibility

Once the content has been identified, the next step is formatting the presentation such that it can be consumed by an audience. Accessibility thus means leveraging available digital storytelling methods and tools to reach the widest niche audience possible. This includes the language in which it is presented and the medium in which the audience receives the content.

Language - So We Speak Different Languages, Subtitle It!

[14] Chang, J. *Can't Stop Won't Stop: A History of the Hip-Hop Generation*, Macmillan. 2005.

Though most in the developing world have been consuming foreign language content without translation, through both American and South Asian Films, there has been increasing demand for local content that can be consumed by those who may not speak the foreign nor official state language. Today's technology allows for many ways of either dubbing or subtitling content to make it accessible to both audiences who speak different languages or are hearing impaired.

South Africa, with 11 official languages and a constitution that grants equal status to all of them, has shown how content can be brought to the masses by considering multi-lingual formatting[15]. On soap operas, the audience would find characters speaking IsiZulu, English and Afrikaans on the same show. Subtitles are then used to translate, for example, the IsiZulu and Afrikaans portion of the scripts into English. Thus, allowing for writers to create in the natural language of their imagination, yet still making it available to an English-speaking audience that could be in Ghana or Canada.

Medium – Content Designed for the Web and Mobile

ICT has revolutionized our world in terms of how and where we obtain our entertainment and content. Therefore, content producers must consider these new mechanisms in which the content is obtained. Further, great strides have been made by the availability of fiber-optic cables and the 3rdgeneration mobile networks that provide for streams of video, music and other rich media to be distributed and accessible.

Producers must now envisage these new tools when creating their work. ICT has empowered both the audience in terms of choice, and producers in terms of access. With animation, for example, one could envision a new cartoon based on a traditional story being leveraged to create a website for further engagement with the kids, ringtone, and picture to be downloaded onto one's mobile handset. Each of these extensions from the original intellectual property provides for additional revenue streams that were not present in the past.[16]

As we've seen crafting culturally compelling content from the range of stories available across the diverse regions of the African continent are possible by embracing what is different about each storyteller and understanding the specific attributes and opportunities present in the mediums used to get that content out to wider audience.

A Crowd-Powered Content Model

In his book *Wisdom of Crowds*, James Surowiecki[17] argues that a large grouping of diverse, independent and decentralized people will often make better predictions and decisions than experts. This insight is a central theme of many of the Web 2.0[18] technologies that have wreaked turmoil on the business model of the traditional media industries (music, film, television and newspapers). There are many crowd-powered services that aggregate the intellectual, economic or technological might of individuals to create new products, markets, services and innovations. Sites such as Kiva.org, Digg.com, Fundable.com and Spot.Us all utilize a crowd-powered model to

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[15] See http://www.southafrica.info/about/people/language.htm for further information

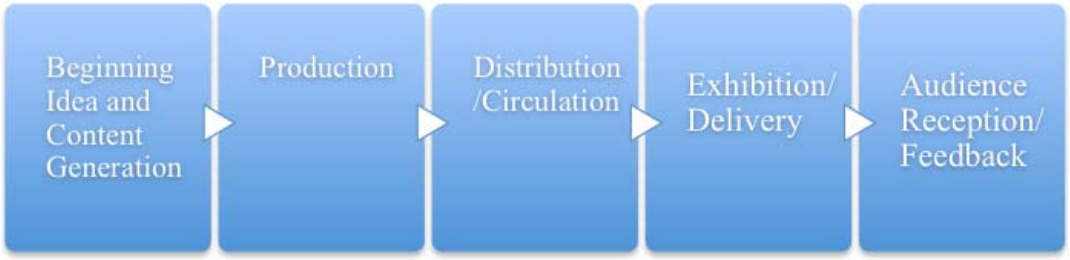
[16] See *http://www.cartoonnetworkshop.com/, http://mobile2.cartoonnetwork.com/*, and *http://www.aniboom.com/* for case example of animation IP leveraged for new revenue streams.

[17] Surowiecki J. The Wisdom of Crowds, New York Random House. 2004.

[18] Web 2.0 is an evolving term used to describe a suite of tools, sites and services built around the central tenants of openness, peering, sharing and global action. It does not refer to an existing technology or technical upgrade.

achieve their goals. It is this model that we propose to leverage in order to overcome the social, technological and policy impediments to a thriving digital media economy for African storytellers.

We have discussed elements of culturally compelling content and suggested a crowd-powered model to harness it but are confronted with the real barriers that are faced by today's average storyteller on the African continent. Going beyond qualitative attributes of what makes content "good" or viable, content creators need access to financing, production tools, and technical expertise. These are nearly impossible to obtain if one has little disposable income, technical infrastructure and education. Though significant improvements have been made, even basic access to the tools of ICT, Internet and mobile telephony, is still only found in urban centers and/or among those with higher than average incomes. Therefore, it is difficult for the average African storyteller or content producer to move from the idea generation stage to the final audience reception. So how does a twenty-year old Griot from a small village with little education and no access to modern tools communicate his story? The Community.



UN Creative Economy Report 2008,Pg. 102 [19]

A Brief Explanation of Kiva – Web 2.0's Online Lending Community

Kiva is an online micro-lending organization that has distributed close to $40,000,000 dollars in 42 different countries through 88 "Field Partners"[20]. It was founded in 2005 and works through NGO partnerships providing micro-loans to entrepreneurs in various countries. The loans carry no interest rate and are not tax-deductible under the US tax code, despite Kiva's non-profit status.

Kiva partners with in-country NGO's, who are then responsible for management of the relationship with the micro-loan candidates (entrepreneurs). These NGO's upload information about various entrepreneurs and the project/business endeavor for which they seek funding to the Kiva website. People from around the world (the audience) view those stories and select entrepreneurs and business ventures to whom they would like to lend a minimum of $25 USD. Once the project is fully funded the monies are dispersed to the NGO, which then disperses it to the entrepreneur. The NGO also provides periodic updates to the site from the entrepreneur on their progress. These updates might include personal notes, photographs and business progress reports, Kiva requires that partners have and be able to use digital cameras and daily email.

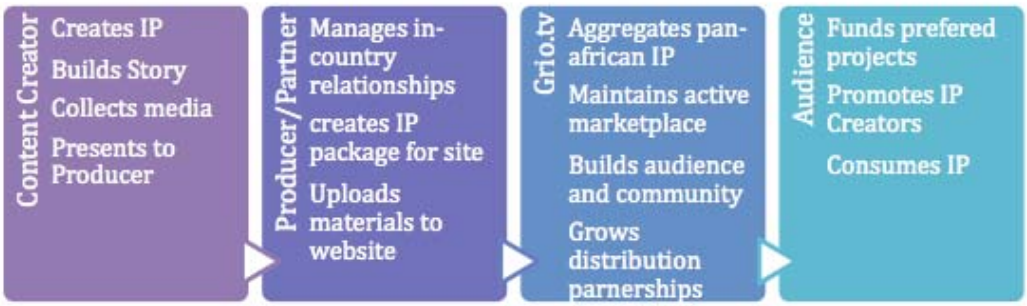
[19] *The Challenge of Assessing the Creative Economy towards Informed Policy-making*, UN Creative Economy Report 2008, © United Nations 2008

[20] See http://www.kivafriends.org/index.php?action=graphs for further information

Grio.tv: The Kiva model for African Story-tellers

Kiva has demonstrated that a crowd-sourcing model can work to provide large scale micro-credit opportunities to the worlds poor, quickly and efficiently. Drawing on lessons from Kiva, Cambrian House and Zeros2Heros [21] it is possible to replicate and adapt this model for the needs and realities of the African storyteller.

The Grio.tv system would have four core stakeholders whose interest must be aligned. These are the content creators, in-country partners, Grio.tv and the audience.



The Content Creators

The content creators face a slew of challenges both environmental as well as technological in getting access to the tools of content production, the audience which might want that content and the resources to fund its development. Using the Grio.tv model a storyteller (content creator) would be able to work with an in-country partner to make their content idea available to the audience on Grio.tv for funding. The storyteller could generate a base line level of information about the project using Grio.tv content guidelines and any available media (from raw music to film/ story synopsis) to describe their project idea and what might make it both viable and compelling to an audience.

The creator would provide their plans for content to their local partner organization who would generate the needed online information, thus expanding the reach of the service well outside of the urban centers and financial elite. Much of this information will be biographical (personal story, content background etc…) and the balance would be any media available. This model would open the realm of available content to include anyone with a creative bent and a product idea, from urban rappers and Zouk artists to drumming groups and village folklorists.

The content creators would retain their IP rights to their content whether the project is fully funded by the audience or not. Their goal and motivation is to have their project seen, voted on and potentially funded by the crowd. Overtime, a modern Griot who was initiated to new media tools by Grio.tv would later become a resource themselves,

[21] Cambrian House is a web-based community owned business that combined crowdsourcing and peer production to find and select viable software development ideas. http://www.cambrianhouse.com/ .Zero2Hero is a Canadian website which allows users to submit and vote on comic book ideas for publication in Web, print and film. http://www.zeros2heroes.com/

aiding other creators. If their work has become commercially successful, there will be yet another avenue, financial, for them to promote newer storytellers.

The In-Country Partner

These organizations might be local NGO's, public, cultural or academic institutions or private enterprises who wish to assist in the creation and distribution of new African centered content. Their input is on a frontline basis, managing the initial relationship with creator, ensuring fulfillment of basic requirement, media capture (images, audio, video). They will also conduct and facilitate training sessions to solicit submissions and increase initial quality standards, a known issue with many mass collaboration projects.

Aside from altruistic aims, the in-country partner will optimally have a commercial interest in growing the IP market in their local communities. These commercial interests would tie the success of the creator directly to improved income for any commercial partners. In addition, the platform would allow for feedback and comments on the service level of the partner by the creator.

While content partners have no IP rights in the product they benefit from the relationship development and the insight into the commercial viability of content in their local market. It is also very likely that as commercially viable content becomes apparent through crowd interaction that the management of IP and exploitation rights across borders is something that will be required.

The Grio.tv Site

The site is the global aggregator of the content from African storytellers across media forms. It serves as an intermediary between the unwired, unbanked creative masses and the audience seeking their stories. Grio.tv will initially provide two basic types of functionality:

Peering – this suite of functionality allows content creators to display projects, receive feedback on projects ideas, in the form of offers of support, votes and funds.

Marketplace – this suite of tools allows for content creators and content consumers to establish rules to exchange value for specific digital media products.

The site will provide a trusted partner for the commercial transactions and micro-financing aggregation. It will also handle third-party commercial partnership for services like iTunes, Amazon Unbox and Jaman. While initially there is unlikely to be either the demand or capabilities to handle international distribution agreements the service could be built with an eye towards helping to manage that workflow. Grio.tv is positioned as the messaging hub for African storytellers, much like Kiva which is, in many circles, synonymous with online micro-lending. Like Kiva, Grio.tv can become self-sustaining through voluntary and transaction related fees.

The Audience

The audience drives the service. It is through the demand based model of peer review and peer funding that any of the content creators will realize a financial incentive to continue to participate and expand the service. Audience members will select the stories/content that will be further developed. As in the Zero2Hero or Cambrian House models, Grio.tv has a two-tiered system where ideas/projects are both voted on to filter out the most viable for funding and then presented for funding. The audience can have either a fixed or variable time in which to fund projects (determined by the content

creator) and projects not fully funded in given time frame are returned for reworking and the moneys dispersed back to contributors.

Conclusion

In our globalized world where someone in Lilongwe, Malawi wakes up to the weather forecast for Leeds, England, even local content is in competition with the offerings from global content providers. Despite the asymmetry in access to tools and resources that larger more experienced global content providers have, The Bollywood, and more-so the Nollywood movie industry, shows us that there is a market for culturally compelling content that delivers and makes accessible different identities of the world.

In Africa's context, a great many of the creators are limited not by content ideas or sources, but by tools for content production, finance, and distribution. The creator is not only limited in reaching a broad local audience, but also potential audience members in the international market. Therefore, a sustainable Web 2.0 approach is suggested through involving the creator, an in-country partner, the Grio.tv operation, and the audience that allows demand for African oriented content to drive the process and supplement weak points in the value chain for producing more content reflective of the African tradition.

REFERENCES EMBEDDED AT END OF PAGE IN THIS PAPER.

Effect of Feeding *Moringa Oleifera* Leaf Meal on the Growth Performance of *Oreochromis Niloticus* Fry

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Key words: *Moringa oleifera*, heat treatment, fishmeal replacement, growth performance.

Abstract

The study was conducted to determine the suitability of heat-treated M. oleifera leaves as a protein source for Oreochromis niloticus fry. Four experimental diets were used; Diet A had 5 % boiled moringa and 95 % frymeal; Diet B contained 10 % boiled moringa and 90 % fry meal; Diet C had 5 % steamed moringa and 95 % frymeal and Diet D contained 10 % steamed moringa and 90 % frymeal. Diet E was the control diet containing fishmeal. A standard 24-day fry feeding trial was carried out in 10 fry tanks with each tank stocked with 15 000 fry. The growth rate, feed conversion ration and protein efficiency ratio of fry fed the five diets were similar. The body weight gain ranged from 0.012 to 0.014 g/d for fry fed boiled moringa and the control diets. Fry fed diets C, D and E had higher FCR values of 1.1, 1.1 and 1.0, respectively, compared to those on diets A and B (1.2 and 1.3, respectively). Fry fed steamed diets had better growth performance than those on boiled diets although the differences were not significant. It is concluded that steam-heated moringa leaf meal can be used to substitute 10 % of dietary protein in Nile tilapia fry without significant reduction in growth performance.

INTRODUCTION

The Nile tilapia (*Oreochromis niloticus*) was one of the first fish species cultured and is still the most widely cultured species of tilapia in Africa. Positive aquacultural characteristics of tilapia species include their tolerance to poor water quality and the fact that they eat a wide range of natural food. Of the total world production of fish, which amounted to 112.30 million tonnes in 1995, 18.97 % came from the aquaculture sector while the rest came from the captured fishery [1]. Most of the increase in fish production is expected to come from aquaculture, which is currently the fastest growing food production sector of the world [2].

In aquaculture systems the increasing price of feed is considered one of the most important factors that limit profitability, caused mainly by the cost of fishmeal used as a primary source of protein [3; 4]. As a result, there is a need to search for alternative protein sources for aquaculture diets. The high cost and fluctuating quality of imported fish meal have led to the need to identify alternative protein sources for use in fish feed formulations [5]. The identification and utilization of non-conventional and lesser–utilized plant protein sources to replace fishmeal, either partially or totally in practical fry diets has been an area of focus in aquaculture nutrition [6]. Earlier studies have shown that, *Moringa oleifera* is a promising protein source for inclusion in fish diets at low levels [7]. Plant proteins are cheap and readily available, but have some antinutritional factors that limit their use as aquaculture feeds. These limitations could be successfully overcome by

different methods of heat treatment [5; 8]. The objective of the study was to determine the effects of heat-treated moringa supplemented diets on the growth performance of the Nile tilapia (*Oreochromis niloticus*) fry.

MATERIALS AND METHODS

Experimental Animals

O. niloticus fry with average body weight (ABW) of 0.01 g were taken from Lake Harvest hatchery. The collection and transportation of the fry was done as recommended [9]. They were taken to the experimental tanks in the early hours of the day from 0500 to 0700 hr.

Fry tanks and fry stocking

A total of ten fry tanks were used and each treatment diet was randomly allocated to two fry tanks. Water in the fry tanks was continuously exchanged throughout the experiment that lasted for 24 days. A compressor was used to supply oxygen into fry tanks via air stones and this ensured adequate dissolved oxygen to be above 80 % saturation. Each individual experimental tank with the volume of 3.16 m^3 was stocked with 15 000 fry. The fry were weighed at the beginning and progressively at weekly intervals. No feed was given on the weighing days to prevent stress.

Processing of moringa leaves and diet preparation

M. olifera leaves were taken from Lake Harvest forestry unit and were dried under shed. After drying, some of the leaves were either heat treated by boiling or steam heating at a temperature of between 60 ˚C – 80 ˚C for 15 minutes. Steam heating and boiling was meant to minimize or deactivate the antinutritive factors such as tannins, phytic acid and saponins that inhibit the digestion of plant proteins in Nile Tilapia. After the heat treatments the leaves were allowed to dry under shed before being milled through a 0.01 mm screen.

Four isonitrogenous diets were formulated to have 450 g/kg DM of crude protein (CP). Diets A and C were composed of 5 % boiled and 5 % steamed moringa leaves, respectively, whilst 95 % by mass was fry meal. Diets B and D were composed of 10 % boiled and 10 % steamed moringa leaf meals, respectively, whilst 90 % by mass was the fry meal. The standard fry meal, Diet E, which contained no moringa leaf meal, served as a control and had fishmeal as a protein source.

Feeding

The fry were fed a daily ration at a rate of 15 % of bodyweight. The daily ration was divided into eight feedings per day at an hourly interval from 0800 hours to 1500 hours.

Data collection

The fry in each tank were weighed weekly in order to assess their growth performance. A Tefal electronic digital scale was used to measure weights of fry per week. The fish fry were weighed and returned into their respective fry tanks. No feed was

offered during sampling days. Salt was added to fry tanks at a rate of 5 mg/l after sampling to prevent stress, which would have caused high mortalities.

Growth performance were analyzed in terms of total body weight gain (BWG), average daily gain (ADG), feed offered (FO), feed conversion ratio (FCR), protein efficiency ratio (PER) and survival percentages. The following formulae as described [10]:
BWG (g) = Final body weight – Initial body weight
ADG (g/d) = BWG/21 days
FO = Total dry feed offered (g)
FCR = Total dry feed offered (g)/ Live body weight gain (g)
PER = Wet body weight gain (g)/Crude protein fed (g)

Laboratory analysis

The diets were used were analyzed for dry matter (DM), crude protein (CP), crude fibre (CF), Ash, Ca, P and energy content using the standard procedures [11].

Statistical analysis

The growth performance was analysed using the one-way analysis of variance (ANOVA) using Minitab Version 12.1.

RESULTS

Chemical composition of diets

The chemical composition of the diets is presented in Table 1. The diets had CP content of that ranged from 46.4 to 46.9 % CP. The crude fibre of the diets that contained moringa leaves was high, ranging from 2.95 to 4.17 % as compared to that of fry meal of 1.97 %. The ash content of diet A and C was higher as compared with other diets as shown in Table 1. The calcium and phosphorus concentration in the diets was not different. The energy content of the five diets ranged from 8.2 to 12.5MJ/kg.

Table 1: Proximate composition of experimental diets (% on DM basis)

Constituent	[1]Diet A	Diet B	Diet C	Diet D	Diet E
Dry matter	87.9	89.9	88.1	89.6	90.00
Crude protein	46.5	46.4	46.7	46.4	46.9
Crude fibre	3.44	4.17	2.95	3.32	1.97
Ash content	17.27	13.37	18.57	11.03	11.12
Calcium	2.42	2.68	2.48	2.49	2.41
Phosphorus	1.42	1.5	1.76	1.14	1.07
M.E (MJ/Kg)	10.7	9.8	8.2	12.3	12.5

[1]Diet A contains 5% boiled moringa leaves and 95% fry meal
Diet B contains 10% boiled moringa leaves and 90% fry meal
Diet C contains 5% steamed moringa leaves and 95% fry meal
Diet D contains 10% steamed moringa leaves and 90% fry meal
Diet E contains fry meal only

Feed intake, growth performance and feed utilization

The growth performance and feed utilization in terms of body weight gain (BWG), average daily gain (ADG), feed conversion ratio (FCR) and protein efficiency ratio (PER) are presented in Table 2. There was no rejection of feed until the end of the experiment and the acceptability of the diets was similar. No mortality or any signs of disease were observed in any of the dietary groups during the study period.

There was no significant difference ($P > 0.05$) on total body weight gain and average daily gain of the fry fed the five diets. Fry on diets C, D and E produced the best FCR and PER as compared to all other diets, but this did not differ significantly ($P > 0.05$). In general, among the five diets, fry fed diets containing steamed moringa leaves showed better growth performance in terms of final body weight, gain in body weight, FCR and PER than those fed boiled moringa leaves.

Table 2: Growth performance and nutrient utilization of tilapia fed different experimental diets.

Parameters	Diet A	Diet B	Diet C	Diet D	Diet E
IBW (g)	0.01	0.01	0.01	0.01	0.01
FBW (g)	0.261	0.253	0.279	0.288	0.298
BWG (g)	0.251	0.243	0.269	0.278	0.288
ADG (g/d)	0.012	0.012	0.013	0.013	0.014
FO (g)	3074	3074	3074	3074	3074
FCR	1.2	1.3	1.1	1.1	1.0
PER	1.8	1.7	1.9	2.0	2.0

IBW = initial body weight, FBW = final body weight, BWG = body weight gain, ADG = Average daily gain, FO = Feed offered, FCR = Feed conversion ration, PER = Protein efficiency ratio

DISCUSSION

The crude protein content of the experimental diets used in this study was within the range used in a previous study [3]. Protein is very important in fish growth and thus crucial ingredient in fish diets. A comparison between the amino acid composition of the raw and extracted moringa leaves to that of soybean revealed an almost identical composition of essential amino acids. The proximate analysis of the experimental diets showed that the crude protein was ranging from 45.4 % to 46.9 %. This range is within Lake Harvest requirements for the growth of fry which ranges from 45 % to 47 % CP.

The diet which contained 10% steamed moringa leaves (Diet D) showed the highest growth performance as compared to all other formulated diets, except for the fry meal (Control diet) although the differences were not statistically different. In terms of growth rate, fish which received the diet which contained 5 % steamed moringa (Diet C) had low growth rate as compared to diet D. This is contrary to the previous study [12] which showed that higher inclusion levels of moringa leaves in fish meal had an impact on

lowering the growth performance because of the presence of antinutrients such as phenols, tannins, phytates and saponins. This present study indicate that a 10 % inclusion level of moringa in fry meal yielded good growth performance possibly because the antinutritrients such as phenols, tannins, phytates and saponins were could have been inactivated by steam heating [13]. This could have resulted in the reduction of palatability-reducing factors.

Heat treatment methods employed might have increased the digestibility of proteins and other dietary components such as starch related compounds leading to high FCR and PER in fish fed with diets C and D. The reduction in antinutrients by processing techniques such as soaking, drying and heat treatment on plant-based fish ingredients have resulted in better palatability, increased feed digestibility and growth in fish [10; 13]. Generally steam heating reduces loss of soluble nutrients from moringa leaves since that process does not involve a solvent media to dissolve the nutrients. Apart from that, steaming employed in this study might have resulted in little protein being denaturated thus making more quality protein been made available in steamed leaves than boiled leaves.

Boiling breaks cell components like cell walls and cell membranes of plants cells. Some of the nutrients within the cells of boiled moringa leaves were lost to boiling water during the heat treatment process. The soluble cell components such as soluble proteins and glucose molecules might have dissolved in water during boiling. This could have caused the reduction of essential amino acids (EAA) in diet A and diet B. Boiling might have caused the inactivation of antinutrients such as saponins, phytates, phenols and tannins that bind some quality proteins and inhibit digestion in fish. Apart from breaking the cell components; boiling induces the precipitation of polyphenolic and other phytochemical compounds which might have depressed the growth of fish receiving feed with boiled moringa leaves. Boiling also induces the formation of colloidal starches as a result this reduces the amount of available glycoproteins to fish [13].

Boiling and steaming showed no significant effect on the crude fibre content but it was within Lake Harvest requirements for the growth of fish; except for diet B that had a higher crude fibre content of 4.17 %. This might have contributed to the lowest growth rate of fish fed with diet B. It has been shown that fibre can bind nutrients like fats, proteins and essential minerals, and reduce their bioavailability [10; 12]. Dietary fibres apparently influence the movement of nutrients along the gastrointestinal tract and significantly affect nutrient absorption.

CONCLUSION

The results of this study indicate that up to 10% inclusion of steam heated moringa leaves can be recommended for *Nile tilapia*. In view of the favorable amino acid profile of moringa leaves and their wide and ready availability throughout the tropics and subtropics, moringa can be considered as a potential feed component with high nutritive value for *Nile tilapia*.

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Milk Production from Lactating Holstein Cows Fed Cereal-Tree Forage Legume Silages

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Key words: Silage, *Acacia boliviana, Leucaena leucocephala***,** Milk yield, Milk composition.

Abstract

Trees are important throughout the world because of the services and products they provide to humankind. Use of tree leaf meals in feeding livestock adds value to trees at household level. The objective of this study was to assess the nutritive value of A. boliviana and L. leucocephala-maize silages as partial substitutes for commercial dairy meal in lactating Holstein dairy cows. The tree forage legumes were ensiled together with maize in a 50:50 ratio (w/w). The ensilage was carried out in plastic bags for seven weeks. The crude protein content of the maize-legume silages ranged from 176 to 209 g/kg DM and was greater than that of maize silage, 71 g/kg DM. The neutral detergent fibre content of the silages was not significantly different with values of 608, 658 and 603 g/kg DM for bagged maize, maize-leucaena and maize-acacia silages, respectively. The modified acid detergent fibre content of maize-leucaena silage of 357 g/kg DM was higher compared to that of bagged maize, 304 g/kg DM, and maize-acacia, 319 g/kg DM silages which themselves did not differ. The milk yield was higher in cows fed mixed maize-acacia, 15.7 kg/d, and maize silages, 17.0 kg/d, compared to animals on mixed maize-leucaena silage, 14.1 kg/d. However the milk composition in terms of butterfat, lactose, protein and total solids was not different across the treatment diets. It is concluded that mixed silages can be used to partially replace commercial feed supplements without loss in milk yield or quality.

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INTRODUCTION

In the tropics and sub-tropics there is a general shortage of natural grazing during the dry season resulting in high use of commercial feeds in livestock production during this period. The lack of all year round supply of high quality on-farm forages is one of the major limiting factors to improved milk yield in the tropics [1]. In the smallholder dairy sector of Zimbabwe commercial feeds account for over 60 % of the total production costs [2]. In this regard dairy producers would benefit if the amounts of commercial feeds were reduced in their feeding systems without a decline in yield and quality of milk.

Traditionally silage has been made from cereals and grasses whilst legume silages have some potential [3]. The cereal silages are rich in energy but low in protein whilst the converse is true for legume silages [4]. The protein content of the maize silage can be improved significantly by ensiling it together with tree forage legumes [5]. The objective of this study was to assess the nutritive value of *A. boliviana* and *L. leucocephala*-maize silages as partial substitutes for commercial dairy meal in lactating Holstein dairy cows.

MATERIALS AND METHODS

Crops and harvesting

The forage-tree legumes (FTLs) used in this experiment were *Acacia boliviana* (Acacia) and *Leucaena leucocephala* (Leucaena) and the material used came from coppices of the 1999 harvests. The coppices were cut 0.7 m high when more than 25 % of the coppices were at flowering stage. The leaves were stripped by hand from the branches and twigs. A long season white maize variety, SC709, was used. The crop was managed in line with a commercial maize crop in terms of fertilizer application and weeding as well as pest and disease control. The maize was harvested a medium-dough stage. Hand harvesting was used and a motorised chuff cutter was used to chop the maize into pieces of ± 15 cm long.

Ensilage process

Ensilage was done in 50 kg plastic bag silos [5]. Five kilograms of freshly chopped maize was thoroughly hand mixed with five kilograms of the respective freshly cut leaves of the forage tree legume (FTL). The mixed forages were then packed in the plastic bags and compacted by hand to exclude as much air as possible and then tied by a string ensuring air-tightness. The material was left to incubate in a room for seven weeks before samples were taken for laboratory analyses. At the same time, maize from the same crop was ensiled in a bunker silo. This silage provided the basal diet for the trial animals.

Samples preparation

Samples of freshly milled maize and mixed maize-legume material were taken for laboratory analyses. After a seven-week incubation period three bags of each of the respective silages were randomly selected, opened and thoroughly mixed before three two-kilogram samples were taken for laboratory analyses.

Ration formulation

Individual animal rations were formulated to give an overall CP content of 130 g/kg DM and energy concentration of 11.0 MJ/kg ME. The bunker silage provided the basal diet for the experimental animals. A commercial lactating meal (19.6 % CP and 13 MJ/kg ME) was used to balance the rations for overall CP and energy content. The diets consisted of 10 kg treatment silage, 20 kg of basal maize silage (from the bunker) and 6.5 to 10.5 kg of a commercial lactating meal (19.6 % CP and 13 MJ/kg ME).

Animals and treatment allocation

Twelve Holstein cows with a mean of 610 ± 71 kg live weight and all in mid-lactation (days in milk 166 ± 27) were used in the study. The animals were arranged into four groups of three animals each according to parity. The three cows in each group were randomly allocated to one of the three treatment silages namely maize (control), maize-leucaena and maize-acacia. All the experimental animals were then randomly allocated to individual feeding troughs in the feeding shed.

Feeding management

The cows were given three meals per day at 06:00, 12:00 and 17:00 hours for a period of 21 days of which 14 days were for adaptation followed by seven days of data collection. The meal was mixed with the silage to prevent excessive selection against the roughages. The apparent intake was calculated as the difference between the amount

offered and the refusals for each meal. The animals were given access to water in-between meals every day. Daily milk yields were recorded during the morning and evening milking sessions.

Milk samples

Milk sampling was done twice per week during morning and afternoon milking sessions. Twenty millilitre samples were collected into sample bottles with a Bromopol (2-bromo, 2-nitropraine, 1,3 Diol + Natamycine) preservative tablet to prevent any spoilage before chemical analysis.

Laboratory analyses

All samples were milled through 1.5 mm screen before analysis. The parameters analysed on the fresh material and the silages included oven dry matter (DM), neutral detergent fibre (NDF), modified acid detergent fibre (MADF), crude protein (CP) and ash. All analyses were done in duplicate. The DM in fresh forages and silages were determined in a forced air oven at 60 °C for 48 h. The CP content was determined by the Kjeldahl method. The NDF and MADF were assessed using standard procedures [6]. Energy in the forages was estimated from the MADF values according to the following formula: ME (MJ/kg) = 0.16D (where D is the estimated digestibility of the forage calculated from the MADF value from the formula; Digestibility (D) = 99.43 - 1.17*MADF). The milk samples were analysed for butter fat (BF), lactose, protein, and total solids by a Bently 2000 infrared milk analyser.

Statistical analysis

The data on parameters for nutrient content was analysed using the Statistical Analysis Systems (SAS) [7] analysis of variance (ANOVA) procedures for a completely randomised design as represented by the model below. Tukeys method was used to separate the means.

$R_{ij} = \mu + T_i + e_{ij}$

Where: R_{ij} = response variable (e.g. dry matter, crude protein),
μ = Overall mean,
T_i = treatment effect (i = 1, 2, 3),
e_{ij} = random error.

In the feeding trial the general linear model procedure of SAS, for repeated measurements in a completely randomized block design was used for the analyses of DMI, milk yield and milk composition data. The following model was used:

$R_{ijk} = \mu + P_i + T_j + e_{ijk}$

Where: R_{ijk} = response variable (DMI, milk yield, protein, butterfat, lactose etc)
μ = overall mean,
P_i = effect due to parity (i = 1, 2, 3 or 4),
T_j = treatment effect (j = 1, 2 or 3),
e_{ijk} = random error.

The differences among the means were assessed by Tukeys method.

RESULTS

Nutritional composition of the silages

The NDF content of the silages were not different but they were all significantly different from that of the meal ($P < 0.05$) as indicated in Table 1. Bagged maize silage and mixed maize-acacia silage had similar MADF values of 304.4 and 318.6 g/kg DM, respectively. The bunker maize silage and the maize-leucaena silage had significantly higher MADF values of 353.5 and 357.4 g/kg DM, respectively, compared to the other silages. The bagged maize silage had the highest D-value followed by the, mixed maize-acacia silage, bunker maize silage and the mixed maize-leucaena silage. The estimated D value of the bagged maize silage was significantly different from that of the maize-leucaena and the bunker maize silage ($P < 0.05$) but similar to that of the maize-acacia silage. The maize-acacia silage was not significantly ($P > 0.05$) different from that of the bunker silage and the mixed maize-leucaena silage. The same trend was found with the estimated metabolizable energy values.

The CP content of maize- acacia was the highest whilst the bunker maize silage had the lowest. The ash content was highest ($P < 0.05$) in the mixed maize-leucaena silage followed by the bagged maize silage and then the lactating meal with similar levels to those of the bunker silage and the mixed maize-acacia silage.

Table 1: The nutrient content of the silages .

	Bagged maize silage	Maize--Leucaena silage	Maize--Acacia silage	Standard Error of means
DM (g/kg)	271^{a}	276^{a}	339^{a}	12.3
CP (g/kg)	71.2^{c}	176.0^{b}	208.7^{a}	0.5
NDF (g/kg)	608.2^{a}	658.4^{a}	602.6^{a}	17.5
MADF (g/kg)	304.4^{b}	357.4^{a}	318.6^{b}	4.4
ME (MJ/kg)	10.21^{b}	9.22^{c}	9.95^{bc}	0.1
Ash (g/kg)	6.6^{ab}	7.4^{a}	5.6^{b}	0.2
Digestibility (%)	63.8^{b}	57.6^{c}	62.2^{bc}	1.5

^{abc}Values with different superscripts in a row are significantly different ($P<0.05$)

Dry matter intake

The dry matter intake (DMI) levels of the silages are shown in Table 2. The cows given mixed maize-acacia and maize silage had higher intake levels than those fed the mixed maize-leucaena silage ($P < 0.05$).

Milk yield and quality

The milk yield (Table 2) was higher ($P < 0.05$) in cows fed mixed maize-acacia and maize silages compared to animals on mixed maize-leucaena silage. However, the milk composition in terms of butterfat, lactose, protein and total solids was not different ($P > 0.05$) across the treatment diets.

Table 2: DM intake, milk yield and milk composition from animals fed mixed cereal-legume silages.

	Maize silage (control)	Maize-Leucaena silage	Maize-acacia silage	Standard error of means
DMI (kg/100 kg live weight)	3.30[a]	3.11[b]	3.31[a]	-
Daily milk yield (kg)	17.02[a]	14.06[b]	15.7[a]	0.69
Butterfat (%)	3.59[a]	3.72[a]	3.57[a]	0.11
Protein (%)	3.36[a]	3.44[a]	3.45[a]	0.05
Lactose (%)	4.58[a]	4.57[a]	4.48[a]	0.04
Total solids (%)	12.47[a]	12.74[a]	12.48[a]	0.16

[ab]Values with different superscripts across the rows are significantly different at $P<0.05$

DISCUSSION

Nutritional composition of the silages

The CP of the mixed silages that ranged from 170 to 210 g/kg DM is comparable to that of commercial dairy feeds and this gives them the advantage over the maize silage that had a CP content of 68 g/kg DM. These findings are similar to those in an earlier study [5] although the values in this study were slightly higher. However, the efficiency of utilisation of the CP in the mixed silages is not guaranteed due to the perceived interference from the polyphenolic compounds. In view of the interference from the polyphenolic compounds, the feeding value of mixed silage can best be judged from the performance of animals in a practical feeding trial. CP content and the availability of the protein in any livestock feed is quite important in that it has a bearing on the supplementary requirements, if any, for this expensive nutrient.

The NDF levels of the mixed maize-FTLs are within the range for some forage silages in the tropics. For example, guinea grass silage in Sri-Lanka had 69.9 - 71.9 NDF [1], napier grass silage in Thailand had 64.2 - 70.2 NDF [8]. The MADF of forages and silages should be within the 220 – 500 g/kg DM range [9]. The lower the MADF the higher the energy level in a forage or silage. The levels found in this study are within this range and this indicates that the mixed maize-FTL silages have a potential to replace the silage from traditional crops such as maize and sorghum if other factors are ideal. It is important to note though that the NDF and MADF levels are dependent on the maturity stage of any given forage since they are essentially indicating the levels of cell wall components mainly the cellulose, hemicellulose and lignin (for NDF) and cellulose and lignin (for MADF).

Similarly the DM and CP of silage all depend on the type and stage of maturity of the crops at the time of ensiling in addition to the methodology of harvesting and technique of ensiling. It is generally known that feeds with high fibre content have low digestibility and hence are of poor quality. The MADF of the bagged maize silage and that of the mixed maize-acacia were similar and so were those of the bunker maize silage and that of the mixed maize-leucaena silage but they were all within the 22-50 % range suggesting that the quality is acceptable. If NDF is considered, the picture is different, with all the four silages having similar content. In this regard MADF seems a better

parameter to indicate the potential digestibility of a given silage than NDF. The MADF was used to calculate the estimated digestibility values (D-value) for each silage. The digestibilities of all the silages are slightly higher than those reported in literature. The variation could be due to the differences in maturity of the various crops at the time of ensiling, with better digestibilities being found in young forage material. After the laboratory work there is need to confirm the estimated feeding value (the D-value) of the mixed silages through proper feeding trials.

The ash content of the mixed silages was comparable to that of the maize silage and the lactating meal. Mixed maize-leucaena silage had a significantly higher level of the ash than the lactating meal and other silages used in this study. This suggests that there may be no need to add commercial mineral supplements if the mixed silages are used. However there is need to analyse the ash for the quantities of calcium, phosphorus, iron, magnesium and other minerals required by lactating cows in order to ascertain the sufficiency from the silages.

Dry Matter Intake

There was no significant difference between the DMI of maize-acacia (3.31 kg/100 kg liveweight) and the maize silage (3.30 gkg/100 kg liveweight). This demonstrates the potential of the mixed maize-acacia silage as a source of protein in dairy cattle feeding. DMI is an important parameter in assessing the nutritive value of a feed or forage. The CP content of a feed influences the DMI of that feed because it tends to improve the palatability. However the CP content alone can not be responsible for high DMI because the energy content of the feed also plays an important role since animals eat to satisfy energy requirements [10]. The DMI reflected the influence of NDF, MADF and digestibility levels in the experimental treatment silages. The low DMI of the maize-leucaena silage could have been due to high fibre levels resulting in the rumen fill effect.

It is quite interesting to note that the DMI seems to have been influenced by the fermentation quality of the silages. Generally, it is believed that if forage has high levels of total phenolics its intake may be low. In this study mixed maize-acacia had the highest levels of total phenolics but its dry matter intake was similar to the control that had the lowest levels of phenolics. The reason could be that even the levels detected in the maize-acacia silage might not have been enough to exert significant negative effects on DMI. This is supported by earlier studies [11; 12], which showed that low levels of tannins (20 - 40g extractable CTs/kg DM) may in fact be beneficial by reducing protein degradation in the rumen and increase amino acid absorption from the small intestines without depressing fibre digestion and voluntary food intake.

Milk yield and quality

Milk yield and quality are influenced by stage of lactation, parity, animal size and the body condition at calving within the same breed in addition to the type of feed and level of feeding. It is a fact that rations that stimulate high milk yield will depress butterfat and increase total solids content. Good levels of feeding tend to stimulate high milk yields and lactose but depress BF, protein and minerals. Conversely under feeding results in high BF, protein and minerals and low milk yield and lactose [9]. In this study maize silage had milk yields similar to that of the maize-acacia silage and this indicates that the mixed silage has the potential to replace the maize silage without affecting yields. However the potential of the mixed silages cannot be guaranteed as this depends on the prevailing economic situation. Low DMI levels seem to have affected the milk yield from the maize-leucaena silage. Milk yields from animals supplemented with *L. leucocephala* hay were higher than those from animals fed *Acacia angustissima* and *Calliandra calothyrsus*

supplements [13]. These findings seem to suggest that the processing done prior to feeding the animals influence the performance of forages. In any case it has been found that sun or oven or freeze drying have varying effects on tannin levels [14; 13] and this has an effect on dry matter intake and subsequently the milk output.

There were no differences in the quality of milk across the treatments although studies [15] suggested that milk yield and composition in dairy cows might be influenced by the source of roughage. The data generated in the present study seem to be in agreement with the conclusions made that the dairy cow can maintain similar milk yield despite marked differences in the type of end products arising from carbohydrate and protein digestion [16]. Similar studies [17] using mixed maize-red clover silage and lucerne silage reported that the mixed silage increased milk yield compared to the maize silage alone (control) but lucerne silage was out performed by the control. The same authors also reported that the legumes compared to the maize silage lowered milk fat and protein levels. The varying results indicate that there is need for more research into the subject of mixed silages and their influences on milk yield and composition in given environments. This is important since the quality of milk has an influence on processing milk into milk products. Long-term studies are needed to determine the effects of mixed forages on udder development and the subsequent milk yields.

CONCLUSION

Mixed silages of good quality can be produced and used to partially replace commercial feed supplements without loss in milk yield or quality. However, there is need to ascertain the trend with low yielding dairy cows especially crossbreeds cows where there is potential to completely replace the commercial feeds with mixed FTLs and increase profits.

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Alfalfa Yield Under Subsurface Drip Irrigation Applying Secondary Domestic Effluent

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Key words: alfalfa, lateral spacing , secondary domestic effluent, sprinkler irrigation, subsurface drip irrigation, water use efficiency

Abstract
Scarcity of fresh high-quality water has heightened the importance of wastewater reuse in dry regions together with improving its efficiency by using the most effective irrigation method. In this study, field experiments were conducted during two years on the commercial farm of Revivim and Mashabay-Sade Farm (RMF) southeast of the City of Beer-Sheva, Israel. The response of alfalfa (Medicago sativa) to secondary effluent application was examined. Subsurface Drip Irrigation (SDI) system was compared with conventional sprinkler irrigation. In the SDI the emitters were installed at 20 and 40 cm below the soil surface and lateral spacing was 100, 150 and 200 cm. In an adjacent field alfalfa was cultivated and sprinkle-irrigated. The amounts of effluent applied were around 12,000 m^3/ha during summer and 5,000 m^3/ha during winter for both sprinkler irrigation and SDI system. The results of dry weight yields of SDI showed higher yields (from 3% to 25%) than sprinkled-irrigated. The average Water Use Efficiency (WUE) indicate the highest mean value of WUE of up to 1.7 t/ML (tone per mega liter of water) for alfalfa in SDI plots. This shows that SDI system under the examined conditions of RMF, have best alfalfa yield when properly designed and managed.

INTRODUCTION

In many places throughout the world, the utilization of treated wastewater for irrigation is becoming acceptable. However, wastewater contains a variety of excreted organisms and pathogens that pose risk to the humans [1], [2] and [3]. The factors influencing the transmission of diseases by irrigation are: the degree of wastewater treatment, the crop type and the harvesting practices used (e.g. human consumption or not, consumption after cooking or not, animal consumption fresh or sun-dried, etc), the degree of contact with the treated wastewater and the irrigation method.

The intense use of effluent for irrigation has attracted public awareness of environmental pollution and the impact on water quality [4], [5] and [6]. This was mainly due to the fact that sprinkler irrigation was the primary application method associated with microorganism distribution in the air. With the advent of advanced innovative technology, on-surface drip irrigation (ODI) and subsurface drip irrigation (SDI) have become the preferred methods. In the SDI method the laterals and drippers are buried below the soil surface in the vicinity of crop root zone [7]. SDI method allows precise application of water, nutrients and other agro-chemicals directly to the root zone of the plants. The depth and placement of subsurface drip lines is determined by the soil composition and the crop needs. An efficient installation together with frequent irrigation provides continuous root zone wetting.

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The purpose of this work is to evaluate SDI system for growing alfalfa with treated domestic wastewater over the conventional sprinkler irrigation system in terms of yield production and water use efficincy. The ultimate goal is to come up with recommendation for SDI implemenation for alflafa irrigation.

MATERIALS AND METHODS

Experimental Site

Field experiments were conducted on the commercial farm of two community farms (Kibbutzim), Revivim and Mashabay-Sade farms (RMF). The field is located a few kilometers southeast of the City of Beer-Sheva, Israel. Mean annual precipitation is around 200 mm, mainly received from November to March. Mean maximum temperatures reach 33^0C during July and August and decrease to a mean minimum of 4^0C during January. The soil moisture content by weight of the silt loam soil derived from loess at field capacity was about 16% and the volumetric dry weight of the soil was about 1.55 g/cm^3.

Crop Planting

The total area for the SDI plots was about 2,900 m^2 and according to the treatments was divided into two blocks. In each block six treatments were defined. The area for each replication was 240 m^2 (40 m long and 6 m wide). Alfalfa (*Medicago sativa*) was cultivated by the use of SDI system with emitter depths of 20 and 40 cm below the soil surface, and lateral delivery pipe spacing of 100, 150 and 200 cm depending on the treatment as shown in Table 1. Emitters on lateral spacing was 100 cm and flow rate of 4 l/hr was used during irrigation.

In an adjacent field, alfalfa was irrigated by sprinklers. The sprinkled field was divided into two sub-sections of about 500 m^2 each to facilitate two different harvest timings. The alfalfa in one of the sprinkled sub-sections was harvested at the same age as the SDI system while the other was cut at maturation (when flowering reached about 50%) as conventional agricultural practices. Alfalfa was planted in the month of November at a seeding rate of 40 kg/ha. Prior to planting the field was ploughed, disked twice and cultivated with a roller. To stimulate germination, 20 mm of effluent (200 m^3/ha) was applied by sprinkler irrigation since the initial soil water contents were not adequate [7]. The experimental field was fertilized at the beginning of experiment with urea (40% N) at a rate of 75 kg/ha.

Table 1: Lateral spacing and emitter depths (cm) in different treatments for SDI system experimental plot

Treatment number	Lateral spacing (cm)	Emitter depth (cm)
1	100	20
2	100	40
3	150	20
4	150	40
5	200	20
6	200	40

Effluent Source

Almost all raw domestic wastewater from the City of Beer Sheva is diverted to the treatment plant. The wastewater plant consists of four settling ponds, two facultative

ponds, two maturation ponds and an effluent reservoir with capacity of about 500,000 m^3. Daily raw sewage inflow was approximately 10,000 m^3/day and retention time for the wastewater (in the ponds only) varied from 12 to 20 days. The effluent was pumped from the reservoir and applied for irrigation. Total five day biological oxygen demand (BOD_5) of incoming raw sewage was about 215 mg/l. Prior to application, the effluent was filtered through a series of net screen filters to diminish emitter clogging. Concentrations of various constituents in the effluent are listed in Table 2.

Effluent Application

The SDI plots were irrigated twice a week with a locally developed crop coefficients based on evaporation measurements taken from an adjacent class "A" pan [8]. About 1,200 mm of effluent were applied during the summer and 500 mm applied during the winter. The sprinkled plots were irrigated every 10 to 14 days, similar to conventional practice in the region. Total amount of effluent applied per year for all treatments were similar during the

Table 2: Constituent concentration range of the effluent applied as irrigation water on the RMF for the 1st Year and 2nd Year of experiment

S/No	Constituent	1st Year	2nd Year
		Concentration (mg/l)	Concentration (mg/l)
1	Total COD	281-426	199-436
2	Ammonia	33-47	29-64
3	PO_4	22-42	32-39
4	Na	218-263	227
5	Ca	95-105	82
6	Mg	36-41	49
7	K	28-33	20
8	TSS	90-121	60-149

experimental period of two years (Figure 1). Effluent application during the winter season was adjusted to precipitation rates and events. Total amount of effluent applied during the first year and second year of experiment were between 1,310 and 1,480 mm, respectively. Total precipitation during the related periods was 197 and 116 mm, respectively.

RESULTS AND DISCUSSION

Yield

The alfalfa yield obtained in one of the sprinkled sub-sections was harvested at the same age as the SDI system. Two sub-samples for the yield assessment were taken for each harvest, from a sampling area of 21 m^2. A similar sampling area was taken in the sprinkle-irrigated portion of the experiment. The fresh samples were oven dried and used for yield analysis. The samples were dried for about 48 hours at 70 ^{0}C to obtain dry weight. The dry weight yields obtained at the same age in SDI and sprinkler system were compared as presented in Figure 2.

(Values with similar letters for the data are not different according to Post Hoc test at 5% significance). The results show that in the first year of experiment in all treatments of SDI, the yield of alfalfa was 11%-25% higher than the yields obtained from sprinkler irrigated system. In the second year of experiment all treatments of SDI showed higher yields (from

3% to 9%) than sprinkled-irrigated except when the lateral spacing was 200 cm where yield was 5% less.

In general, the yields of the two experimental years indicate higher yields of alfalfa in all SDI treatments than sprinkler irrigation system when the lateral spacing was 100 cm and 150 cm. The highest yield was obtained when emitter depth was 40 cm with lateral spacing of 100 cm in the first year and 150 cm in the second year of experiment.

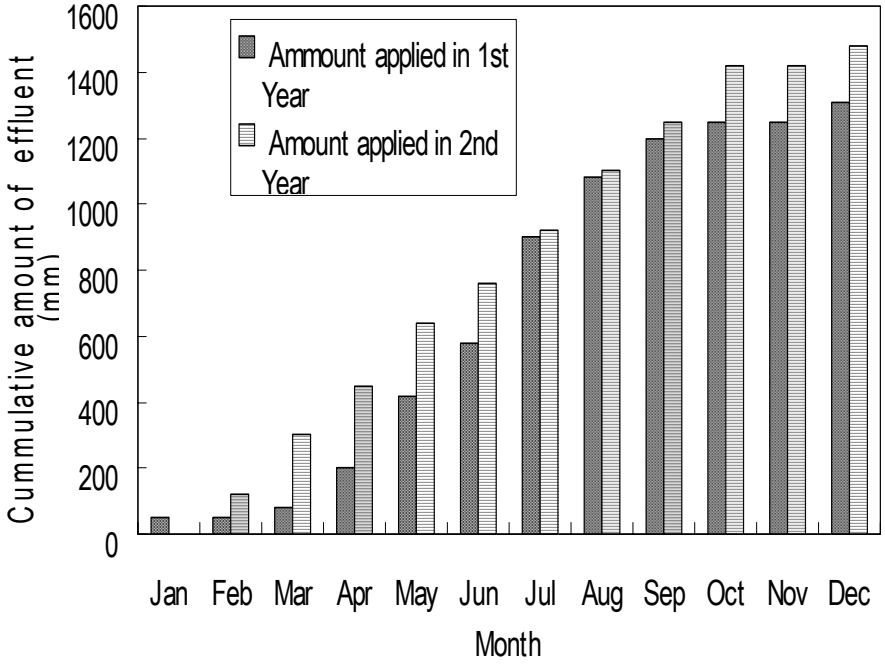

Figure 1: Effluent received by alfalfa on RMF for the 1st Year and 2nd Year of experiment

Water Use Efficiency

Water Use Efficiency was compared not only for the yields harvested at the same age as SDI in the sprinkler plot but also the plot harvested at maturation (50% flowering). *Water Use Efficiency, WUE* (t/ML), was calculated by the amount of alfalfa produced (tones/ha) per mega liter (ML/ha) of irrigation water applied [9].

$$\mathrm{WUE(t/ML)} = \frac{\text{Yield (tonnes)/ha}}{\text{Water applied (ML/ha)}}$$

The *WUE* for two experimental years are presented in Table 3. The results show that in the first year of the experiment all SDI treatments had *WUE* values that were higher than those obtained from sprinkler irrigated system (Table 3). Alfalfa harvested at maturation in the sprinkler irrigated sub-section produced the lowest *WUE* of all treatments as well as in the second year. In the second year of the experiment all treatments of SDI showed higher *WUE* values than sprinkled-irrigated except treatment number 5 and 6 where the lateral spacing was 200 cm. In general, the average *WUE* of the two experimental years indicate higher *WUE* of alfalfa in all SDI treatments than sprinkler irrigation system as indicated by mean value of *WUE* (Table 3).

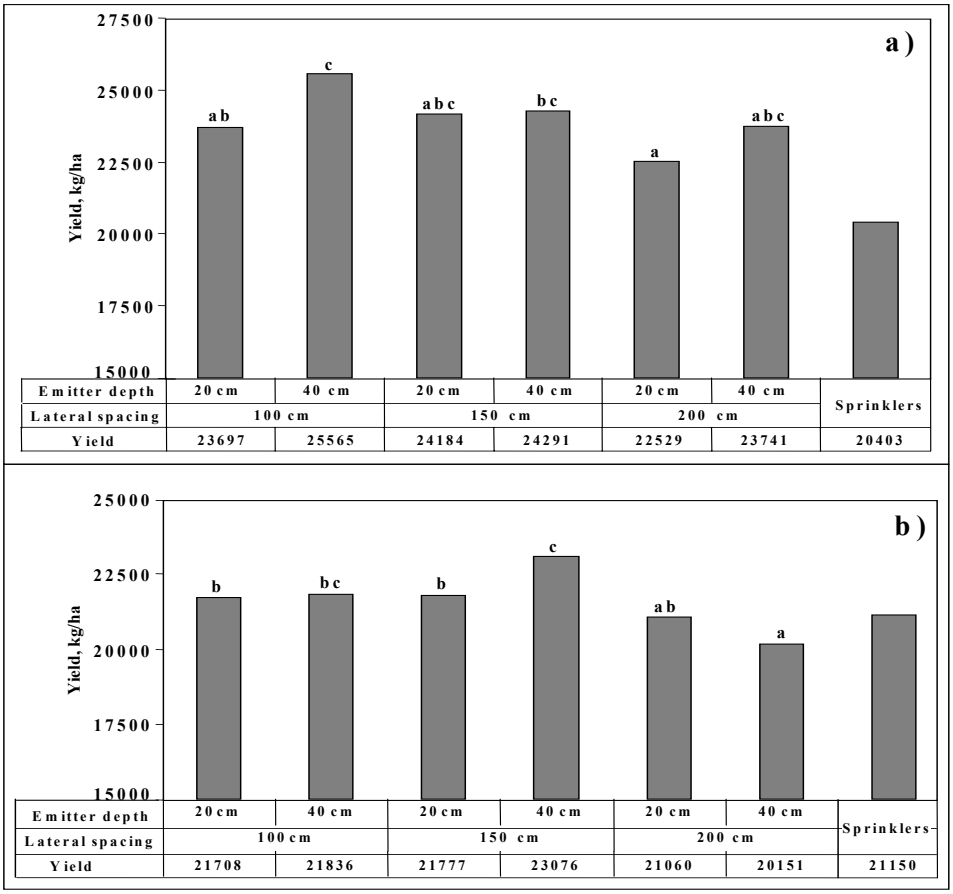

Figure 2: Alfalfa yield response to different parameters (lateral spacing and emitter depth) of SDI system comparing to conventional sprinkle irrigation. [a) and b) first and second years of experiment respectively].

Table 3: Annual WUE (t/ML) of alfalfa for the 1st Year and 2nd Year of experiment

Treatment Number	Lateral spacing (cm)	Emitter depth (cm)	Water Use Efficiency, (t/ML)		
			First Year	Second Year	2 years Mean
1	100	20	1.57	1.36	1.47 ± 0.15
2	100	40	1.70	1.37	1.53 ± 0.23
3	150	20	1.60	1.36	1.48 ± 0.17
4	150	40	1.61	1.45	1.53 ± 0.11
5	200	20	1.49	1.32	1.41 ± 0.12
6	200	40	1.58	1.26	1.42 ± 0.23
Sprinkler			1.35	1.33	1.34 ± 0.01
Sprinkler (50% flowering)			1.31	1.25	1.28 ± 0.04

Treatment number 2 with lateral spacing of 100 cm and lateral (emitter) depth of 40 cm produced the highest value of *WUE* in the first year of experiment while treatment number 4 with lateral spacing 150 cm and lateral depths of 40 cm indicated highest value of *WUE* in the second year. In general the highest average value of *WUE* of 1.7 t/ML was obtained in treatment number 2. The average *WUE* in the sprinkle-irrigated that were harvested at the same age as SDI was 1.34 ± 0.01 t/ML while that at maturation (50% flowering) produced only 1.28 ± 0.04 t/ML of dry weight. The extra yields obtained under SDI are due to two main outcomes: (i) the yield per cut under SDI was higher than under sprinkler irrigation due to the earlier maturation in the drip plots, and (ii) there was at least one additional harvest per year in the drip plots as compared to the sprinkled plots.

Conclusions

A field study with SDI of alfalfa was compared with sprinkler irrigation of alfalfa showed that treated wastewater can be effectively and economically applied through a SDI system. The SDI systems offer many technological and agronomical advantages. Additional benefits are gained with the convenience of field cultivation in the SDI system. The followings are the outcomes of this study:

1. The best alfalfa yields were obtained from SDI system at a trickle lateral depth of 40 cm and when the lateral spacing is 100 cm and 150 cm. This shows that SDI system have the best yield of alfalfa when properly designed and managed compared to sprinkler irrigation system.
2. The results also showed that when lateral spacing was 200 cm the SDI system produced less yield compared to sprinkler irrigation. Therefore, depending on the soil type and kind of crop, the SDI system installation and use parameters have to be studied thoroughly for better efficiency when SDI is to be used.
3. The average water use efficiency show that SDI system has higher water use efficiency than sprinkler system when properly designed and managed.

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Small Scale Palm Oil Process Improvement for Poverty Alleviation and National Development

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Keywords: Oil palm**,** Palm oil, *kaizen*, moisture content, impurities, free fatty acids (FFA), yield

Abstract
What makes oil palm development more strategic and economically sound is that there exist enormous opportunities globally for palm oil and products from it. Currently, there is an estimated external market for 2.6 million tonnes of crude oil and allied products from Ghana and West Africa but only 800,000 tonnes is produced annually in the sub-region. Indeed, there are even greater long-term opportunities in oleo chemicals and paints and as bio-fuel because of the rising cost of fossil fuels. Thus this study sought to improve yield and quality of palm oil produced by using 10 palm oil mills for the initial background study and subsequently 4 of the studied mills were chosen for the validation phase in the Ashanti Region of Ghana. The results showed that moisture content, impurities and FFA were poor and could be improved considerably by training the stakeholders. The yield of palm oil could also be improved considerably following recommended procedures to improve returns with minimal layout changes costing next to nothing. The quality and quantity gains improved access to the market which was hitherto not the case. Oil recovery from the sludge for the local soap industry did boost the incomes of millers. The main difficulty at the mills was the mountains of palm nuts crying to be processed into palm kernel oil. The outcome of this work could be replicated in oil palm producing countries on the continent to improve the livelihood of the poor and accelerate national development.

Introduction

The current population of Ghana is estimated at 22 million based on the 2000 population census. Ghana currently produces about 100,000 tonnes of palm oil annually but her annual requirement is estimated at about 240,000 tonnes. There is therefore a deficit of 140,000 tonnes which is imported at great cost to the nation. The nation can therefore save up to about $200 million in terms of import substitution alone by producing her palm oil requirements since conditions for doing so are right. Ghana with her peaceful environment and democratic credentials see herself as the gateway to the sub-region with many international agencies relocating their offices to the country. The economic integration of the 15-member Economic Community of West African States (ECOWAS) is progressing satisfactorily. This promises a market of some 250 million people. There is also a deficit of 1.8 million tonnes of crude palm oil in the sub region.

Ghana is a West African country lying along the Gulf of Guinea between latitude 40°44'N and 11°11'N, and longitude 3° 15'W and 1° 12'E. It is bound on the east by Republic of Togo, on the west by La Cote d'Ivoire and the north by Burkina Faso. Kumasi is the capital of the Ashanti Region of Ghana. Ghana is predominantly an agricultural country with about 50.7% of the working population working in agro-industry which accounts for approximately 42% of her GDP. The government of Ghana has also

encouraged the development of non-traditional industries over the past decade in order to diversify the country's export base.

Crude Palm Oil (CPO) is extracted from the mesocarp which in turn can be further refined. The refined oil and fat is used in industrial production of non-dairy creams, ice cream powder, salad additives and fat spread. It is used as substitute in the formulation of soaps, detergents, margarines and baking fats. Palm oil is also a rich source of vitamins A, D and E which are indispensable in the pharmaceutical industry. The fibre is used in mills (boilers) as fuel and for stuffing car seats and mattresses. The list of products cannot be complete without reference to the nut which comprises a shell and a kernel. The shell of the palm nut is used as fuel and as activated carbon for bleaching purposes. This product is in high demand on the international market. The kernel is a rich source of lauric acid, a vital ingredient for the soap, cosmetic and confectionary industry.

What makes oil palm development more strategic and economically sound is the fact that there exist in Ghana, West Africa, the rest of Africa and the world at large enormous opportunities for palm oil and products processed from it. It is currently estimated that there is an external market for 2.6 million tonnes of crude oil and allied products from Ghana and the sub-region but only 800,000 tonnes is produced annually in the sub-region (PSI, 2003). Indeed, there are even greater long-term opportunities in oleo chemicals and paints. Others are researching into its use as a bio-fuel because of the rising cost of fossil fuels. For example, the energy content of industrial diesel oil per tonne is 42.3 GJ and that of palm oil is comparable of value 41.0 GJ. There is scope for the use of the waste for the generation of electricity from boilers or biogas plants. A wealth of technical know-how also abounds locally to be tapped for this industry.

The peak season for harvesting palm fruits in Ghana is from January to June. The period from July to October is regarded as the mid-season and the lean season is from October to December. During the lean season, production of palm oil is cut down due to a drop in the supply of raw materials. This is being addressed by breeders and also putting much larger areas under cultivation. There is also the need to ensure that seedlings of the *tenera* variety is produced and sold to farmers for cultivation since it gives the highest yield in terms of fresh fruit bunches and oil. Farmers are also being taught the correct lining and pegging techniques to maximise production on farms. In order to overcome the problem of shortage of fruits for processors, the government of Ghana is pursuing an aggressive policy to add 20,000 ha of oil palm plantations per year for the next five years.

Materials and Methods

The palm oil process involves a point where harvested bunches are received at the factory or mill and these may be loaded into cages in a factory setting or stripped at an association mill. The bunches are then taken through, sterilisation, threshing or stripping, digestion, pressing for the palm oil, separation of the fibre from the nuts, clarification of the oil, storage of the oil and disposal of the sludge. Each of these stages was monitored to ascertain the losses occurring. The layout of each factory and mill visited was also measured as part of the study. The quality of fruits/bunches used in the preparation were also assessed. Most of the measurements entailed some level of weighing either using normal scales or in the case of bigger factories, weighing bridges. Samples of the oil were taken for laboratory analysis of the free fatty acids content, moisture content and impurities.

Results and Discussions

Table 1-3 show the studied mills in the Ashanti Region, the areas under oil palm production and employment offered especially to women respectively. During the main season a lot of casual employment is offered to inhabitants in the areas of manual stripping of the fruits, fetching water, separating of fibre from nuts, provision of firewood and vending of food. Where no casual labour is provided, the association members assist themselves with free labour known as '*nnoboa*' locally to contain cost and maximise profits. The mill at Amaning is the only one wholly controlled by women.

The availability of a company farm may help but it is not a necessary condition for starting an oil mill in Ghana. All the mills are located in areas with oil palm plantations owned by individuals. The desirable fruits are ***tenera*** which contains 21-24% oil. Unfortunately the traditional varieties are still in the system since millers buy fruits with different varieties which are difficult to differentiate just from the looks as shown in Table 4.

The capacity of the cooperative mills is just a tonne per hour. Those of the factories were between 2-13t/h. The sources of funding for the factories/mills were individual member shares, bank loans and the district assemblies. The Rural banks have been assisting in the development of these rural enterprises. Technoserve, an NGO (Non-Governmental Organisation), has also been assisting the mills with technical expertise. Palm oil processing is a lucrative business. The cost of the fruit per tonne is about $70 but crude palm oil sells for about $1000/t, the kernel oil for $1087/t and the shells could sell for $136/t. The cost of machinery, water, labour and other incidentals need to be factored into the cost though.

Table 1: Location of Studied Oil Mills

	Name of Oil Mill	**Location**	**District**	**Distance from Kumasi (km)**
1	Antoakrom	Antoakrom	Amansie West	55
2	Sekyere East Oil Mill Limited	Asokore	Sekyere East	55
3	Pease Oil Palm Association	Pease	Bosumtwi-Atwima-Kwanwoma	32
4	Ntinanko Cooperative Oil Palm Farmers Society Limited	Ntinanko	Amansie East	44
5	Ayokoa (Sir Speedy)	Ayokoa	Adansi North	82
6	Afotom Oil Palm Processing and Marketing Society Limited	Afotom	Offinso	45
7	Amaning Women's Association	Amaning	Offinso	65
8	Adansi Oil Mills Limited	Dompoase	Adansi North	63
9	Juaben Oil Mills Limited	Juaben	Ejisu-Juaben	50
10	Anwiankwanta Oil Mills Limited	Anwiankwanta	Amansie East	35

Table 2: Production of Oil Palm in Ashanti Region (2005)

No.	Districts	Area under Cultivation (ha)	Production of Fresh Fruit Bunches (t)
1	Ejisu Juaben	4,163	14,986.8
2	Asante Akim North	1,821	6,555.6
3	Asante AkimSouth	3,902	14,047.2
4	Sekyere East	3,122	11,239.2
5	Sekyere West	1,301	4,683.6
6	Ejura Sekyedumase	520	1,872
7	Kwabre	1,821	6,555.6
8	Efigya Sekyere	1,821	6,555.6
9	Offinso	3,643	13,114.8
10	Ahafo Ano South	3,122	11,239.2
11	Ahafo Ano North	3,122	11,239.2
12	Atwima Nwabiagya	3,122	11,239.2
13	Atwima Mponua	3,122	11,239.2
14	Amansie East	3,122	11,239.2
15	Amansie West	2,081	7,491.6
16	Amansie Central	3,122	11,239.2
17	Adanse South	3,643	13,114.8
18	Adanse North	3,643	13,114.8
19	Obuasi Municipality	1,041	3,747.6
20	BAK	1,041	3,747.6
21	KMA	0	0
Total		52,295	188,262

Table 3: Employee breakdown of oil mills

	Name of Oil Mill	Actual Employees			Casuals	Total
		Male	Female	Managerial		
1	Antoakrom	12	21	1	100	134
2	Sekyere East	5	145	-	150	300
3	Pease	1	14	-	-	15
4	Ntinanko	12	26	7	-	45
5	Ayokoa (Sir Speedy)	6	2	2	6	16
6	Afotom	4	15	-	10	29
7	Amaning	3	11	-	5	19
8	Adansi	18	1	4	3	26
9	Juaben	125	125	6	251	557
10	Anwiankwanta	24	2	2	6	34

Fruits were kept for too long at the association mills. A maximum period of 3-5 days is recommended to prevent deterioration and higher FFA's in the oil. Sterilisation is also done for too long and with too much water at a lower temperature which is not optimal for the efficiency of oil yield. There is temperature loss during digestion and pressing because of the sheer distances between sterilisation and digestion. Clarification temperatures at the association mills also needed some fine-tuning.

Table 4: Raw material base of oil mills

	Name of Oil Mill	Size of company farm (ha)	Type of fruits used (%)	
			Tenera	Dura
1	Antoakrom	230	80	20
2	Sekyere East	Nil	60	40
3	Pease	Nil	90	10
4	Ntinanko	4.5	90	10
5	Ayokoa (Sir Speedy)	50	90	10
6	Afotom	Nil	100	Nil
7	Amaning	Nil	100	Nil
8	Adansi	Nil	90	10
9	Juaben	175	70	30
10	Anwiankwanta	Nil	80	20

Apart from the free fatty acids content at the factories which were within the recommended average of 5-5.5 %, all the others were just too high. To target the international market, FFA will have to come down to about 2-3 %. This will mean processing the fruits in far fewer days than is currently the case. Currently, fruits are stored for up to 14 days at some places. This does not include the period harvested bunches are kept in the farm. They are piled up and some are stored in fertiliser sacks in the open. These generate a lot of heat leading to faster deterioration, mouldiness and bruising which cause higher free fatty acids. Storage is slightly better at Ntinanko and Asokore where fresh fruit bunches (FFB's) are stored on wooden platforms.

The standard for impurities is 0.045 %. Unfortunately, the dirt content is way too high but better at the factories. Much of this is due to poor storage of bunches and lack of patience to allow settlement before skimming-off the oil. The introduction of filters at the cooperatives will be helpful. The pressing of oil from the pulp present a problem of nuts in the fibre which is a limitation on how much pressure can be exerted. Pressures of 200kPa are exerted by the presses at the factories. In the case of manual screw presses, the pressures are up to 22 kPa which is woefully inadequate.

The yield of *tenera* is high in the range of 22-24 % (Poku, 2002). This is the preferred fruit for palm oil production. Unfortunately, there is this tradition of not destroying economic crops during land preparation. Also squirrels and other animals disperse the palm fruits to all sorts of places. Wild *dura* fruits are also harvested for consumption and sale. Some farmers also produce their own seedlings and some unscrupulous people produce seedlings to cash in on the booming seedlings business. No wonder a lot of *dura* is available in all the production centres studied. There is the need to intensify education on seedling production and sale. Certified seedling producers must be encouraged and farmers made aware through agricultural extension officers. Finally, buyers of bunches and fruits can be trained to decipher this problem since most mills do not own their own farms. Subsequent studies focussed on the small scale millers because of their many problems and lack of assistance in their activities.

It is recommended that the oven and digester distance should be at a maximum distance of 10 m. This will reduce the carrying of fruits for longer distances which resulted in severe temperature drops to affect the yield of palm oil in the old production techniques studied. The digester and press must similarly be close to prevent further temperature drop. The sum total of these modifications minimised the drudgery associated with the process and more importantly ensured high enough temperatures in the digested mash during pressing to improve yield.

The other problem is the use of inefficient local ovens by essentially placing three stones to form a tripod for the sterilisation/clarification/drying tanks. This led to a lot of smoke in the environment. It is recommended that more efficient ovens should be built with bricks to deal with the unhealthy smoky environments. If improved ovens are built, then the distances between the digester and steriliser could even be closer. The improvements kept temperatures of digested material above 70^{o}C which is a pre-requisite for keeping the palm oil in a liquid state to optimise yield. The digester and press were equally close, thus the temperature of the fibre and nuts after pressing was even around 70^{o}C. Boiled fruits were also not heaped before digestion but were carried in reasonable bits straight to the digester after sterilisation.

Table 5: Analysis of quality/ yield of Palm oil under old and improved processing methods *Standard Deviation in Parenthesis*

Location of Mill	Type of Processing	Afotom	Antoakrom	Ntinanko	Pease
Oil Left in Fibre (%)	Old Method	24.01 (2.31)	18.81 (1.02)	20.20 (0.97)	21.83 (0.68)
	New Method	6.21 (0.86)	5.48 (0.82)	6.23 (1.37)	5.28 (0.70)
Impurities (%)	Old Method	8.82 (1.14)	7.21 (2.01)	8.21 (1.18)	8.66 (0.88)
	New Method	1.50 (0.88)	2.00 (0.56)	1.78 (0.64)	1.41 (0.52)
Moisture Content (%)	Old Method	1.21 (0.28)	1.10 (0.32)	1.05 (0.17)	1.02 (0.16)
	New Method	0.33 (0.10)	0.35 (0.09)	0.30 (0.11)	0.30 (0.10)
Free Fatty Acids (%)	Old Method	10.56 (2.00)	11.38 (1.84)	10.43 (2.02)	9.49 (1.56)
	New Method	6.41 (0.76)	6.30 (0.72)	6.65 (0.73)	6.41 (0.76)
Yield (Theoretical Yield is 22-24) %	Old Method	8.18 (0.84)	10.36 (1.20)	9.77 (2.93)	9.27 (2.64)
	New Method	18.94 (0.98)	17.16 (3.52)	19.31 (0.57)	19.21 (1.01)

The level of impurities reduced substantially simply by pre-washing before boil and also using cleaner containers at all stages. Skimming of the oil layer after clarification must minimise some of the sludge getting in with the oil to be dried. This was the cause of too many particles after the drying process. The technique of skimming of particles after drying must also be improved. By drying until all the bubbles died down, the moisture contents were brought within recommended standards as shown in Table 5 for all the mills. The drying process must be carried out in about 30 minutes. The fire temperature must be managed to keep drying temperature around 120-130^{o}C like Antoakrom in Figure 1. Drying to high temperatures as at Afotom in Figure 1 wasted time and energy and also destroyed the quality of oil. The volatile components of the palm oil vaporised at higher temperatures to destroy its quality.

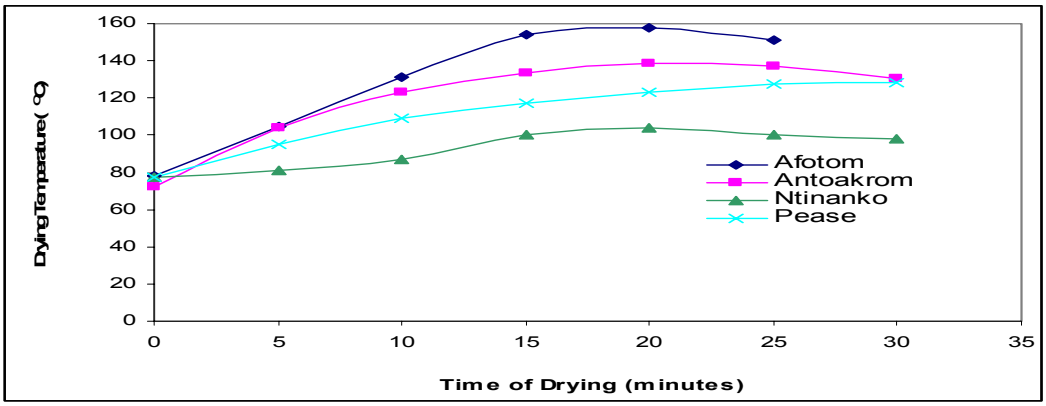

Figure 1: Correlation of drying time with temperature

The FFA of palm oil produced (see Table 5) using the new procedures improved. The yield of palm oil nearly doubled in most cases. This clearly shows that by following the improved methods, millers stand to gain a lot financially. It is the result of not leaving fruits to rot and keeping temperatures very high up to pressing. The extension of the effort arms for manual presses and changing of oil in hydraulic presses to the correct hydraulic oil contributed to this.

Fruits must well-covered to ensure boiling temperature of at least 100^{o}C. It is better to add about 45% of the material volume of the fruits as water. Where there are no weighing scales, a third of the tank to be filled with fruits for sterilisation must be filled with water and covered tightly with no heaping.

The effort arms of the manual presses were extended with galvanised iron pipes to the length of the existing effort arm by about 0.5-1.0 m each side to improve pressing and minimise human effort. An attempt to use bamboo for the extension failed, but more mature bamboo could serve the purpose. Heaping of mashed pulp in the basket for pressing was avoided to prevent pressed oil from falling back into the fibre and nuts to reduce yield. Pressing was gently done to avoid spillage onto the floor and was continued until no more material oozed out. The cake was ejected afterwards and immediately separated manually into fibre and nuts. When enough fibre to fill the cage of the press was obtained, a final pressing was recommended.

The efficiency of extraction improved tremendously from 65% to over 100% in the areas studied with the improvement techniques and also as shown in the low level of oil left in the fibre in Table 5. There is a limitation on how much oil can be squeezed given the pressure available and the presence of concretions in the form of nuts. No matter the pressure, some oil will still stick to the fibre.

The sludge was never thrown away after clarification. It was poured into a 200 litre oil drum (45 gallons) or a reasonably sized container, covered and left for 1-4 days (Kyei-Baffour and Manu, 2007). It is better to avoid longer periods to prevent decay and the emission of offensive odour. A new oil layer appeared on the sludge afterwards, and this was skimmed into a drying container. An equal quantity of clean water was added to the oil skimmed and dried. The quality of this oil is low. It is therefore not palatable or edible so it is best sold to the local soap industry. This can also boost the incomes of millers.
Finally, the sludge must be disposed off in pits dug for the purpose not into natural drains or water ways. The water in the sludge will infiltrate into the soil. When the pit is full, it should be covered with soil to control the stench, flies and scavengers and also to ensure a relatively clean environment.

Conclusions and Recommendations

Serious education is needed to ensure that only certified seedlings of *tenera* are grown in Ghana to optimise palm oil yield. Storage and the general environmental conditions of mills must be improved. Capacity must be improved to minimise the storage of fruits for longer periods. There is the need to train all association type millers to improve on their efficiencies. The factories will need to rehabilitate sensors for monitoring temperatures and pressures as well as all valves and filters. The disposal of sludge is not currently acceptable and serious research is needed to deal with the problem. Millers must be encouraged to go into palm kernel oil production to prevent waste and increase their incomes. The duration of storage of bunches and fruits need to be kept to a minimum of 3-5 days since rotten fruits at the association mill when boiled led to a lot of oil losses through the sterilisation water and higher FFA's in the palm oil produced.

Over-sterilisation must be avoided. Boiling with too much water for over 2 hours is not good. At the factories, the quality of steam is important since this affects the extraction rate, the quality of oil and the efficiency of the machinery. Trapped air in the steriliser happens because of the lack of automatic air vents at the factories studied. This can lead to longer than required sterilisation period because the air forms a barrier to sterilisation. Steam temperature and pressure at the factories of 140^{o}C and 300kPa respectively were the recommended standard.

Inadequate sterilisation leads to poor threshing leading to the loss of oil to bunches. However, the clearance between the inner cylinder of the digester and the beating arms had problems leading to lots of undigested fruits and subsequently longer digestion time for all the mills. Pressures and temperatures were controlled at the factories during pressing. Excess pressure could break the nuts and affect the quality of palm oil. Pressures exerted by manual presses were too small at the association mills.

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Trends in Earthen Construction for Rural Shelter in Zimbabwe: The Case of Tsholotsho in Matabeleland North Province

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Key Words: Durability, earthen construction, rural housing, appropriate technology, sustainability

Abstract

Historically, earth and other local materials have been in dominant use in construction for both rural and urban housing in Zimbabwe. The Matabeleland Provinces in the Southern part of Zimbabwe are no exceptions. With advances in technology and noticeable improvement in living standards, people popularly tend towards a set of building materials, albeit for the purpose of securing more durability and modernity. However, the adequacy and effectiveness of these materials, in terms of affordability and sustainability in rural housing remains below expectations. The use of non-traditional materials is prevalent and the provision of affordable housing is still a major challenge in rural Zimbabwe.

This paper seeks to examine the trends in earthen construction, for housing in the Matabeleland region and specifically, Tsholotsho. It also seeks to explore the potentials for improved, affordable and sustainable earthen construction for shelter housing in Zimbabwe. Alongside, the paper addresses some of the inherent psychological factors militating against the promotion of earthen construction in general.

Introduction

In the history of human settlement development, communities have largely been concerned with locally available materials and their appropriateness to the climatic conditions and other threats. Thus shelter has evolved from olden day caves to the modern structures we have today, where the use, comfort, social customs, convenience and status are some of the factors that influence the choice of materials and construction techniques.

Traditional building materials in rural Zimbabwe include adobe, timber, stone, thatch and other related locally available materials. However these are used with little or no scientific input, leading to their faster deterioration. Hence the shift from these appropriate building materials to the non-traditional materials. The communities desire to construct durable structures and reduce maintenance. Notably, these materials except clay bricks are 'imported', and their prices are beyond the reach of many. Their manufacturing processes and transportation consumes lots of energy. Further more environmental concerns inform the reduction of materials like timber and fired brick as deforestation in the district has risen to alarming levels. Thus the use of non-traditional materials such as steel, cement, plastic floor tiles, aluminium roofing sheets, etc easily proved inadequate. A

study carried out in South Africa showed that traditional construction materials and methods were more cost effective than the conventional [3]. Despite these factors, the popularity of non-traditional building materials continues to grow in Zimbabwe, thus enhancing the ability of families to develop and own houses. Almost everyone sufficiently eligible to own a house is a victim of this negative trend. This paper embodies the outcome of a research carried out in Matabeleland to identify trends in earthen construction with focus on the promotion of sustainable earthen construction. The objectives of the research are essentially to promote earthen materials in rural housing and to investigate the aspects of further exploitation of the potentials of earthen construction in Tsholotsho District.

Recently, earthen construction has gained some recognition in the first world, where various scientific mechanisms are being applied in an effort to improve its durability, aesthetics and cost effectiveness. Regionally, there are research efforts underway in Botswana, South Africa and Zimbabwe to establish a framework for developing performance-based codes. The use of performance-based codes would certainly preserve earthen building materials and methods in Southern Africa [3]. Ngowi [7] has also done some work on improving the traditional earth construction in Botswana. In South Africa, research on earthen construction dates back to 1950. Currently research is being undertaken on the subject by the University of the Free State (Bloemfontein), by the Peninsula Technikon (Bellville) and the Namibian Clay House Project (Windhoek and Otjiwarongo, Namibia). The University of the Witwatersrand and Hydraform Africa have achieved reasonable success in the use of earth and waste materials such as the 'sludge' precipitated at the water treatment plants for the production of masonry elements [6]. In 2003 the International Centre for Science and Technology an institution within the framework of the United Nations Development Organization (ICS-UNIDO) initiated a project on strengthening the capacity of Mozambique in the production of cost-effective building materials based on local clay resources.

In Zimbabwe, the Scientific and Industrial Research and Development Centre (SIRDC) through its Building Technology Institute (BTI) has perfected and promoted rammed earth Technology in Zimbabwe. BTI built rammed earth structures at their premises (1997), in Insiza district (2003), and in Mutoko (2003) and launched a National Pilot Project with the Ministry of Science and Technology. BTI in conjunction with the Standard Association of Zimbabwe (SAZ) also developed standards for rammed earth construction. SIRDC and Practical Action worked on the promotion of stabilized soil blocks as well. In another initiative sponsored by the Department for International Development (DIFD), BTI identified Kalahari sand, river sand and cement as potential materials for stabilized soil brick production for blair latrine construction in Tsholotsho and Lupane Districts where the geological formations are the predominantly unstable Kalahari sands [8]. These are some attempts to promote sustainable use of earthen construction in Zimbabwe.

Although much has been done in the development of earthen construction technology locally and internationally, the innovative earthen materials ideal to ease shelter problem have remained largely unimplemented as a result of a number of challenges. These include but not limited to stigma and perception, social status, psychological mindset, poor marketing of earthen products, ineffective dissemination of research results and the gap between supply and demand. It is therefore vital to address these challenges, which have affected the promotion of earthen materials in Zimbabwe.

Features and Retrospective Issues of Study Area

The study was carried out in Tsholotsho District in the Matabeleland North Province. The District is administratively divided into 20 Wards, and each Ward into six Villages (Fig.1).

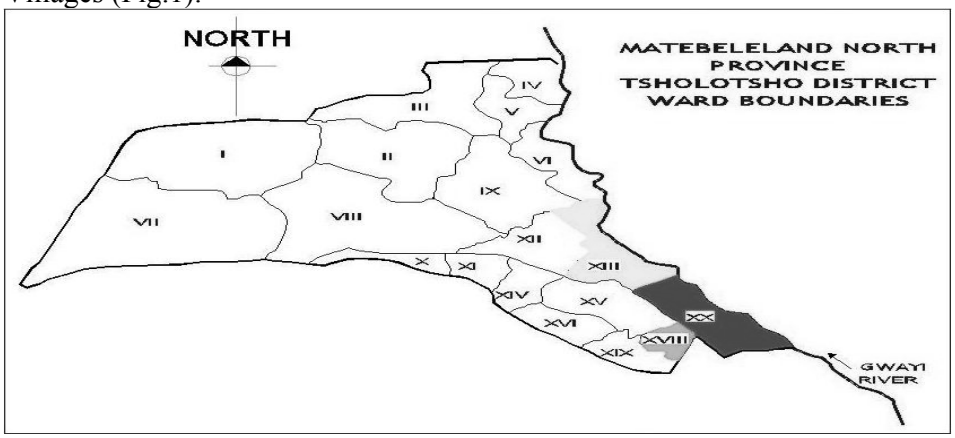

Fig. 1. Location of study area showing the subdivisions of the Wards

The housing situation in Tsholotsho is below acceptable standards for a contemporary rural community. The province has poverty levels averaging 81.1% [2]. It is a general a generally drought prone area. Settlement patterns in Tsholotsho are generally linear or clustered. Generally, the settlement is divided into residential, arable and grazing blocks. A homestead in the District normally consists of an area made up of 4-8 shelter units. These units include: separate main house for the parents/family head, girls' house, boys' house, other relatives' houses as well as the kitchen. Normally, new units are erected as the need arises. The need factors include: family expansion and rebuilding old dilapidated units. Granaries for storing maize and other grains are built closer to the kitchen. A typical homestead in Tsholotsho is shown in Fig.2.

In history, shelter construction can be traced to the eighteenth century when the Ndebele settled into the area, now western Zimbabwe. They migrated after they broke away from the Zulus and headed north from South Africa. The original dwelling type was the Zulu bee hive structure with no distinction between the wall and the roof (Fig.2).

Fig. 2. Typical homestead

Fig. 3. Traditional bees hive housing. Source [4]

By evolution in time, the houses acquired the form with distinct separation between the walls and roof. Walls are made of straight poles with mud infills. These materials soon gave way to sun-dried bricks (adobe) and hand made in-situ bricks (cob). Figure 4. indicates the separation of walls and roof. Colourful clays are then used on both walls to give a unique decorative finish. These three earthen construction methods co-exist even

today. Thatching using grass was, and is still the dominant roofing material. In earthen walls, the roof is supported by a central wooden post and a ring of poles (columns). The crossbeam technique was introduced by the Europeans around 1930. Here, a ring of poles with connecting horizontal poles at the top replaces the central structural support system as illustrated in Figure 5. This technique was later adopted in the modern building methods and marks a remarkable deviation from the traditional method.

Fig 4. Roof supported by the walls

Fig 5. Cross beam technique of supports

In Tsholotsho where there was a high degree of social cohesion and housing construction, the act of shelter building was a major community event in which all able bodied men and women participated [5]. The actual construction work was a culmination of several weeks of assembling of the materials, etc and preparation of the building site. At the end the participants were treated to food and local beer party. This enhanced the continuity of indigenous knowledge in traditional building practices and environmental conservation.

Earthen Construction Practices and the Factors of Change

Until the establishment of the Ministry of Rural Housing and Social Amenities in 2005, there was no Government arm that dealt specifically with rural housing. Although this development is commendable, it is worrying some that the schedule of materials for their model homestead specifies non-traditional materials. Initiatives from other organisations like the Non Governmental Organisations (NGOs) have been restricted to relief and disaster management projects with none addressing the issue of earthen construction materials in their housing programmes. Earthen construction in rural areas is not regulated by any codes, standards or building by laws. The absence of bye-laws and standards has led to a range of sizes of plots, building heights, spaces, material specifications, etc. On the other hand, it encourages creativity and diversity in earthen construction.

There are environmental, geographic, social, cultural and economic factors that influence the design and construction of rural houses and hence the trends in earthen construction. In Tsholotsho, the choice of materials and techniques is attributed to the following: climate, aesthetics, tradition, durability, cost, external influence, source of procurement, government policy, income levels, agricultural practices, diversity of geology etc.

Wall thicknesses vary depending on shelter type and adobe blocks. The walls rest directly on the ground, as there are no formal foundations. Rectangular houses are now the most common type because they can easily be partitioned. The circle is the prime shape for kitchens. The superstructure was found to be of adobe, cob, and pole and dagga. Floors were done by ramming in an appropriate quantity of earth after the removal of top soil.

This incremental beating of mud results in floors as durable as cement. Earthen floor finishes are a product of an earthen mix and cow dung and are smoothed with the regularly shaped coal blocks. In Tsholotsho high quality thatch roofing increases the life span of the earthen walls.

There are no earthen roofs. As this is a generally dry area with an average rainfall between 400mm and 450mm per annum, the buildings have small overhangs. There is also no evidence of longer overhangs on the windward side to protect walls from wind driven rains, neither are there wind breakers nor buffers on the windward side.

Traditionally, the community has a good building maintenance culture. This is done at least once a year during the dry season i.e. between April and October. Normally, plastering, plinthing and re-roofing are the main tasks. Earthen plaster is normally applied externally for waterproofing and internally for appearance and to even out the wall surfaces. It is a common practice to retouch the plastering of the internal wall of granaries. There are little or no extensions to the existing buildings save for internal partitioning. Families either put new buildings or demolish existing ones to create space for a new structure. Three Wards, namely 13, 18 and 20 were selected for case studies. The criteria for their selection are: Ward 13 is a flood prone area; Ward 18 is one of the first areas to be inhabited in this District; Ward 20 is a former commercial farming zone and now a resettled area. In the Villages in the later Ward, save for Dhlula Villages were occupied under the government fast track resettlement programme between 1998 and 2002. Dhlula was set up by ex-farm workers when the previous owner moved out of the country in the early eighties.

Ward 13 Villages

These are Villages along the Gwayi Riverbanks, the main river in the District. As such, they are affected by floods due to the seasonal bursting of the riverbanks during heavy rains. The most severe was the Cyclone Eline induced floods in 2000 and river floods in 2001. Although flash floods occur anywhere in the district, villages in the Gwayi River flood plain have been the most affected especially as was the case in 2005. Floodwater destroys homes, household property, livestock and other important utilities, which suffer extensive structural damage. When people have lost their homes to such natural calamity, only local materials are available for reconstruction. Relief agencies through the Civil Protection Unit (CPU) can only assist in rescuing operations, and provision of relief labour and temporary shelter. In the ensuing scenario the victims have to respond to the situation at a very short space of time using locally available materials mainly in their raw state. Normally the fastest construction techniques are employed, resulting in structures with low durability, unable to withstand the next seasonal floods. Consequently, adobe, grass and wood remain the main building materials in the Ward. Despite the frequency of floods in the area, the communities have not been pro-active in developing technologies/strategies for post flood construction. Thus flooding, speed of construction, availability of materials, external influence and rising incomes are the major factors affecting the trends in earthen construction in this Ward.

Ward 18 Villages

The political situation before independence and the civil strife between 1980 and 1987 led to the slow rate of socio-economic development of this area. Driven out by poverty, unequal opportunities and political unrest, economically active members of the community trekked to South Africa and Botswana as refugees. The males (mainly

craftsmen) were more mobile during the civil disturbances. The resultant attrition of the expert builders created unwanted gap in continuity of building culture and led to low quality shelter construction outputs. Unfortunately, the migration trend has persisted with negative impacts on continuity of sustainable building practices.

Today, Tsholotsho's wealthy sons and daughters in diaspora especially in South Africa give Ward 18 a comparative advantage in infrastructure development over neighboring districts such as Lupane, Hwange and Bubi. Equally true is the rapid disappearance of the local architectural milieu and building practices in favour of diasporian practices in non-traditional materials. Consequently, foreign influence, higher aspirations and rising incomes led to a revolutionary transformation of the architectural landscape of this Ward. Today, more and more people find appealing the use of non-traditional materials and technology to the detriment of appropriate local materials. However not all families have members who earn their livelihoods outside the country. There are still a lot of people who are unemployed who channel their meager resources to their housing needs. They hire out their labour locally for their livelihoods. Their success is solely on fate and chance. This has led to the stratification of the communities in terms of the haves and the have nots. These factors have brought negative trends in shelter development using earthen construction technology. Regularly shaped adobe bricks are the most common type of earthen materials in this area. Deforestation has led to reduced use of pole and dagga. Due to the increasing distance to locations of colourful clays, decorators are opting to use low quality mud and other materials.

In a bid to increase the durability, reduce frequent maintenance and improve appearance, there has been an increased use of impervious/waterproof plasters on external walls, cement mortar and plaster on floors and walls. Although this approach improves the outlook, the plasters often delaminate within two years after application because of weak bonding. This also justifies the use of non-traditional materials eg: cement mortar, for the repairs of earthen structures. The tendency towards application of non-traditional materials on earthen construction is a pertinent issue of concern requiring conserted research for optimization.

Ward 20 Villages

The resettled farmers in this Ward were all originally from different communities within the District. Local materials are available in abundance. However, owing to the shortage of skilled builders, the output quality is poor. Besides, villagers walk up to 10km to fetch water for building purposes. Therefore the scarcity of water contributes to the poor quality of the earthen products. Thus the bricks soon exhibit cracks and other defects. In addition, the high speed of construction affects the durability of the structures. The use of pole and dagga has become the most common earthen construction method. Naturally, the newly resettled farmers need to build many structures to establish their homesteads. These include kraals, houses, perimeter walls and external works. Normally, developments in a homestead are incremental. Building works are normally done during the period of May to October. Except in some special circumstances, only family labour will be available in this period as most households are preoccupied with their pressing commitments.

The prevalent building material used in the Ward is sun dried earth bricks. The moulds are cut from disused five litre cooking oil containers. The pole and dagga technique is not refined and produces irregularly shaped walls. Lack of adequate infill on walls has lead to frequent maintenance as the infill falls away in rainy season. Floors in this area are also earthen. Rendering and painting are practiced here but time constraints have led to fewer houses being rendered.

Trends and Impacts

The desire to build shelter with less frequent maintenance has brought about understandable paradigm shift in shelter construction amongst the communities. It has certainly resulted in a changed architectural milieu. Foreign influence and sub-contracting has brought about the weakening of strong family ties. Developments in earthen technologies have resulted in a discernible level of expertise on traditional practices. Arguably, this has improved family incomes and diversified source of their livelihoods. However much of the familiar archi-forms are fast disappearing in the process. Although burnt bricks are the prime choice at the moment and locally produced in the District, its production entails the use of wood resulting in deforestation and environmental degradation. In spite of the fact that cement stabilized earth blocks are growing in popularity within the district, their rate of use is limited by the hyper inflationary state of the economy and a very erratic supply of cement since 1997. High-pressure compaction machines like the Cinva Ram and the Amandla Press have been promoted by BTI. The dependence syndrome created by the NGOs has made it difficult for many families to acquire these machines.

Government policy for shelter and infrastructure provision for rural communities based on new concepts and materials has a further discouraging impact on the communities who see their indigenous houses as inferior [7]. It further strengthens their perception that traditional earthen houses do not qualify for modern life conditions. There is therefore a need to urge the Ministry of Rural Housing and Social Amenities to re-appraise the current rural housing policy with a view to popularizing innovative materials and technologies.

Conclusion

On the strength of its affordability, abundance and availability, earthen materials will continue to be of fundamental importance in rural housing and as one of the main building materials for rural as well as urban communities in the near future, despite the attendant social stigma and the apparent popularity of non-traditional materials. Naturally, earthen houses provide an environment compatible with the life style, social, and cultural values, economic and physical needs of the rural communities. Doubtless, earthen materials remain the tested and true for human settlement development. From the evaluation of the case studies, it is evident that geographic, physical and climatic conditions in the district affect the layout and choice of earthen construction systems. The prevailing conditions with regards to rising incomes, external influence, migration etc., have led to a high rate of social changes and consequently favour the use of non-traditional building materials. Culture and tradition, natural disasters, database of traditional building skills, poverty, speed of construction, availability of labour were the main reasons for continued use of traditional earthen practices. In the cost analysis factor for earthen construction, the procurement/hiring of compacting equipment and stabilizers should be inclusive. As the cultural, physical, social and even psychological needs change with time, earthen construction must be developed to move with them. Thus from the findings of this research there is a valid case for promoting indigenous earthen dwellings through improved and appropriate earthen construction techniques.

The communities of Tsholotsho and rural Zimbabwe in general should not abandon locally available material, but new technologies must be designed to enhance their quality

and durability as sustainable technology is crucial for shelter delivery in Zimbabwe. This will not only help in sustainable rural development but also have long-term positive impact on the well being of rural Tsholotsho communities.

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Development of Quality Cereal Based Composite Flour for Nutritionally Vulnerable Children Using Locally Available Raw Material

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Key words: Cereal based composite flour, Quality Protein maize, Soybean, Orange fleshed sweet potatoes, nutritional composition

Abstract
Quality protein maize (QPM) based composite flour for nutritionally vulnerable groups was developed using QPM, soybean and orange fleshed sweet potatoes (Caceapedo variety). Single flours of QPM was prepared by soaking the grains into cold water at ambient temperature for 24 hours, drained and then milled into flour using a conventional milling machine. Soybean flour was prepared by roasting the grains and milling them also using a conventional milling machine. Orange fleshed sweet potatoes (OFSP) were prepared by washing, peeling, cutting, soaking in sodium metabisulfite solution for three hours and milling. Single flours were mixed in different proportions. Prepared gruels using different composite flours with traditional methods were subjected to sensory evaluation by 15 testing panellists. Panellists scored the gruels made with 55 g of QPM, 35g of soybean and 10g of OFSP as the more testing than other nine tested gruels. The preferred composite flour and the red sorghum flour taken from Butare market were subjected to nutritional analysis using ISAR chemistry laboratory for comparison. Results showed that the protein concentrations were higher in the composite flour than in the sorghum flour normally used for gruels preparation for young children. The concentrations were as follows Protein: 18.32mg/100g of flour; ash: 3.62mg/100g in composite flour comparing to Protein: 6.25mg/100g and ash 1.85mg/100g sorghum flour.

Background

The term to wean means to accustom and it describes the process by which the infant gradually becomes accustomed to the full adult diet. During the weaning period the young child's diet changes from milk alone to one based on the regular family meals. Milk should be given as a supplement to the child for as long as possible [1]. Weaning is a dangerous time for infants and young children. It is well known that there is higher rate of infection particularly of diarrhoeal diseases during the weaning than any other period in life [1]. This is because the diet changes from clean breast milk with certain anti-infective factors to foods which are often prepared stored and fed in very unhygienic ways. Malnutrition is more common during this transitional period than in the first six months of life because families may not be aware of the special needs of the infant, may not know how to prepare weaning foods from the foods that are available locally, or may be too poor to provide sufficient nutritious foods. Often, the weaning foods for infants are of poor nutritional value and unhygienically prepared and this often leads infection and malnutrition. Today traditional child feeding habits that were reasonably satisfactory can no longer be followed because of urbanization, new patterns of family structure higher prices of foods and changes in the pattern of women's work [1]. The need for weaning food for some babies from six months to two years old is being met through commercially produced weaning foods. These foods are normally excellent products and meet the

nutritional requirements of the infant. However the products marketed are expensive for the target groups who need such product especially in poor communities in Rwanda. It is therefore necessary to develop less costly but equally nutritious weaning foods that may be within the reach of the target group. It is advised that the development of weaning foods should utilize raw material based on locally available staple grains such as maize and other cereals and legumes [2]. It is also advised that the technology for developing such foods should not be sophisticated and should be highly adaptable. From the point of view of children's nutritional requirements, the weaning food mix should be nutritionally well balanced in carbohydrates, proteins, vitamins and essential minerals. It should be precooked if possible so that it can be fed to babies as soft products by simple stirring in hot or boiling water. The fiber content in the material should be low within permitted limits. Traditional cereal foods play an important role in the African diet [3]. Attempts have been made to improve the protein quality of many cereal based foods including ogi in Nigeria, corn dough in Ghana, Kisra in Sudan and many others [3,4]. Supplementation of legumes is one way of improving the protein quality of cereals diets. Most of the protein enrichment of traditional foods has used soybean as source of protein. Another approach is to develop high protein foods with physical and organoleptic characteristics similar to those existing foods but based on readily available commodities and technology. The current study aims at developing a Quality Protein Maize based composite flour for nutritionally vulnerable groups.

Hypothesis

The QPM based weaning gruel is higher in nutrients density than the normal sorghum based gruel from the market and is organoleptiqually acceptable.

Objectives

1. To develop a QPM based composite flour for weaning porridge enriched with either soybean or high Fe and Zn bean
2. To determine the nutrients content of the composites flours
3. To assess the acceptability of the QPM based weaning gruels

Methodology

Materials

The materials used included QPM, high Zn and Fe bean, sorghum, soybean, and orange fleshed sweet potatoes. They were newly produced raw materials from Institut des Sciences Agronomiques du Rwanda (ISAR). We used pool 26 for QPM, Caccarpedo for OFSP, CAB2 for bean and Peka 6 for soybean.

Preparation of QPM grain

In the first methods, grain maize was soaked in water at ambient temperature for (° C) 24 hours after which water was drained. The grain was steamed for about 10 minutes and then sun dried.

In the second method, the grain was soaked for about 24 hours, dried followed by roasting sparingly in order to improve the taste and odor. The reason to use non roasted maize was to see how the lysine lost during the roasting step may be minimized.

Preparation of high Zn and Fe bean

Beans were sorted, washed and then steamed for about 10 minutes. The steamed beans were cooked for about 30 minutes in order to reduce antinutritional factors. Beans were cooled and the skin removed using hands. The deskinned beans were then sun dried and milled into flour using a normal commercial hammer mill at ISAR.

Preparation of germinated sorghum flour

Sorghum was soaked into water for about 2 days. It was then drained, washed and put into a dark place for two days to germinate. The germinated grains were sun dried, and then millet into flour.

Preparation of soybean flour

Soybean was sorted, washed, sun dried and roasted. All these steps were covered for one day. The roasted soybean was then milled into flour.

Preparation of OFSP flour

Orange fleshed sweet potatoes (OFSP) were prepared by washing, peeling, cutting, soaking in sodium metabisulfite solution for three hours. The chips were then removed from the solution, washed and sun dried. They were milled into flour.
All these steps were covered for one day.

The preparation of composite flour for weaning porridge

The simplest recipes for weaning foods are composed of only two ingredients. An example is of cereals and roots mixed with legume and this is called basic mix. However other foods must be added to make a complete meal [5]. Based on this principle, the following square in Figure 1 was proposed by [1] and was used for the preparation of different proportions of simple flours to be used in the mixtures.

Preparation of composite flours

Four composites flours types were prepared. The first formulations were (composite flours I) was prepared by mixing roasted Quality Protein Maize , High Fe and Zn bean flour, OFSP flour and germinated red sorghum flour.

Fig 1: Food square followed during the preparation of composite flours

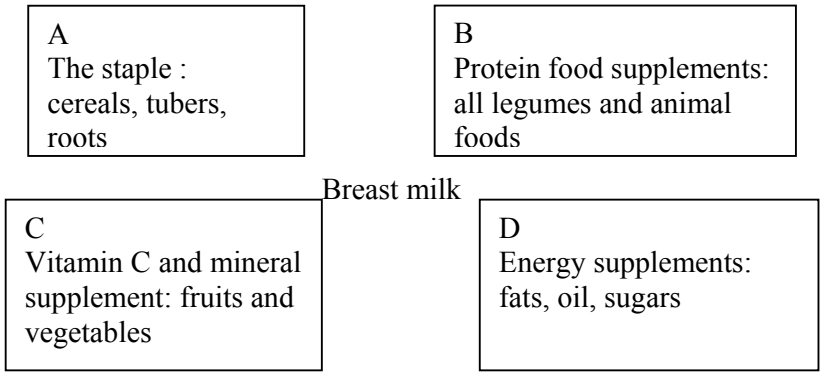

Table 1 shows different proportions of the ingredients used in preparing composite flour I.

Table1: Proportions of ingredients used during the preparation of the gruels for Composite flour I

Samples * codes	Maize roasted (g)	Bean (g)	OFSP (g)	Germinated sorghum (g)
923	85	10	0	5
886	75	15	5	5
779	65	20	10	5
766	55	25	15	5
745	45	30	20	5
445	35	35	25	5
567	25	40	30	5
351	15	45	35	5
614	5	50	40	5

Composite flour II was composed with a mixture of non roasted QPM, high Fe and Zn bean, OFSP, and germinated red sorghum.

Table 2: Proportions of ingredients used during the sensory evaluation of the gruels

Samples codes	Maize non roasted(g)	Bean (g)	OFSP(g)	Germinated sorghum (g)
852	85	10	0	5
735	75	15	5	5
652	65	20	10	5
544	55	25	15	5
432	45	30	20	5
378	35	35	25	5
298	25	40	30	5
427	15	45	35	5
356	5	50	40	5

Composite flour III was made with a mixture of roasted soybean, OFSP and germinated red sorghum (Table3). Composite flour IV was composed with a mixture of non roasted QPM, roasted soybean, OFSP and germinated red sorghum. Table 4 shows different proportions used during the sensory evaluation test of the gruels.

Table3: Proportions of ingredients used for the preparation of the gruels for composite flour III

Samples codes	Maize non roasted(g)	Soybean(g)	OFSP(g)	Germinated sorghum (g)
891	85	10	0	5
224	75	15	5	5
390	65	20	10	5
135	55	25	15	5
265	45	30	20	5
589	35	35	25	5
754	25	40	30	5
537	15	45	35	5
491	5	50	40	5
10	25	20	50	5

Table 4: Proportions of ingredients used during the sensory evaluation of the gruels

Samples codes	Maize roasted(g)	Soybean(g)	OFSP(g)	Germinated sorghum (g)
662	85	10	0	5
859	75	15	5	5
922	65	20	10	5
864	55	25	15	5
591	45	30	20	5
246	35	35	25	5
100	25	40	30	5
340	15	45	35	5
230	5	50	40	5

Preparation of gruels

All the ingredients used in a gruel sample were hand mixed together in the mentioned proportions. The gruels were prepared using the traditional methods of mixing cold water with the flour, putting on the electrical oven and cooking while stirring until the gruel is ready to be tested.

Sensory evaluation

Sensory evaluation was done when the gruel attained the normal temperature at which it is normally consumed at household level. Gruel in identical glass bowls were coded in three digit numbers for the presentation to 13 trained panelists (a mixture of boys and girls) of ISAR. They were given distilled water in colorless glasses to clear the palate. Panelists were asked to taste the foods and indicate how acceptable the foods were using 5 point hedonic scale. The hedonic scale used for samples scoring according to the panelists preferences was as follows: 0= very poor, 1= poor, 2= passable, 3= good; 4= very good; 5= excellent. The sensory attributes evaluated were color, aroma, taste, texture and overall acceptability.

Statistical analysis

Data were subject to one way analysis of variance using MSTAT C, and a difference was considered to be significant at $P<0.05$ according to[6].

RESULTS AND DISCUSSION

The following tables 5, 6, 7, and 8 show the panelists results of different formulations.

Table 5: Mean scores of the sensory attributes for the nine different gruels made with non roasted, QPM, high Fe and Zn Bean, OFSP and germinated red sorghum

Samples codes	color	Texture	Aroma	Taste	Viscosity	Overall acceptability
852	2.615	2.615	2.538	2.615	2.769	2.885
735	2.846	2.385	2.615	2.654	2.538	2.769
652	2.615	2.577	2.615	2.808	2.538	2.692
544	2.615	2.308	3.000	2.462	2.538	2.615
432	2.846	3.007	3.077	3.077	2.538	3.308
378	2.538	2.923	2.92	3.000	2.927	3.077
298	2.769	2.846	2.69	2.615	3.077	2.769
427	2.591	2.427	2.77	2.538	2.923	2.769
356	2.538	2.538	2.538	2.462	2.846	2.462
CV %	24.15	30.57	30.32	28.50	30.69	27.13
LSD (5%)	0.506	0.632	0.650	0.599	0.656	0.595

The above nine formulations were not significantly different for all parameters. Since the overall acceptability parameter is scored after the panelist has considered all the other parameters, and since the formulations are QPM based, the relatively high scored formulation (3.308) under overall acceptability was kept as the one for further analysis. That formulation is a mixture of 55 g of roasted QPM, 25 g of high Fe and Zn bean flour, 15 g of yellow cassava flour and 5 g of germinated sorghum. The time for cooking for this formula was estimated at 5 minutes using a kitchen oven with minimum of 800 ml of hot water.

Table 6: Mean scores of the sensory attributes for the nine different gruels made with roasted, QPM, bean, OFSP and red sorghum flours

Samples Codes	Color	Texture	Aroma	Taste	Viscosity	Overall acceptability
923	2.846	2.923a	3.000	2.846a	2.646	3.000
886	2.692	2.538a	2.615	2.462ab	2.923	2.841
779	2.846	2.846a	2.615	2.846a	2.615	2.923
766	2.923	2.923a	3.000	2.615a	2.462	2.574
745	3.154	1.846b	2.615	2.923a	3.077	2.910
445	3.077	1.923b	2.462	2.615a	3.000	3.080
567	2.923	1.715b	2.308	2.692a	3.231	2.225
351	2.538	1.684b	2.077	1.923ab	2.846	2.000
614	2.231	1.542b	1.826	1.615b	2.077	2.462
CV %	26.60	24.70	31.21	33.91	34.18	27.00
LSD (5%)	0.581	0.508	0.629	0.661	0.730	0.560

The formulations were statistically significant different in texture and taste ($P<0.05$). Thus the most acceptable formulation was a mixture of flours with 55 g of roasted QPM, 25 g of bean, 15 g of OFSP and 5 g of germinated sorghum. The cooking time for this formulation was estimated at 5 minutes using a kitchen oven with minimum of 600 ml of hot water.

Table 7: Mean scores of the sensory attributes for the nine different gruels made with non roasted QPM, soybean, OFSP and Sorghum flours

Samples codes	Color	Texture	Aroma	Taste	Viscosity	Overall acceptability
891	2.846	2.731	3.192	3.000a	2.308	3.000
224	2.692	2.654	2.923	2.808ab	2.462	2.771
390	2.846	2.846	2.923	3.115a	2.769	2.923
135	2.923	2.846	2.885	2.654ab	2.615	2.910
265	2.846	2.077	2.538	2.231ab	2.462	2.412
589	2.808	2.769	2.615	2.369ab	2.538	2.790
754	2.538	3.000	2.846	3.038a	4.000	3.052
537	2.462	2.692	2.308	2.154ab	2.462	3.000
491	2.462	2.500	2.385	2.385ab	2.154	2.531
CV %	22.04	28.57	31.05	32.77	66.57	26.23
LSD (5%)	0.466	0.596	0.668	0.683	1.369	0.520

Overall acceptability of gruels in the above table was statistically similar for all nine formulations. However, for the taste, the formulation made from a mixture with 35 g of non roasted QPM, 25 g of roasted soybean, 15 g of OFSP and 5 g of germinated

sorghum scored high comparing to other formulations with minimum cooking time of 7 minutes and 700 ml of cooking water. This formulation was kept for further analysis.

Table 8: Mean scores of the sensory attributes for the nine different gruels made from roasted, QPM, soybean, OFSP and sorghum flours

Samples	color	Texture	Aroma	Taste	Viscosity	Overall acceptability
662	3.462a	2.769ab	2.962a	3.000	3.154	3.000a
859	3.231a	3.385a	3.154a	3.462	3.192	3.308a
922	2.731ab	2.769ab	2.923a	3.000	2.769	2.923a
864	2.808ab	3.038a	2.269b	3.423	3.000	3.192a
591	3.077a	2.923a	3.000a	3.262	3.308	3.195a
246	3.077a	2.538ab	2.538b	3.615	3.077	2.615ab
100	2.462ab	2.385ab	2.231b	2.692	2.538	2.577ab
340	2.577ab	2.615ab	2.769a	2.462	2.669	2.692ab
230	2.423ab	2.385ab	2.385b	2.462	2.231	2.385ab
CV %	24.77	28.25	26.64	29.33	39.03	23.68
LSD (5%)	0.554	0.606	0.581	0.673	0.862	0.530

Results in Table 8, show that the parameters taste, aroma, color and texture for the formulation made with 55 g of roasted maize, 25 g of roasted soybean, 15 g of yellow cassava and 5 g of germinated sorghum was the most appreciated with minimum time of cooking of 10 minutes and 500 ml of cooking water. Thus, this formulation was kept for further analysis. The most accepted formulation and the sorghum flour were analyzed by ISAR laboratory. Results showed that QPM based composite flour was higher in nutrient density than sorghum flour. The concentrations were as follows Protein: 18.32mg/100g of flour; ash: 3.62mg/100g in composite flour comparing to Protein: 6.25mg/100g and ash 1.85mg/100g sorghum flour. The high density in nutrient content of the QPM based flour was expected. This is because it is well known that the addition of soybean flour and maize with high content of lysine and tryptophan were expected to improve on the nutrition composition of the flour/

Conclusion

The gruels were acceptable for all tested parameters. There was no single rejected formulation of tested ingredients. . Panelists scored the gruels made with 55 g of QPM, 35g of soybean and 10g of OFSP as the more testing than other nine tested gruels. Therefore, knowing that Protein Energy Malnutrition (PEM) is the most common malnutrition disorder among the most nutritionally vulnerable groups (infants, pregnant and lactating mothers in Rwanda, there is a need of developing more recipes using the newly introduced biofortified crops in Rwanda in order to diversify the preparations based on the most simple, less costly methods with maximum nutrient retention. This study also demonstrated successful use of locally available and affordable foods to enhance nutritional quality of nutritionally vulnerable groups.

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Benchmark Study on Husbandry Factors Affecting Reproductive Performance of Smallholder Dairy Cows Subjected to Artificial Insemination (AI) in Nyagatare, Gatsibo, and Kayonza Districts of Rwanda

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Abstract
The objective of this study was to identify existing farmer practices that may influence reproductive performance of cows bred through artificial insemination. A random sample of 1080 households supplying milk to the milk-processing centre was drawn in Nyagatare, Gatsibo, and Kayonza districts of Rwanda between October and November 2007. Extensive grazing (71 %) was the predominant production system identified with only 10 % of the farmers supplementing veld pastures with barna grass during the dry season. Farmers use a variety of signs to detect estrus in cows. Among these, 'standing to be mounted' (6.83 %), was rated the least while mucus discharge (35.58%) was regarded as the most important sign of heat in cows. Further, only 11.54 % of the farmers invited inseminators after observing standing heat, while the majority (88.46 %), observe for signs such as decreased feed intake (26.51 %), 'mounting of other cows' (21.54 %), clear mucus discharge from vulva (15.38 %), swelling of vulva (13.85 %), and 'being followed by a bull' (11.54 %). Non-return to heat after service was the predominant method of pregnancy diagnosis used by about 86 % of the farmers. The major reproductive problems encountered included abortion (13 %), retained placenta (33 %), and dystocia (37 %), while tick borne diseases (27.6 %) and gastrointestinal parasites (18.4 %) were among the most prevalent general diseases reported. Very few farmers (1.1%) vaccinated their cattle against reproductive diseases such as brucellosis and more than 95 % do not keep records. None of the respondents completed the sections requiring disclosure of critical reproductive events such as dates of service and calving. Seventy-eight percent of the respondents were below primary school education. Poor heat detection, diseases, nutrition, and lack of record keeping were the major husbandry factors identified whose performance was below expected. The implications of these findings are discussed in the text.

Background and justification

Artificial insemination (AI) has become one of the most important biotechnologies ever devised for improvement of reproductive performance of farm animals. Todate, it is the main tool for dissemination of outstanding germplasm, control of venereal diseases and cost-effective dairy farming. The dairy industry plays an important role in the agrarian economy of Rwanda. Development of this sector is viewed as a means of reviving the rural economy, achieving national self-reliance and ensuring food security in milk and milk products. However, of the many constraints facing dairy development in Rwanda, low genetic merit of indigenous cattle is understood to be the most important. As a result,

since 1996, the government of Rwanda vigorously pursued genetic upgrading of indigenous stock through crossbreeding with exotic germplasm in order to enhance milk production. In order to rapidly achieve this objective, artificial insemination (AI) was accepted as the primary breeding method [19]. The number of inseminations over the last two years has increased drastically from 10 000 in 2006 to 47 000 in 2007, and milk production improved from 55 500 tonnes in 1999 to 158 700 tonnes in 2007. Over the same period, milk powder imports dropped from 1280 tonnes to 500 tonnes [19].

Although both number of inseminations and milk production has improved to some extent, the overall pregnancy rate following AI has been very low, around 50%. The precise cause of this failure of AI, however, is unknown. The resulting decrease in rates of reproduction has direct economic implications on the Rwandese dairy industry and warrants identification of the aetiological factors involved and formulation of appropriate interventions. Clearly, there is a need to undertake a comprehensive assessment of fertility and to identify various factors affecting the success of AI. With this in mind, a series of studies were designed to assess the performance of the AI service and identify its constraints, in order to develop and implement remedial measures.

Initially, a field survey was carried out to identify prevailing animal husbandry practices among smallholder farmers. Part of the objectives of the initial survey was to identify problems that required further investigations so as to enable generation of tailor – made solutions. These field observations will be complemented with data on measurement of milk progesterone using radioimmunoassay (RIA) to monitor the success of AI. Monitoring the success of AI through conventional methods, such as rectal palpation of genitalia and non-return rate, has very limited value. On the contrary, measurements of progesterone profiles of cows by RIA has been used to assess the suitability of animals for AI, monitor stages of estrous cycle, perform early diagnosis of non-pregnancy [1], and diagnose factors limiting reproductive efficiency [7]. This paper presents the results on the initial benchmark survey on prevailing husbandry practices that may negatively influence success of AI in Nyagatare, Gatsibo, and Kayonza districts. The overall aim of the project is to improve the productivity of smallholder dairy farms through improvement in the performance of AI services.

Materials and Methods

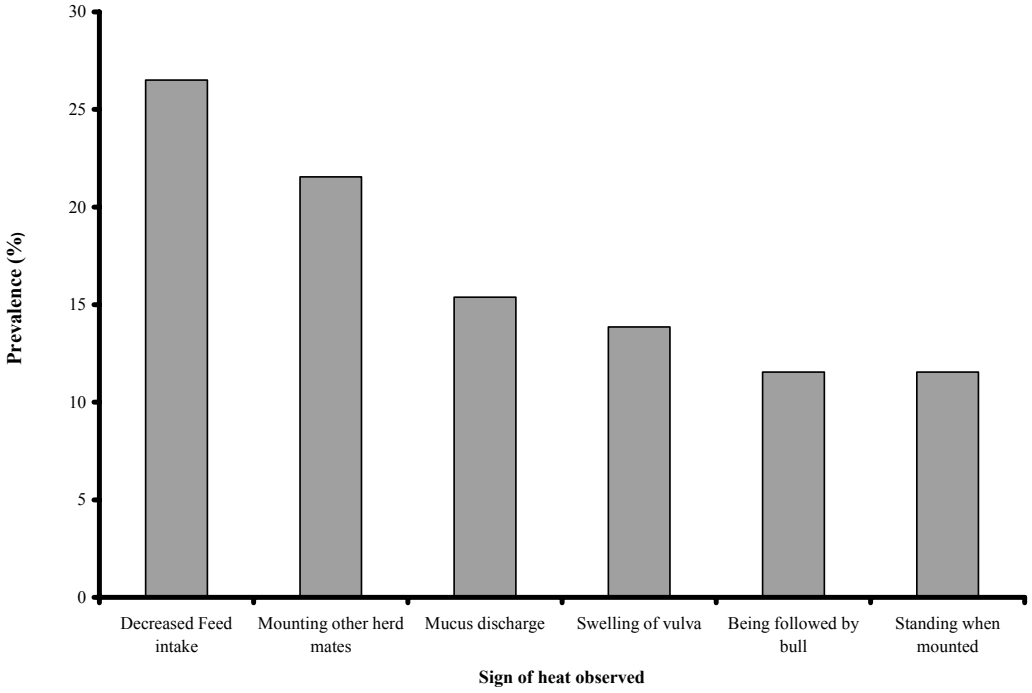
A random sample of 1080 smallholder households in the former Umutara Province (Nyagatare, Gatsibo, and Kayonza Districts) was carried out between October and November 2007. Twenty per cent of farmers delivering milk to each milk collection centre in the target area were randomly selected. Data collection was through household interviews conducted by trained enumerators using a pre-tested semi-structured questionnaire. The information gathered included level of education, record keeping, production system, heat detection, diseases and disease control measures. The number of questionnaires administered to farmers in each district were 761 (Nyagatare), 169 (Gatsibo), and 150 (Kayonza). The data collected was entered into SPSS Version 8 databases for descriptive statistical analyses.

Results

Three production systems were identified with the extensive grazing system (71 %) being the most common followed by semi-zero or mixed grazing (15 %), and zero grazing (9 %). Only 10 % of the non-zero grazing farmers gave extra feed (supplementary feed) to their cows during the dry season. Communal dams or rivers were the major source of drinking water for their cows. Farmers use a variety of signs to detect estrus in cows. Among these, ‘standing to be mounted’ (6.83 %), was regarded as the least important sign

while mucus discharge (35.58%), was ranked the most important sign of heat in cows. Not surprisingly, the least (11.54 %) of the farmers invited inseminators after observing standing heat, while the majority (88.46 %), observe for a number of varied secondary signs of heat such as decreased feed intake (26.51 %), 'mounting of other cows' (21.54 %), clear mucus discharge from vulva (15.38 %), swelling of vulva (13.85 %), and 'being followed by a bull' (11.54 %) (Figure 1). None of the farmers had a heat detection programme, and estrus detection was carried out on an ad hoc basis. After mating, non-return to heat (85.6 %) was the predominant method of pregnancy diagnosis used, followed by rectal palpation (4.8 %), while 4.4 % did not utilize this management tool. General animal health problems identified by the farmers included dystocia (37 %), retained placenta (33 %), tick borne diseases (27.6 %), gastrointestinal parasites (18.4 %), abortion (13 %), Blackleg and Anthrax (9.0 %), Foot and Mouth Disease (8.3 %), Trypanosomiasis (8.2%), Lumpy Skin Disease (7.9%), and many others reported by less than 5% of the farmers. While vaccination was used to control general diseases such as Foot and Mouth Disease, Anthrax and Lumpy Skin Disease, very few (1.1 %) vaccinated their cows against specific reproductive diseases such as brucellosis. Seventy-eight percent (78 %) of the farmers had not attended school beyond the primary level, and 95 % did not keep records. None of the respondents completed sections requiring disclosure of critical reproductive events such as dates of service and calving.

Table 1. The distribution of signs of heat observed before inseminators are invited.



Discussion

Extensive grazing management systems where cows are given very little supplementary feeding may affect reproductive performance of cows subjected to artificial insemination. These systems do not generally guarantee enough feed for the cows unless a comprehensive supplementary programme supports it, and, the mixing of cows from

different herds and different disease status promotes spreading of diseases. As reported by Obese [17], and Domecq et al [8], lack of supplementary feeding in extensively grazed dairy cows affect their reproductive performance. Frequently, extensively grazed cows are exposed to heat stress, which suppresses estrus activity in cows [13, 20, 25], making its detection difficult. In addition, exposure to heat stress 1-3 days after insemination induces embryonic death [9], leading to poor conception rate and repeat breeding.

Almost eighty-nine percent (88.46 %) of farmers under study are inseminating cows while they are not in true estrus. Such a level of heat detection error is alarming, and well outside the 5 – 30 % range frequently observed on most farms [21]. Estrous detection errors are brought about by identifying cows to be inseminated based on secondary signs of estrus. The problem with use of secondary signs is that they vary in duration and intensity, and may occur before, during, or after standing heat. As such, these signs cannot be used to correctly predict the time of ovulation. Therefore, inseminating cows based on secondary signs of heat will result in asynchrony of sperm-oocyte interactions leading to poor conception [12, 11, 16], and wastage of semen and labor [18, 24]. Perhaps, instead of using these signs for deciding when to inseminate, farmers should use these signs as clues or watch the specific cow more closely for standing behavior.

There are many possibilities as to why farmers in the study inseminate cows based on secondary signs of heat. Common practices resulting in high heat detection errors include inadequate animal identification, poor record keeping, lack of a specific heat detection programme, and lack of knowledge on significance of the various heat signs displayed by cows. All these negative practices are highly prevalent in the study area. Standing to be mounted' (6.8%), was ranked the least important sign of heat yet the converse is true. This shows that those responsible for checking for heat do not fully understand signs of heat. In the absence of a heat detection programme, people involved in heat detection will only be present with the cows at regular working hours. This can give rise to increased missed heats because the pattern of heat onset in cows is variable, with the greatest activity occurring early morning and late evening [2]. According to Senger [23], the ideal goal for estrous detection error rate should be less than 2% in any herd. With 89 % of farmers failing to observe standing heat, it is clear poor heat detection is the major reproductive management problem in the study herds. The error margin as reported herein is a serious cause for concern. It should be noted, however, that estrous detection efficiency is under the total control of the management team and significant improvements in overall herd reproductive performance can be achieved if estrous detection is improved [15]. Implementation of programs designed to focus exclusively on detection of estrus is highly recommended.

Farmers in the study use non-return to heat 18-24 days after service as a sign of pregnancy. However, while this is considered the easiest and cheapest method of pregnancy diagnosis, it requires keen and timely observation superimposed on heat detection skills for it to be accurate. As observed, farmers in the present study have a serious problem with heat detection, hence pregnancy diagnosis using non-return rate could be inaccurate and misleading. As reported by Senger [22], the efficiency of non-return rate is further confounded by embryonic mortality, which results in lower calving rates. This method further suffers the disadvantage that farmers are generally not keen to follow up on heat detection on the same cow after insemination. In addition, cattle kept under zero grazing (though a small percentage in our study), exhibit a high degree of silent heats, which are difficult to detect. Because of these shortfalls, rectal palpation remains the most reliable, efficient method of pregnancy diagnosis. However, its requirement for skilled labour may explain why it is not a favorite with the farmers.

Farmers identified a number of systemic and reproductive diseases, which are a major cause for concern. Among the reproductive problems reported, dystocia was the major cause for concern. Dystocia means "difficult birth." The prevalence of dystocia (37 %) reported in this study is much higher than the 2-12% as reported from many field studies [23]. Although it can occur due to other causes, the crossing of exotic, large framed breeds such as the Friesian Holstein with the short, framed local Ankole cows precipitate feto-pelvic disproportions (calf too large for the birth canal) leading to dystocia[3]. The problem with dystocia is that with few exceptions, cows that have 'difficult births' almost always have "downstream" reproductive problems inclusive of retained placenta, metritis, delayed uterine involution and poor cyclicity [23]. Similar findings were reported by [15, 25]. Further studies are needed to identify the true factors behind this unprecedented increase in prevalence of dystocia.

The causes of retained placenta are fully known [23]. Nevertheless, the prevalence of retained placenta (33 %) reported in this study is much higher than the literature values of between 4% and 10% [22, 23]. Like dystocia, cows with retained placenta almost always experience infertility syndromes characterized by delayed return to estrus, increased services per conception, lengthened calving interval, higher culling rate, reduced milk production and increased days open [6, 10]. These infertility syndromes are believed to be because of the subsequent endometritis and pyometra that develop following retained placenta [4, 5]. The combined high prevalence's of abortion and retained placenta is highly suggestive of the presence of brucellosis infection among the cows [14]. Because of zoonotic and reproductive effects, urgent longitudinal studies are needed to rule out the suspicion on brucellosis.

Regardless of when and how pregnancy diagnosis is carried out, the identified reproductive problems affects performance of Ai through poor conception, embryo mortality, and abortion, hence farmers might be justified in their complaints on poor pregnancy rate in dairy cows subjected to artificial insemination. However, it must be noted that problems such as dystocia, retained placenta, and abortion, are under the direct influence of the reproductive system of the cow. For that reason, these factors are somewhat difficult to manage and control because the cow's reproductive system is the primary component influencing the outcome. Nevertheless, reduction in incidence of dystocia can almost always occur when sires used in AI are selected for a high degree of calving ease especially in heifers. Further, calvings should be accompanied by attendants with the appropriate obstetrical skills. Thus, management can exert a strong preventive influence by keeping records and selecting calving-ease bulls for use in heifers and employing proper heifer management and maternity pen care. Further, a good reproductive health program, which provides for checking normal uterine involution and return of ovarian cyclicity, is required.

Apart form specific reproductive disorders, a high prevalence of general systemic diseases such as East Coast fever (ECF), black leg, anthrax, and lumpy skin (to mention but a few), were observed. These diseases result in sickness and or death of cows. In particular, East Coast Fever can have severe impacts on exotic cattle. Diseases, whether associated with the reproductive system or other systems of the body, have deleterious effects on fertility of dairy cows [15]. The high prevalence of diseases for which disease control technology such as effective vaccines, and acaricides is available maybe taken to reflect failure of veterinary extension. Further studies are needed to determine the effectiveness of veterinary extension in the country.

More than 95 % of the farmers in the study did not keep records, while the few records being kept were incomplete, inaccurate or not updated. Poor record keeping affect performance of artificial insemination in several ways. Any attempt to improve the efficiency of AI has to be based on an understanding of the most important causes for failure under each specific production system. Traditionally, methods used to gain this understanding rely on accurate recording and analysis of reproductive events such as estrus, services, pregnancies and calvings. However, farmers in the study area rarely kept records, and even when available, they do not allow an assessment of the importance of factors such as efficiency and precision of estrus detection by the farmers or incorrect timing of insemination. Without proper records, elements used when reproductive performance is evaluated such as conception rate, numbers of services per conception, pregnancy rate, day's open, calving interval and many others cannot be measured. Simple, complete and accurate records about the entire reproductive life of the dairy cow are required to monitor components contributing to reproductive management. This aspect of management needs to be improved. Poor record keeping has been reported to be one of the major management attribute affecting AI in dairy cows [1, 11].

The majority of farmers interviewed (77 %) were illiterate. This might possibly be a directly aftermath of the 1994 genocide which wiped out most of the skilled labour force of the country. While it is debatable, in our view, such a high illiteracy level among farmers is a potential in breeding of animals through AI because it creates imbalance balance between technical demands of the AI technology and the skills of the existing farm laborers. Further analyses are needed to determine the impacts of education level on reproductive performance.

Conclusion

Artificial insemination is a comparatively sophisticated method of animal breeding whose impact on cattle development is closely linked to the simultaneous introduction of reasonable standards of animal husbandry. In our study, the major basic animal husbandry practices are well below expected standards. Poor heat detection, diseases, nutrition, and lack of record keeping were the major husbandry factors identified that needed further investigation. Training is needed to uplift management capacity of most of the farmers because most if not all of the factors identified fall directly or indirectly under the control of the individuals performing the task or making a decision about the task. It is our conviction that fertility factors controlled by man, can be improved significantly with the appropriate management decisions and implementation of well-focused herd health, production and reproduction management programmes. For example, greatest improvement in reproductive performance can be made by improving estrous detection efficiency, estrous detection accuracy, nutritional management, and record keeping, among others. The probability of successfully implementing and controlling most of the factors identified in this study is much higher than attempting to control other factors, which cannot be totally controlled by the management team.

Recommendation

The nature of our study, do not allow us to determine any causal relationships. It is therefore imperative to carry out further studies to determine the effects of each of these factors on reproductive performance of artificially inseminate cows before any corrective measures can be taken.

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The Prevalence of Bovine Brucellosis in Milking Dairy Herds in Nyagatare and its Implications on Dairy Productivity and Public Health

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Abstract
Between April and June 2008, 998 serum samples from 205 herds located in 10 different sectors within the district were screened for brucellosis using Rose Bengal Plate test. Out of a total of 998 serum samples tested, 99 (9.9 %) reacted positive for brucellosis using the Rose Bengal Plate Test (RBPT). Bovine brucellosis was detected in nine out of the ten sectors in Nyagatare, and out of the 205 herds studied, 62 were seropositive. The overall brucellosis herd prevalence rate (HP), i.e. at least one positive RBT reactor identified in a herd, was associated with sector (X^2 = 8851.228, P = 0.000), Breed (X^2 = 413.567, P= 0.002), and parity of the cow (X^2 = 580.292, P = 0.000). Significantly higher brucellosis herd prevalence values were reported for Byera (100 %), Katabagemu (45.45 %), and Rwimbogo (42.86 %) sectors. The herd prevalence was 29.62 % in Ankole cattle (95 % CI: 28.36 to 30.87) and 23.71 (95 % CI: 17.23 to 30.19) in purebred Friesian-Holstein cattle, with a statistically significant difference (x^2 = 413.567, P = 0.000). Individual animal prevalence (IAP), i.e. number of individual positive reactors, differed (P < 0.05) between and within the sectors, and was also associated with the breed of the cow. Significant higher overall IAP´s were found in Byera (20 %), Rwimiyaga (12.17%), and Rwimbogo (12 .00 %). Individual animal prevalence was 9.75 % (95 % CI: 9.34 to 10.16) in Ankole cattle and 7.15 % (95% CI: 5.46 to 8.84) in Purebred Friesian-Holstein cattle with a statistically significant difference (x2 =335.339, P= 0.000). There was no statistically significant difference in individual prevalence between Ankole cows and crossbred cows. On the other hand, the prevalence of brucellosis in cattle was also found to be higher in the older parities than younger ones. Overall seropositive reactors recorded were 12/204 (5.9 %) for parity 1, 20/181 (11.05 %) for parity 2, and 11/77 (14.29 %) for the fourth parity cows. However, no statistically significant difference was observed in the prevalence of brucellosis between male and female animals. Overall, the study reveals that bovine brucellosis is endemic in Nyagatare. The public health and livestock productivity implications of the present findings are discussed.

Background and justification

Bovine brucellosis is a highly contagious systemic bacterial disease caused by Brucella abortus (12, 7). It is primarily a disease of ruminants (5), and is regarded as one of the most widespread zoonoses in the world (13). The disease is of economic importance in dairy production because it adversely affects the reproductive and productive potential of dairy cows and is a major impediment for trade and export of livestock products (28). Infection in pregnant cows is characterized by abortion, birth of dead or weak calves, retained placenta, endometritis, repeat breeding, infertility, as well as reduction or complete loss of milk yield after the abortion. In bulls the disease result in testicular lesions such as orchitis, epididymitis, and seminal vesiculitis which affect their breeding capacity.

Besides the impacts of the disease on livestock, brucellosis is also an important zoonoses, more commonly known as undulant fever. Infection in human beings result in chronic debilitating illness which requires prolonged treatment. The established mode of transmission of *Brucella* spp. to humans is usually by direct contact with infected animals or their carcasses (32), or through ingestion of infected unpasteurized milk or dairy products (12). Affected humans develop a chronic debilitating, on- and off (undulating) febrile flu-like illness (8, 33), that is frequently confused with malaria or typhoid with the result that inappropriate treatment is often given. The course of the disease is prolonged leading to considerable medical expenses in edition to loss of income due to loss of working hours.

Brucellosis is of particular public health importance in societies that live closely together with their livestock. In Rwanda, about 92% of the population live in rural areas and depends on agriculture for survival. The rural areas or 'villages' in Nyagatare are generally regarded as resource-poor areas with a weak infrastructure, a high unemployment rate and subsistence livestock farming dominate over other agricultural activities. As observed elsewhere (21), consumption of unpasteuralised milk, undercooked or fresh meat are not uncommon in the rural households. However, very little is known about the prevalence of important zoonotic and production diseases of cattle in these areas, which is essential information for the prioritization and implementation of disease control schemes.

In our previous study (6), we observed unusually higher incidences of abortion, retained placenta, and infertility of unknown origin in dairy cattle in Nyagatare, Gatsibo, and Kayonza Districts. Although these symptoms are commonly seen in brucellosis infected herds (29, 22, 21), there is no documentation about the occurrence of this disease in this district. To gain an understanding of the prevalence of brucellosis in Nyagatare, and to seek possible explanations on the causes of abortion in dairy herds and devise appropriate control strategies in the area a large scale serological brucellosis screening survey was undertaken.

Materials and methods

Study site

Nyagatare is located in Eastern Rwanda, bordering Uganda, and Tanzania. The district is about 150 km away from Kigali, the capital city. Nyagatare, Gatsibo, and Kayonza (the former Umutara Province) hold about 40% of the cattle population of the country currently estimated at just over 1.2 million. While some of the milk produced in the district is sold at big urban markets in Kigali, most of it is sold through the informal market within the district. Presently the province is in a transition phase from the extensive traditional husbandry to the market orientated systems. The cattle population consists of predominantly local Ankole types and various crosses between these and exotic breeds, raised in extensive traditional husbandry system. However, there is an increasing proportion of introduced purebred cattle such as Friesian- Holsteins, Jerseys and Guernsey. Both cattle and small ruminants are often grazed or tethered together. All study herds were selected by stratified random sampling, milk collection centers being the strata. The criteria for selection of herds was the supply of milk to local milk collection centre, and high reported prevalence's of abortion, and retained placenta of unknown origin in previous studies (6).

Blood Sample Collection

About 10 mL of blood was collected form the jugular or coccigeal vein of each selected animal using plain vacutainer tubes and allowed to clot overnight at room

temperature. The serum samples were separated and transported in iceboxes to Rwanda Animal Resources Development (RARDA) Veterinary Research and Diagnostic Laboratory, in Kigali and stored at -20°C until testing.

Serological detection of Brucella antibodies

At RARDA, the Rose Bengal Plate test (RBPT) was used to screen the serum samples to detect the presence of *Brucella* agglutinins. Serum samples from cattle were tested using RBPT according to standard methods as described by (1, 2). Briefly, the sera and antigen were brought to room temperature for 45 min before use. One *Brucella* positive and one negative reference samples were used on each plate. Equal volumes (30 µl) of serum and antigen (concentrated suspension of *B. abortus*, Weybridge strain 99; Institut Pourquier, France) were mixed and rotated on a glass plate for 4 minutes. Presence of agglutination was regarded as positive.

Data analysis

The data collected in the field were entered into a computer on a Microsoft Excel spreadsheet. Statistical analysis (multivariate logistic regression) was performed using 'Statistical package for the social sciences' (SPSS), version 11.5 (for Windows). The prevalence proportion was calculated as the number of animals testing positive by the RBPT, divided by the total number of animals tested. Three epidemiological parameters were generated, the herd prevalence, within-herd prevalence, and individual prevalence. Herd prevalence was calculated by dividing the number of herds with at least one reactor in RBPT by the number of all herds tested (Equation 1). The within-herd prevalence was calculated by dividing the number of RBPT reactors within a herd by the number of serum samples tested in the herd (Equation 2). The individual or total prevalence was calculated by dividing the number of RBPT positive animals by the total number of animals tested (Equation 3). Equations below show how the three epidemiological parameters were derived.

1. *Herd prevalence =* $\dfrac{\text{number of herds with at least one positive reactor}}{\text{Number of herds sampled}}$
2. *Within-herd prevalence =* $\dfrac{\text{number of positive reactors}}{\text{Number of serum samples tested from this herd}}$
3. *Individual animal prevalence =* $\dfrac{\text{number of individual positive reactors}}{\text{Number of serum samples tested.}}$

Analyses were carried out to compute proportions of seropositive animals (stratified by sector, breed, sex, and parity where relevant) and their 95% confidence intervals (CI). The association between each risk factor and the outcome variable was assessed using the Chi-square (2) test. For all analyses, statistical significance between variables was examined using P-value at critical probability of $P < 0.05$ (a *p*-value of less than 0.05 was taken as significant).

Results

Out of a total of 998 serum samples tested, 99 (9.9 %) reacted positive for brucellosis using the Rose Bengal Plate Test (RBPT). Bovine brucellosis was detected in nine out of the ten sectors in Nyagatare, and 62 herds out of the 205 herds studied were seropositive. The overall brucellosis *herd prevalence* rate (HP), i.e. at least one positive RBT reactor identified in a herd, was associated with sector (X^2 = 8851.228, P = 0.000), Breed (X^2 = 413.567, P= 0.002), and parity of the cow (X^2 = 580.292, P = 0.000).

Significantly higher HP values were reported for Byera (100%), Katabagemu (45.45 %), and Rwimbogo (42.86 %) sectors (Table 1). In Gatunda sector, while all the two herds from Byera Sector were seropositive giving an HP of 100 %. HP in other sectors ranged from 0 % to 33.33 % (mean 15.46 % ±11.35) in Karama sector, 7 % to 60 % (mean 32.18 ± 13.21) in Karangazi sector, 0 % to 41 % (mean 35.49 % +/- 8.920) in Rwimiyaga sector, and, 0 % to 100 % (mean 18.41 % ± 26.60) in Tabagwe sector. The herd prevalence was 29.62% in Ankole cattle (95% CI: 28.36 to 30.87) and 23.71 (95% CI: 17.23 to 30.19) in purebred Friesian-Holstein cattle, with a statistically significant difference ($x^2 = 413.567$, P = 0.000).

Individual animal prevalence (IAP), i.e. number of individual positive reactors, differed (P < 0.05) between and within the sectors. Significant higher overall IAP´s were found in Byera (20 %), Rwimiyaga (12.17%), and Rwimbogo (12 .00 %) (Table 1).This study showed a higher seroprevalence (by RBT) of brucellosis in local cows than purebred Friesian Holstein cows (Table 2). Individual animal prevalence was 9.75 % (95 % CI: 9.34 to 10.16) in Ankole cattle and 7.15 % (95% CI: 5.46 to 8.84) in Purebred Friesian-Holstein cattle with a statistically significant difference (x2 =335.339, 28 df, P= 0.000).

There was no statistically significant difference in individual prevalence between Ankole cows and crossbred cows, Ankole and purebred Jersey, and Ankole and purebred Guernsey cattle (Table 2). Similarly, the prevalence of brucellosis in cattle was found to be higher in the older parities than younger ones. Overall seropositivity to bovine brucellosis was 5.9 % (12/204) for parity 1, 11.05 % (20/181) parity 2, 11.04 % (18/163) parity 3, 14.29 % (11/77) parity 4, and 8.82 % (3/34) for parity 5. However, no statistically significant difference was observed in the prevalence of brucellosis between male and female animals.

Table 1. Herd, within herd, and individual animal prevalence based on RBT stratified by sector in Nyagatare

	N^1	+ve herds	Herd prevalence in % (CI)	Within Herd prevalence in % (CI)	N^2	Cases	Individual prevalence in % (CI)
Byera	2	2	100.00^{a} (100.0, 100.0)	20.00^{a} (20.00, 20.00)	10	2	20.00^{a} (20.00, 20.00)
Gatunda	3	0	0.00^{b} (0.00, 0.00)	0.00^{b} (0.00, 0.00)	9	0	0.00^{b} (0.00, 0.00)
Karama	15	2	15.46^{c} (11.15, 19.78)	8.05^{ai} (-1.92, 18.02)	29	3	10.34^{c} (9.47, 11.22)
Karangazi	81	26	32.18^{d} (30.92, 33.44)	9.92^{ag} (8.36, 11.49)	427	42	9.84^{dc} (9.38, 10.30)
Katabagemu	11	5	45.45^{e} (45.45, 45.45)	11.53^{ah} (7.01, 16.04)	59	7	11.86^{ec} (11.86, 11.86)
Matimba	8	1	12.50^{fc} (12.50, 12.50)	1.89^{c} (0.54, 3.23)	53	1	1.89^{fb} (1.89, 1.89)
Musheri	5	1	20.00^{gc} (20.00, 20.00)	5.56^{d} (1.68, 9.44)	36	2	5.56^{g} (5.56, 5.56)
Rwimbogo	7	3	34.38^{hd} (34.38, 34.38)	21.71^{af} (11.93, 31.50)	35	7	12.00^{hc} (12.00, 12.00)
Rwimiyaga	54	19	35.49^{ih} (34.45, 36.53)	11.19^{aj} (9.14, 13.23)	286	32	12.17^{ieh} (11.82, 12.52)
Tabagwe	19	4	18.41^{jcg} (11.15, 25.67)	5.56^{e} (0.91, 10.20)	54	3	5.56^{jg} (4.21, 6.90)
Total	**205**	**63**	31.66 (30.68, 32.65)	9.93 (8.85, 11.01)	**998**	**99**	9.92 (9.62, 10.22)

N^1 = Number of herds, N^2 = number of animals sampled, CI = Confidence interval
Figures with similar superscripts within a column are not statistically different at P < 0.05
Figures in parentheses represent the lower and upper limits of the confidence interval

Table 2. Herd, within herd, and individual animal prevalence based on RBT stratified by breed in Nyagatare.

Breed	N	Cases	Herd prevalence in % (CI)	Within-Herd prevalence in % (CI)	Individual Prevalence in % (CI)
Ankole	520	52	29.62^{a} (28.36, 30.87)	11.19 (8.57, 13.81)	9.75^{a} (9.34, 10.16)
Friesian	53	3	23.71^{b} (17.23, 30.19)	4.03 (1.76, 6.29)	7.15^{b} (5.46, 8.84)
Crosses	248	22	33.16^{c} (31.07, 35.24)	8.42 (6.67, 10.16)	9.50^{a} (8.91, 10.09)
Jersey	12	1	28.89^{ac} (-10.40, 68.19)	6.11 (-3.89, 16.11)	8.88^{ab} (1.29, 16.46)
Guernsey	13	1	31.69^{ac} (-16.25, 79.63)	4.00 (-7.11, 15.11)	7.17^{ab} (-2.18, 16.53)
Total	**832**		**30.30 (29.18, 31.42)**	**9.83 (8.10, 11.55)**	**9.49 (9.15, 9.82)**

Figures with similar superscripts within a column are not statistically different at $P < 0.05$

Discussion

The serological prevalence of brucellosis for 6 out of the 9 infected sectors of Nyagatare district included in this survey was around 10 % with a 99 % confidence. Considering that no formal control programme is in place, that about 1.1 % vaccinate their cattle against brucellosis each year (6), and that other surveys in East African and sub-Saharan Africa frequently encountered prevalence in excess of 10 % (31), the high prevalence of the disease here, is not surprising. Overall, our results indicated that bovine brucellosis was endemic in Nyagatare district.

Since very few vaccinations against brucellosis are carried out in the district, the seroprevalence figures obtained are a reliable estimate of exposure to wild type *Brucella* spp. The mean prevalence of the disease ranged from 1.89 % in Matimba sector to 20 % in Byera sector (Table 1). The finding of such a higher prevalence of the disease among the sectors is supported by observations of high incidences of abortion and retained placenta previously reported in Nyagatare (6).

The observed significant difference in herd, within herd, and individual animal prevalence of brucellosis signifies differences in breeds of dairy cows kept and animal husbandry practices prevailing among the different sectors. For example, 18 out of the 54 animals tested in Tabagwe sector (individual prevalence 5.56 %) were improved breeds while 55 out of the 59 tested in Katabagemu sector (individual prevalence 11.96%) were crosses between exotic and local cows. The low prevalence in herds with a higher proportion of improved breeds is likely to be explained by zero grazing feeding practices that minimizes contacts between herds and animals. Most purebred cows are concentrated along the peri-urban centers, townships, and are mostly fed barna grass through the cut and carry system (6). However, the "cut and carry" system of feeding may serve as a potential risk for bovine brucellosis when the fodder is collected from areas used by indigenous traditional cattle.

The higher prevalence of bovine brucellosis in herds with a higher proportion of local or cross bred breeds of cattle is likely to be explained by the extensive system of grazing management practiced for such cows. In extensive grazing, animals from different locations, and likely of different brucellosis status, come into close contact in pastures or at watering points which facilitates spreading of the disease between and within herds (16, 17). Discharges from aborting animals or following normal birth contaminate pastures and possibly lead to higher herd prevalence rates in extensively managed animals. In addition, the mixing of local and exotic herds favors increased spreading of brucellosis between and within herds (26, 27). The prevalence of brucellosis in cattle in the extensive management system in this study agrees with reports from other countries with similar cattle husbandry systems (15, 4, 19, 26, 27).

It was observed that the local Ankole cattle or their crosses with exotic breeds made up the majority of the total sampled and also the sero- positive animals, hence, breed alone may not have played a key role in the results reported. As explained above, the breed factor relates more to how the breeds are perceived and managed rather differences in breed susceptibility to brucellosis per ser. It can be argued that the observed differences in prevalence of brucellosis between indigenous and exotic animals are mostly attributed to differences in exposure to infectious animals or materials as a result of differences in management. The finding of high proportions of seropositive animals in indigenous as apposed to exotic breeds conform to results of a recent study in Tanzania which also reported similar observations [18].

There was no further investigation to identify the *Brucella* species infecting cattle in this area, where breeding of cattle alongside goats and sheep is a common practice. It is therefore not possible from the results of this study to rule out that besides *B. abortus* infections, *B. melitensis*, originating from the small ruminant reservoir, may also infect cattle as described by OIE [24]. However, despite this limitation, this study has revealed that, in spite of the fact that official data from Rwanda about brucellosis is lacking, the disease is still enzootic in some parts of the country and the risk posed to the human population and the economy of cattle production should not be underestimated [11].

In this discussion, parity was taken as a rough estimate of age and it appears a statistically significant effect of parity on prevalence of brucellosis existed. The prevalence of brucellosis increased with increasing parity or age of the cow. Susceptibility of older cows has been attributed to the effects of sex hormones and erythritol, which stimulate the growth and multiplication of *Brucella* organisms. These substances tend to increase in concentration with age and sexual maturity of cattle (30). The observations that the prevalence of brucellosis increases with parity or age of the cow are consistent with the findings of several other researchers who reported significantly higher proportion of positive reactors in older animals (29, 3, 34, 21).

In the present study, no male reactors were identified. None of the bulls tested in the present study reacted positively to RBPT. However, the absence of male reactor animals in this study could probably be due to the smaller number of male (n = 24) animals studied as compared to females (n = 974). Even though it is difficult to draw a firm conclusion, due to the smaller sample of males, the lack of difference between the two sexes observed in this study corroborates established facts about the disease. Hirsh and Zee (14) have reported that male animals are less susceptible to *Brucella* infection, due to the absence of erythritol. Further, testes of infected male animals do not always react to the infection or show low antibody titers [23, 10], thereby contributing to low seroprevalence in this particular sex. Present observations are comparable with many others (3, 4, 21).

In estimating exposure to brucellosis, the Rose Bengal Test (RBPT) should ideally be used as a screening test, followed by more specific tests such as Serum agglutination (SAT) or compliment fixation test (CFT) because the specificity of this test is low (20). In addition, RBPT has limitations in the diagnosis of chronic brucellosis because the test mainly detects IgM, yet the amount of IgM in serum of infected animals declines with time to levels below the sensitivity of this test (34). However, these more specific tests are currently not available in Rwanda. Nevertheless, regardless of low specificity, RBPT is an excellent test to use in order to detect early infections (11). Therefore, it's possible the prevalence reported herein maybe an underestimation of the true situation on the ground.

Despite the dairy productivity implications, the high prevalence of brucellosis as observed in this study pauses undisputable risk to the human population given the fast growing dairy farming sector and intensification of livestock production in Nyagatare. The

high prevalence of bovine brucellosis, a livestock and zoonotic disease, which is easily amenable to control through effective use of existing disease control technology such as use reliable vaccines reflects failure of veterinary extension within the country.

Conclusion

From this study, it can be concluded that brucellosis is enzootic in Nyagatare and could be the major cause of reproductive wastage previously reported from the same district (6). This disease presents a significant impediment to the economic potential of dairy production and is a zoonotic hence preventive and control measures should immediately and strictly be implemented to protect animals and humans from brucellosis. Further significance of the present findings relate to the fact that brucellosis is a significant health hazard in human beings, causing a variety of chronic debilitating illnesses for people who either come into contact with infected animals or consume infected dairy products. Both, the control of infertility and prevention of brucellosis infection in humans provide enough justification for the advocacy of brucellosis control measures.

Recommendations

The authors recommend further epidemiological studies and isolation and identification of the biotypes of *Brucella* responsible for infection in Nyagatare. Such investigations have important implications for the type of vaccine that should be used and when monitoring the efficacy of control programmes. The further investigations above could should pave the way for mass vaccination to reduce the incidence of the disease to significantly low and manageable levels prior to implementing a test and slaughter policy where cattle, sheep and goat testing positive for brucellosis are slaughtered to remove source of infection from the herd.

Large-scale studies are also required to determine the epidemiology of brucellosis in humans. The impacts of the disease on the health of the local population can be decreased through awareness campaigns which can be initiated through training of animal health technicians on the routes of infection and preventive measures such as boiling of milk before consumption and avoidance of contact with aborted material and placentas. Owing to the relatively nonspecific symptoms in humans and a frequent lack of information on zoonotic diseases [(9)], it is further important to inform and collaborate with the human health services to increase the likelihood of correct diagnosis and treatment as well as to advocate the prevention of the disease through precautionary measures.

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The Role of Government in the Establishment of Appropriate Industries for the Manufacture of Construction Products with Non-Conventional Materials

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Key words: Non-conventional construction products, appropriate technology industries, government role, development economics

ABSTRACT

The cost of construction materials represents a disproportionately larger percentage of total construction costs for a building compared to costs for the same building in a developed economy. This is partly attributable to the developing economy's dependence on construction products manufactured by the developed economies. These imported construction products are often inappropriate to the local socio-economic environment where they are used. They bear a high energy cost in their manufacture and transport and generate excessive carbon emissions into the atmosphere. Significant research has been conducted in non-conventional construction materials (NOCMAT) and technologies which are non-polluting, consume little energy in their production and utilization, are low in cost, and are environmentally sustainable. This paper takes a look at the critical role government must play in the establishment of appropriate manufacturing industries which utilize this body of research to make affordable, environmentally friendly, construction products. Government can be the change agent for the creation of appropriate industries which feature NOCMAT-based construction products by shaping, enabling, and regulating public policy.

Introduction

For certain developing and underdeveloped economies, the prolonged reliance on conventional construction materials is inappropriate to their economic development. The use of these same construction materials by developing and industrialized economies is environmentally inappropriate with global impacts. Buildings consume 71% of the electricity and generate 65% of the waste in the United States. Their environmental contribution to carbon dioxide emissions is around 39% [1]. The world-wide movement towards sustainable construction is a direct effort to reduce this dependence on energy intensive, environmentally insensitive construction materials. This paper considers the body of research in non-conventional construction materials (NOCMAT) and looks towards their rapid integration into the construction industry. To this end, government is expected to play a significant role.

The development of new industries and the reshaping of existing ones based on NOCMAT products must first make economic sense. In a competitive marketplace, industries have little incentive to embrace NOCMAT unless the rules of the game dictate it. The marketplace has no environmental conscience. Instead, the pursuit of profitability perpetuates a culture of waste of global proportions. Government has the ability to positively shape the rules of the marketplace and take leadership in the creation of appropriate industries which are responsive to their economic and environmental priorities.

"A critical examination of current design and build (or manufacture) practices shows its close tie to trends in conventional industry, which "take, make and waste" ideal can only produce what environmentalists refer to as "cradle-to-grave materials and products, designed for a one-way trip to the landfill". Under exploitation, these products generate waste which are toxic, dangerous to health, impacts negatively on the environment and are not renewable – hence the search for a burial place for them after use. Within their life span as buildings, they unsustainably consume energy and other non-renewable resources with the emission of abundant waste. And at the end of their useful life, the body parts remain a nuisance to the natural system."[2]

Appropriate Construction Industries

The use of the term 'appropriate', in this paper, is an adaptation of green engineering principles established at a 2003 conference in Sandestin, Florida. [3] The criteria of appropriateness for the manufacture of construction products is presented below.

Criteria of Appropriateness for Manufacture of Construction Products

1. Holistically use systems analysis and integrate environmental impact assessment tools in their development
2. Conserve and improve natural ecosystems while protecting human health and well-being
3. Use life-cycle thinking in their implementation within the built-environment
4. Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible
5. Rely on renewable natural resources common to the geographic region
6. Strive to minimize waste and maximize resource conservation
7. Are grounded in engineering solutions which are responsive to the physical environment, socio-economic conditions, and potential for workforce development in the local marketplace.
8. Reflect sustainable engineering solutions beyond current or dominant technologies
9. Are easily implemented and maintained without high levels of education and training
10. Includes input from local communities in their development process
11. Are affordable
12. Specifically address society's basic need for shelter; particularly for those who have been the least satisfied.

Rooted in the principles of appropriate technology, the criteria seeks to make technology relevant to the real needs of the society that uses it, is affordable, is harmonious with the environment, does not compromise the quality of life for subsequent generations, and results in economic empowerment at the broadest level.

Most construction products begin by converting commonly available raw materials into refined materials which can then be used to create products such as: roof shingles, wall and floor sheathing, framing elements, and exterior cladding. For example, the steel industry melts iron, burns off its impurities, and then blows oxygen through the molten material to reduce the carbon content. A wide array of structural shapes, with varying physical and geometric properties, is then produced for construction use. Other staples of

the construction industry include: concrete, masonry, lumber products, aluminum, gypsum, glass, stone, plastics, and a range of composites.

The environmental cost of conventional construction materials borne by society is only now being quantified. The manufacture of cement, for example, a key component of concrete, emits significant quantities of CO_2, NOx, SO_2, particulates and dioxins into the atmosphere. Quarrying activities associated with the cement industry also impacts land use and biodiversity [4]. In the case of steel, the environmental cost is linked both directly and indirectly to its energy cost.

The energy consumption of steel production in the United States, one of the largest steel producers in the world, represents about 2.5% of domestic energy use and about 8% of all U.S. manufacturing energy use. About half of this energy is derived from coal. [5]Under pressure from government agencies and environmental groups, voluntary goals have now been set for these industries to reduce their greenhouse emissions and use renewable energy.

IC-NOCMAT and ABMTENC

Since 1984, IC-NOCMAT (the International Committee on Non-Conventional Materials and Technologies) and ABMTENC (Brazilian Association of Materials and Non-Conventional Technologies, founded in 1996) have organized a series of events and collaborations to promote the development and dissemination of knowledge on non-conventional construction materials which are non-polluting, consume little energy in their production and utilization, are low-cost, and are environmentally sustainable. Their principal areas of research are:

1) Bamboo as a construction material, 2) Vegetable fibers and soil construction, 3) Environmentally friendly, energy-efficient construction, 4) Technology applied for low-cost housing, 5) Durability aspects of non-conventional materials, 6) Composite materials, 7) Non-conventional materials and technologies management, and 8) Waste materials in building construction.

Given this body of research, NOCMAT-based construction products are still far from integration into the construction marketplace. What are the pathways to product development, manufacturing, and conventionalization of these technologies? What is the character of a marketplace where these industries are both healthy and satisfy the essential criteria of appropriateness? What forms of partnerships between government, industry, and academia are required to facilitate a healthy marketplace and a healthy economy? This paper examines the role the government must play to advance such industries.

Governments Role to Protect and Enhance the Commons

The commons refers to the common heritage resources which are the collective birthright of our species, to be shared equitably by all. The commons includes all aspects of our natural environment, our freedoms, and the vast mosaic of our heritage on this planet [6]. Given the general inclination of individuals to pursue their self-interest, issues of community and our collective welfare (past, present, and future) are typically placed under the domain of government. It is the accepted role of government to protect and enhance the commons. The establishment of a thriving business environment which is in alignment with the principles of appropriateness and stewardship of the commons must, therefore, begin with government.

Good governance, at any level, will rally to this responsibility of protection and enhancement of the commons. Good governance balances self-interest with the common

good. Three generic areas of responsibility will be examined with respect to the development of appropriate NOCMAT industries. They are: 1) Declaration of sound economic development policy based on research, 2) Enabling policy implementation, and 3) Regulating, enforcing, and modifying policy.

A seminal document proclaiming government's responsibility to protect the commons came out of a United Nations Conference on Environment and Development in Rio de Janeiro in 1992 [7]. The document promoted cooperation among nation-states and key sectors of society to protect the integrity of the global environment and the developmental system.

Subsequent conferences in Santo Domingo and Peru have continued to build upon these declarations and are the root of the Millennium Development Goals and Agenda 21, a comprehensive blueprint of action to be taken globally, nationally and locally by organizations of the UN, governments, and major groups in every area in which humans impact on the environment.

By establishing policy, governments are able to establish national priorities in the interest of the commons and shape the behavior of the marketplace. Using Brazil as an example, the Agenda 21 declarations and goals were adopted as national policy in the Green Protocol of 1996. One of the guidelines of the document was the creation of special lines of credit and financing for undertakings which promote environmental protection and preservation. Public banks committed themselves against financing environmentally aggressive undertakings and to provide support to sustainable production systems. To this end, the banks adapted their procedures for analysis and concession of credit. Policy was translated into economic growth and it shaped the behavior of the marketplace.

Declaration of Sound Economic Policy

Government must place a high priority on the protection and enhancement of the commons through its public policy. Sound economic policy must be fact based, relying on a breadth of research. There is already an abundance of research and experiential data relative to global warming and environmental degradation to warrant alarm and immediate corrective policy from all levels of society. Within the United States, local governments are now rapidly establishing policy on low-carbon emissions and embracing the construction standards of the U.S. Green Building Council [8]; this trend, in spite of resistance at the federal level to do the same with greater impact [9].

The critical gap between research and initiation of public policy for the construction industry requires the active involvement of technocrats (technically trained managers employed in government) who are able to comprehend the essentials of NOCMAT research, validate, analyze and then debate their long-term economic and ecological fit for their targeted communities. Technocrats are able to simplify and craft this information into a rational, sustainable public policy. Consider the dramatic and rapid rise of India in the global marketplace. The role of the Indian Institutes of Technology (IIT) in expediting this development is obvious but is not always publicized. Commensurate with India's economic and technological growth has been the prevalence of IIT graduates in government and industry. "Many of these graduates (IIT) occupy the highest echelons of the private (and even Government) sector bureaucracy. They also form a significant proportion of the scientific manpower pursuing cutting edge research across the globe."[10]. The absence of technocrats in key decision-making positions will inevitably frustrate all efforts to implement meaningful public policy and can hinder an agenda of appropriate economic development.

Unfortunately, the looming threats to the commons are often heard but rarely translate to policy until there is a crisis. "After it suffered severe damage from natural disasters in the late 1990s, the Baha de Carquez (Ecuador) government and nongovernmental organizations working in the area forged a plan to rebuild the city to be more sustainable. Declared an "Ecological City" in 1999, it has since developed programs to protect biodiversity, re-vegetate denuded areas, and control erosion. The city, which is marketing itself as a destination for eco-tourists, has also begun composting organic waste from public markets and households and supporting organic agriculture and aquaculture."[11]. Systematic structures are needed in government which filter out special and self-interests, objectively evaluates reliable, fact-based environmental policy demands, and generates proactive, appropriate responses. Once policy is established, feedback mechanisms must be in place to validate its adequacy and need for improvement. Proof of reduced environmental degradation and the stimulation of economic self-sufficiency on a region level are desired outcomes.

Enabling Policy Implementation

Government must initiate actions which enable its policies to be successful. They can facilitate the nurture of thriving and appropriate construction manufacturing industries through a variety of development incentives, bonds, low-interest financing solutions, regulatory process, tariffs, and taxes. A healthy business environment can be facilitated if both scale and partnerships are comprehensively addressed within a regional economic master plan, guided by effective leadership. The master plan must consider the character of the local labor force and their guiding self-interests, required investments in training, existing and projected demand for construction products, local availability of raw materials, and transport costs.

The creation of the Brazilian Business Council for Sustainable Development**,** a part of the Latin American Council of the Business Council for Sustainable Development, was significant to the development of "green industries" in Brazil. The organization has an ambitious plan for sustainable development of the Amazon which balances both economic and environmental priorities.

> *"We all understand that the Amazon needs to develop, but we also understand that there had to be a development model that is well thought-out, and not predatory, just like we have in other regions of the country,"*
> President Luiz Inacio Lula da Silva [12]

One sector of NOCMAT implementation where government has a clear role involves the recycling of wastes from agriculture and industry to produce building materials. For example, vegetable fibers such as bagasse, a by-product from the extraction of sugar from sugar cane, may be used to form cementitious composites for use as roof tiles [13]. Bagasse is already used in Brazil's ethanol industry where the material is burned as an energy source to operate the plants. Brazil now boasts the world's first sustainable bio-fuel economy. With three quarters of the world's sugar made from sugar cane in tropical zones of the southern hemisphere and with increasing concern for the disposal of agricultural residues, this industry has the potential for tremendous gains in efficiency by selling bagasse to manufacturers of cement products. Other vegetable fibers with favorable research results include bamboo, coconut, sisal, coir, banana, and eucalyptus pulp. Even disintegrated newsprint offers similar value. An array of actions may be introduced by government to facilitate win-win partnerships where the wastes from the agricultural industry may be directed into the manufacture of affordable, locally-manufactured construction products.

Other forms of waste materials which may be introduced into NOCMAT industries include: soil reinforced with waste tire shreds, egg shell waste substituted for sand in mortars, rice husk ash, peanut husk ash, and corn leaf ash as a pozzolanic material in cement, building demolition waste ground into fine recycled aggregates and substituted for sand, and the residue of marble and granite in mortar and concrete.

Bamboo is the most important non-wood forest product and, in India, is known as the 'poor man's timber'. In China, it is the valuable raw material for the booming bamboo industry. Its high strength, light weight, low cost, and fast growth cycle are some of its notable physical properties. Although, additional research is needed relative to its durability and susceptibility to decay, it remains a superior substitute for wood, bamboo-based panels and boards are hard and durable. Bamboo can be used as posts, roofs, walls, beams, trusses, and fences. Bamboo offers tremendous potential as a NOCMAT industry leading to increased economic and environmental development and international trade.

The cultivation and harvest of bamboo is an early stage market sector which must be established. Unless there is a clear financial benefit for small and medium-sized farmers to cultivate bamboo, their economic situation will demand that the land be used for food crops or shared with more reliable cash crops. There must be a matrix of economic incentives that must be initiated by government to foster the widespread cultivation of bamboo, in all its feasible species and varieties.

Government must also play a key role in promoting regional reliance on bamboo as an affordable construction material or as the raw material of a manufactured product. India presents one successful example of government investment in the bamboo industry. The National Mission on Bamboo Applications [14] has been tasked with helping to enlarge the bamboo sector, and with supporting the efforts of the Government of India to augment economic opportunity, income and employment. Areas of investment have included: 1) improved bamboo propagation and cultivation techniques, 2) development of a range of efficient, sturdy and low-cost tooling and processing machinery, suited to Indian conditions and species, to reduce drudgery, improve productivity and minimize waste, 3) developing mechanisms, methodologies and markets to encourage entrepreneurs to take up the processing of bamboo shoots for the marketplace, 4) supporting application-oriented research and developmental activity, utilizing bamboo for constructional applications, and 5) enabling activities to develop and validate technology, encourage entrepreneurial and community enterprise, test products and promote their usage and application. The mission promotes the use of bamboo and bamboo-based composite material and innovation with different construction techniques. It sets benchmarks of quality for construction, functionality, strength, safety and aesthetics

Technical training is a necessary investment to the large scale cultivation of bamboo. Beyond the background of agricultural science required for successful bamboo cultivation, principles of industrial engineering are also needed. The harvested bamboo must be sorted and systematically rated and graded, presumably at a mill, with processes similar to those found in the lumber industry. Agricultural and technical institutes established near the source of bamboo production must have programs to train the local labor force to carry out this work.

India's National Mission on Bamboo Applications can serve as a practical model for how government initiatives can spearhead the creation of appropriate industries. Starting with policy statements, an action-oriented structure was established to stimulate local and regional economic activity in alignment with a national agenda for sustainability. A premium was placed on building a knowledge base and transferring it to all levels of production. In support of the needs of the marketplace, research and standardization of

products is an on-going activity. Projects which best demonstrate the economic value created by this agency are: 1) Design, development and prototyping of hydraulic hot presses for the manufacture of bamboo composite materials in Hyderabad, 2) Preparation and dissemination of a data base written in the form of an annotated bibliography of bamboo literature (published in CD form), 3) Arched engineering models for wide-span structures in low-cost housing, 4) Development of simple processing and packaging technologies for bamboo shoots intended to provide value addition and income generation options at the community and tiny enterprise level, and 5) Testing of the physical, chemical and mechanical properties of bamboo culms, slivers and composites of identified species.

Regulating, Enforcing, and Modifying Policy

In the time-sensitive, cost-conscious world of construction, building codes help to ensure minimum standards of public safety by establishing material specifications and engineering performance expectations. Collaborations between government, engineers, builders, and the manufacturers of construction products are essential to effective code development. Engineers specify construction products based on building code requirements. These products must be accessible to the point of use, should come in modular dimensions, compatible with other construction products, must be routinely tested and certified to be reliable, and must not require a highly skilled labor force to install. Building inspectors and building permit agencies serve as the agents of government to enforce building codes in their respective regions. While this fabric of relationships and infrastructure is inherent for conventional construction materials and products, it is still at an embryonic stage for NOCMAT. Developing economies which lack the technological resources and trained workforce needed for regulatory enforcement commonly adopt the codes and standards of the more industrialized nations. Code enforcement, however, remains problematic and ineffective.

Conclusions

Research in the area of NOCMAT has been a high priority for developing economies, particularly those in the southern hemisphere. The infrastructure required to develop appropriate industries which manufacture construction products based on NOCMAT is still in its infancy. However, substantial progress has been made in some countries where national policy has declared this a priority. In contrast, for many other economies, the United Nations' Millennium Development Goals are far from within reach and they remain victims of their own history. In 1999, the Declaration of Santo Domingo recognized that the countries of Latin America and the Caribbean need to collaborate with one another to confront the declining quality of life of their inhabitants and health of their respective economies. Similar collaborations and partnerships between Africa, Asia, and Latin America are needed to address the Agenda 21 goals, in general, and the integration of NOCMAT into the construction industry, in particular. A change of culture from waste to sustainability is mandated on a global scale.

> *There are two different aspects to be considered in the fight against waste. The first involves the change in consumption patterns which ultimately is a cultural change. However, it is necessary to start this combat against waste while still during the productive process, by adopting technologies less intensive in energy and which are less demanding on raw materials. Civil construction is a segment which has a lot to contribute as, for example, searching for alternatives to waste practices in the work sites.[15]*

As a steward of the commons, government carries the burden of addressing global, national, and regional issues on behalf of individual communities. Through the establishment of sound public policy and initiatives which enable those policy goals to take shape, and through the adoption of regulatory standards which are then reasonably enforced, a reversal of the chronic under-development and the un-sustainable management of natural resources of the can be experienced. The ranks of government must include technically trained professionals who possess the communication skills needed to translate NOCMAT research into profitable and appropriate industries. A marketplace based on collaboration rather than on competition may best lead to eliminating the disparities which plague our global community and slow the rapid erosion of our common heritage.

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Phenotypic Characterization of Goats Raised Under Traditional Husbandry Systems in Bugesera and Nyagatare Districts of Rwanda

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Key words: Rwanda, Goats, Indigenous, Phenotypic characterization

Abstract

Phenotypic characterization is a simple, non-invasive, inexpensive technology that can be utilized in mapping out an inventory of characters peculiar to a group of animals. A random sample of 487 non-descript village goats in Bugesera and Nyagatare were characterized according to their phenotypic characteristics. Three age categories, based on dentition, were examined: milk, young, and adults. Parameters assessed included face, back, and rump profiles, presence of beards and toggles,,tail, and ear lengths, coat color and pattern, presence of horns, live weight, heart girth, wither height, body and back lengths. Overall, 77.2% of goats sampled had a flat face while 22.8% had concave faces. More than ninety eight percent (98.4%) had flat backs with 1.6% having a hollow back. All the goats in the study had a sloping rump. Only 6% had beards. About fourteen percent (13.5%) had toggles averaging 3.4 cm in length. Average horn length varied from 4.3± 0.2 cm in the milk category to 8.0 ±-0.1 cm in the mature goats. Horn diameter varied from 3.3 +/0. cm in the kids to 8.6 +/-0.2 cm in adults respectively. The mean tail length ranged from 9.6(+/-0.1 to 12.0 +/-0.1 cm for the same age categories as above. Average mean ear length ranged from 10.3 (+/-0.1) to 11.5(+/-0.09) (milk-adults). There was no significant difference (P > 0.05) from one dentition category to another. The predominant coat color was the uniform multi-colored coat pattern. The mean live weight (kgs) recorded were 13.1 (+/-3.3) (kids), 25.5 (+/-0.7) (young), and 33.3 (+/-0.5) (mature goats). Mean heart girth (cm) recorded was 54.4 (+/-0.5) (Milk), 67.0 (+/-0.5) (Young), and 74.0 (+/-0.4) (mature goats). Our results show that goats in the study are predominantly not the East African Small type, but rather, are an improvement from the typical East African Small. Implications of the present findings on goat breeding and productivity in Rwanda are discussed.

Background and Justification

In Rwanda, it has been estimated that there are approximately 1,379,895 goats in the country (12). Goats are a very valuable genetic resource that is suited for low-input agricultural production systems. They require low inputs and are easy to manage, making them suitable for the resource poor rural households (1). The abilities to reduce their metabolism, efficiently use water, minimize nitrogen requirements, and efficiently digest high-fiber forage are among the desired adaptive features of goats (7, 19, 14, 11). These characteristics enable them to continue providing milk and meat even when cattle have succumbed to drought (16). On account of their adaptability, goats can survive on woody browses and infrequent watering during droughts, and after drought, their high reproductive rate and short generation interval enable their owners to recover quickly and

economically (9, 15). Other valuable attributes of goats include provision of food (9), fibre (18), income generation (18), and creation of employment (9), for poor rural families, especially women and children. They can be sold to attain immediate cash assets for poor goat holders, helping them improve livestock and crop farming and financing social events (14). Last but not least, the value of goats for the use of the vast areas of natural mountainous and hilly regions where crop production is less practicable should not be overlooked (9).

Despite their multiple roles and economic importance, information collected by the Food and Agriculture Organization (FAO) of the United Nations indicates that approximately 30% of the world's farm animal breeds inclusive of goats are at risk of extinction (FAO, 1999). The major threat has come from animal breeding practices that have emphasized productivity and specialization, and by so doing, promoted prevalence of a relatively small number of breeds at the expense of locally adapted, but less productive native breeds. Unfortunately, once animal genetic diversity has been lost, it cannot be replaced. Unlike breeds from temperate regions, most of the available goat genetic resources in Rwanda have undergone natural selection (8,6). As a result, the reproduction performance and production of most tropical goat breeds are both low. To improve this situation, native goats should be selected for their abilities to produce and reproduce efficiently and survive in the environments in which they are kept (3). Breed characterization should thus be prioritized, if we are to select superior animals.

Characterization means the distillation of all knowledge which contributes to the reliable prediction of genetic performance of an animal genetic resource in a defined environment and provides a basis for distinguishing between different animal genetic resources and for assessing available diversity. It thus includes a clear definition of the genetic attributes of an animal genetic resource and the environments to which it is adapted or known to be partially or not adapted to at all. It also include the population size of the animal genetic resource, its physical description, adaptations, uses, prevalent breeding systems, population trends, predominant production systems, description of environment in which it is predominantly found, indications of performance levels (milk, meat, growth, reproduction, egg, fibre, traction etc.), genetic parameters of the performance traits and information on genetic distinctiveness of the animal genetic resource and its evolutionary relationship with other genetic resources in the species (8, 6)

Phenotypic breed characterization is an essential, initial step in breed identification (4). However, very little effort has been made towards characterization of indigenous goat breeds in Rwanda. The lack of information on characterization of a genetic resource may lead to the underutilization of that resource, its replacement, and dilution through crossbreeding despite their local adaptation to prevailing environmental constraints. Therefore, assessment of genetic variability in domestic animals is an important issue to preserve genetic resources and maintain future breeding options in order to satisfy the demands of changeable markets (10). Unplanned and indiscriminate breeding among native stocks is directly or indirectly responsible for the dilution of Rwandan livestock germplasm. Hence, identification and characterization of the goat breeds in Rwanda is a must to identify our genetic resources and also to prioritize breeds for conservation.

Characterization of animal genetic resources promotes continuing use and conservation of indigenous livestock, which are usually more productive than exotics under low levels of input. Given that most of the goats in Rwanda are in the resource-poor rural households, promotion of breeds that thrive under low input systems is envisaged to result in increased farmers' incomes and food security. Presently, Rwanda does not have a complete inventory of the indigenous goat breed resources nor a basic description of many of the current species. It is therefore important to obtain an inventory of domestic animal

genetic resources in general and goats in particular, and to characterize these resources at the phenotypic and genotypic levels. In this endeavor, physical or morphological characteristics can be particularly useful in the classification of populations, strains, or breeds within a species (21). The objective of this study was therefore, to make an inventory of phenotypic characteristics of and genetic diversity among indigenous goat breeds in Nyagatare and Bugesera districts of Rwanda. The information so generated will be used in determining their relationships which may thereafter be useful as potential predictors of performance traits.

Material and Methods

Sites of study

The two site chosen for characterization exercise were Tabagwe and Kamabuye sectors in Nyagatare and Bugesera districts respectively because these sectors are known for keeping purely indigenous breeds. The type of climate experienced in both sites is equatorial and are found in the low altitude zones of the Eastern and South-Eastern parts of the country respectively. The approximate distance between the two districts is 261 km. The study area is located 30' 30^0– 30^0 25' East and 20 05'- 20 30' South and an altitude of 1400 m a.s.l with average temperature 25^o C in wet season and 30^o C in dry season and relative humidity of 74% . The rainfall received is a moderate bimodal, fairly well distributed within the year, with the short rains (Season A) falling between September and December, while, the long rains extends from March through May (Season B).

The most popular goat production system is semi-intensive where tethering the goats close to the homesteads or some take them to graze freely in communal areas beginning at about 9.00am to mid day, then they are brought home and either kept in sheds/pens or tethered on pegs and they are supplied with twigs, banana leaves, peels, potato vines, leaves etc. till at about 4.00pm. They are normally taken back to the grazing area, where they are tethered till 6.30 to 7.00pm. Banana leaves and pseudo-stems are cut and fed to the animals in the sheds at resting time at mid day when the ambient temperatures are high outside. Supplementation with agro-industrial by-products and other sources of supplements is rather uncommon within the farming systems. The local goats have been adapted to the environment and bear tremendous resistance to a good number of diseases prevalent in the region. Common diseases in the area include helminthiasis and contagious pustular dermatitis. Generally disease control is done on an *ad hoc* basis. The lack of effective disease control measures has been attributed to inefficient veterinary services and lack of awareness by farmers who rely on use of indigenous technical knowledge. Few farmers keep bucks for breeding. Normally nearly all born male kids are castrated when less than three month of age for improved meat quality. As a result, the farmer keeping a buck, whenever, other farmers bring does for mating they pay for that service and the price varies between 0.4– 0.6 US dollars

Data collection

Data on a random sample of 238 and 249 goats was collected from Nyagatare and Bugesera districts respectively. The goats were categorized by dentition ranging from young animals with no permanently ruptured teeth (milk teeth) to those with four pairs permanently ruptured teeth (Full Dentition). This is because farmers seldom keep birth records, so to determine various stages of growth, dentition was found to be the most appropriate. Goats without any permanently ruptured teeth were classified as milk goats while those with one or two permanently ruptured teeth were grouped together and referred to as young and those with three or four permanently ruptured teeth were considered as the mature category. All goats were weighted using a spring balance after

ascertaining their dentition. Measurements were recorded using a tape measure in cm. These included; heart girth, wither height, body length and back length from the base of the neck to the root of the tail. Tail, ear type and their lengths were also recorded. Horn orientation, its length, and diameter at the base were also noted. Presence of toggles, their length and if single which side they occur was also recorded.

Data Analysis

Data was analyzed with SAS using the general linear models. ANOVA for live weight and linear measurements was carried out to determine the fixed effects of dentition, coat color, origin, and their interactions. Least square means were computed for all the tested factors. Coefficients of correlation between the measured parameters were computed for the various dentition categories in Nyagatare and Bugesera districts to determine linear associations. Stepwise regression models of body weight as the dependent variable with linear measurements as the independent variables for milk, young and mature categories of goats in both districts was determined. This was done to find the most suitable models showing relationships between live weight and linear measurement of heart girth, withers height, back length, and body length for various dentition categories. Proportion of live weight to heart girth, withers height, back length, and body length was calculated for the various dentition categories to determine the trends of these associations. Other linear proportion that was considered were heart girth with withers height and back length for various dentition groups.

Results

Three age categories (based on dentition) were examined: milk, young, and adults. Parameter assessed included face, back, and rump profiles, presence of beards and toggles, horn, tail, and ear lengths, coat color and pattern, presence of horns, live weight, heart girth, wither height, body and back lengths. The predominant coat color was the uniform multi-colored coat pattern. Overall, 77.2% of goats sampled had a flat face while 22.8% had concave faces. More than ninety eight percent (98.4%) had flat backs with 1.6% having a hollow back. All the goats in the study had a sloping rump. Only 6 % had beards. About fourteen percent (13.5%) had toggles averaging 3.4 cm in length. Polledness was observed in 8.9 % and 4% of goats in Nyagatare and Bugesera districts, respectively. The horn length and diameter varied from 3.4 cm to 8.8 cm and 4.3 cm to 8.3 cm respectively from milk to mature groups. Average horn length varied from 4.3(+/- 0.2) in the milk category to 8.0 (+/-0.1) in the mature goats. Horn diameter varied from 3.3 (+/0.1) cm in the kids to 8.6 (±0.2) in adults respectively. Fifty one percent (51%) of the horns shape was straight and the orientation of 67.9% being backwards. The mean tail length ranged from 9.6 (+/-0.1) to 12.0 (+/-0.1) for the same age categories as above. Tail length did not differ with age category. Average mean ear length ranged from 10.3 (+/-0.1) to 11.5(+/-0.09) (milk-adults). There was significant difference ($P< 0.05$) in ear length from one dentition category to another. The mean live weight (kgs) recorded were 13.1 (+/-3.3) (kids), 25.5 (+/-0.7) (Young), and 33.3 (+/-0.5) (mature goats). Goats with black/brown coat coloration were the heaviest followed by black/white and uniform black (Table 2). Heart girth increased as dentition category increased but the difference between consecutive categories reduced progressively. Mean heart girth (cm) recorded was 54.4 (+/-0.5) (Milk), 67.0 (+/-0.5) (Young), and 74.0 (+/-0.4) (mature goats). A similar trend was observed for wither height, back length and body length. Just like weight, black/brown goats had larger linear measurements. Within the dentition groups the proportion of live weight to linear measurements (heart girth, wither height, body length and back length reduces progressively (Table 1). Live weight was significantly correlated

with heart girth ($P < 0.01$). There was strong indication that heart girth is a good predictor for live weight as it appears in all dentition categories.

Table 1. Linear measurement and live weight for the different age-groups of goats in Nyagatare and Bugesera Districts, Rwanda.

Dentition	Weight (Kg)	Heart Girth (cm)	Wither height (cm)	Body Length (cm)	Back length (cm)	Tail length (cm)	Ear length (cm)	Horn length (cm)	Horn diameter (cm)	Toggle length (cm)
Milk	13.1± 0.3	54.4 ± 0.5	49.3 ±0.5	46 ±0.5	44.1 ± 0.4	9.6 ± 0.1	10.3 ± 0.1	3.3 ± 0.15	4.3 ± 0.2	3.3 ± 0.3
Young	25.5 ± 0.7	67 ±0.5	59.6 ± 0.4	57 ± 0.5	55.3 ± 0.4	11.1 ± 0.12	11 ± 0.1	6.7 ± 0.1	6.8 ± 0.1	3.36 ± 0.17
Mature	33.3 ± 0.5	74 ± 0.4	63.1 ± 0.4	62 ± 0.3	59.2 ± 0.3	12 ± 0.10	11.5 ± 0.09	8.6 ± 0.2	8 ± 0.1	3.7 ± 0.2

Table 2. Live weight and linear measurements of the different colors of Goats in Bugesera and Nyagatare Sectors (mean + SE of mean)

Coats Color	Live weight	Heart Girth	Wither Height	Back Length	Body length
Black	25.22 ± 0.73	66.20 ± 0.74	57.81± 0.59	53.49± 0.60	55.42± 63
Black/white	25.32± 0.91	66.07± 0.78	58.03± 0.60	53.25± 0.64	55.12± 0.67
Brown	21.50± 2.99	65.30 ± 3.05	55.60 ± 2.73	52.90± 2.10	53.50± 2.51
Black/ Brown	28.28± 1.70	69.40 ±1.62	59.80± 1.37	55.57± 1.20	57.33± 1.41
White	21.00±2.60	62.00±2.77	55.11± 2.16	49.78 ±2.48	54.67± 3.11
Ikivuzo (mixes of black and white)	21.64 ±2.20	61.56± 2.57	55.40 ±1.70	52.52± 2.10	54.04± 2.21
Black/Ikivuzo	24.72±1.97	65.85± 2.28	58.63± 1.98	54.26 ± 2.14	55.93±2.23

Discussion

The World Watch List for Domestic Animal Diversity [WWL-DAD] prepared by the Food and Agriculture Organization of the United Nations (FAO) in 1993, and which has since been revised two times (1995 and 2000), has defined a breed as: either a homogenous, sub-specific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species, or a homogenous group for which geographical separation from phenotypically similar groups has led to general acceptance of its separate identity. The colour ranges recorded in this study is in line with other observations on East African Goats, which is described as ranging from pure white to pure black with various intermixes of roan and speckled brown (20). However, horn length in the pure East African goats is reported to range from 2.5-20 cm in length(20) whereas our findings were that horn length ranged from 4-8 cm. Our findings showed great variation in all characteristics studied in relation to those of known breeds hence little could be said about the breeds under study. However, while little is known about the actual breeds of goats in these study sites, differences in their horn shapes indicate that two or more breeds could have been present.

Based on coloration, and all other phenotypic characteristics studied, it appears all the indigenous goats under study belong to the Small East African goat type. 'Indigenous goat' is the collective term used for all varieties of native East Africa goat breeds.

However, it is almost impossible to classify a group of goats into different populations using phenotypic characters commonly used to describe goat breeds (coat colour, horns, physical body measurements and productive traits) (2), because there is considerable variability within and among the populations. As a result, it is difficult to combine different characters in order to have a useful tool for assigning individuals to their source populations. Elsewhere, attempts have been made to assign specific breed names according to the geographical areas in which they occur, or the names of breeds and types were taken over from the nations or tribes that own them (8). However, this classification system does not accommodate thousands of indigenous goats found outside these specific locations, hence it has not been well accepted.

Discrimination among individuals is essential for effective and proper management of livestock breeds for conservation, especially for Rwandese breeds which are not adequately characterized even at phenotypic level and have no pedigree information. To overcome this, microsatellites can be used to determine the genetic differences between closely related goat populations thereby paving the way for assignment of anonymous individuals to their source populations. Though no definite breeds were identified, phenotypic characterization is an essential, initial step in breed identification, which should be followed by in-depth genetic characterization of indigenous goat breeds. A lack of information on genetic resource characteristics may lead to the underutilization, replacement, and dilution through crossbreeding of local goat breeds, despite their local adaptation to environmental constraints.

The presence of toggles in 13.5% of the goats studied contrasts with observations of (17) who recorded toggle presence of between 68% and 98% in Spanish goats. Polledness was observed in 8.9% and 4% of goats in Nyagatare and Bugesera districts, respectively. The low prevalence of Polledness can be explained by the fact that the hop allele which is present in both sexes determines the presence of horns and is dominant over the Ho+ which when homozygous, determines the presence of horns in both male and females (17). The Hop+ allele is generally therefore, of low frequency in East African goats.

Overall, present findings indicate that the indigenous goats of Rwanda vary in horn and coat types, colour, ear length, and size, and are mostly of medium size. Variation in size between goat types is attributable to environmental extremes. Nevertheless, the local breeds of goats are well adapted to their varied natural environments. This might have influenced the phenotypic characteristics observed herein. Similar observations were reported (13) in Botswana. Heart girth increased as dentition category increased but the difference between consecutive categories reduced progressively. This was the same for wither height, back length and body length (Table 1). The mean live weights and linear measurements for various coat colors observed (Table 2), shows that goats with black/brown coat coloration were the heaviest followed by black/white and uniform black. Black/brown goats, similarly exhibited larger linear measurements. When we consider live weight as a proportion of linear measurements we find that for all the linear measurements the proportions reduce as the age of goats increases for each measurement. This could be due to morphological changes as result of tissue accumulation relative to linear growth as the animal gets older.

It was also observed that within the dentition groups the proportion of live weight to heart girth, wither height, body length, and back length reduces progressively. However, when we consider wither height as proportion of heart girth measurements, constant proportions for all dentition categories for heart girth with wither height and back length are observed. This indicates that there is a proportionate increase of linear measurements as the goats' age. As has been observed by various authors live weight associates

significantly ($P<0.01$) with heart girth and therefore heart girth could be a reliable indicator for live weight, particularly in circumstances where a weighing balance is unavailable. The association reduces as the animals get older. Similar trends are also observed for other linear measurements exhibiting stronger association. These observations are in agreement with those of (20).

Conclusion

Goats from the two regions of Rwanda differ in various linear measurements and live weights. Thus there is need to plan to harmonize the classification criteria such that the various strains, landraces and breeds of goats can clearly be identified to plan for an appropriate selection, methodology leading to improvement and thereafter conservation of some of these unique indigenous genetic materials. The characterization exercise forms the beginning of identifying the different heterogeneous goat strains located in the various localities nationwide that constitute previously uncharacterized populations.

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SURVIVAL ETHICS: CONSEQUENCES FOR APPROPRIATE TECHNOLOGY

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Key words: ethics, science, appropriate technology, survival

Abstract

This essay examines critically the demarcation of ethics and science. While its method is theoretical rather than experimental, it proposes a research program as a logical next step to test its conclusions. It offers a conceptual foundation for a new ethics whose chief aim is the survival of life. Only a global consensus can challenge contemporary threats to life. The foundation of this new ethics is compatible with classical ethical systems. The essay's concluding sections will sketch the consequences of survival ethics for new definitions of "appropriate" technology. The conclusion proposes both a new discipline called teleonomics *that combines philosophy, science, and technology, as well as a demonstration project to test the feasibility of this new discipline.*

INTRODUCTION

The discipline of ethics has never achieved consensus. Historically, this aspect of ethics has been an asset rather than a failure. The varieties of philosophical disagreement have amplified our choices about how we should live our lives. However, humanity now confronts a crisis never before experienced: the human destruction of life as we know it. A nuclear war of significant proportion will destroy the food chain through nuclear winter. Growing consensus acknowledges that global warming carries the threat of imminent species extinction. The unprecedented magnitude of these threats to life demands a global response. That response must be grounded in a common sense of ethics, a *whole earth* ethics.

Saturated in the wrangling that characterizes philosophy, current ethical systems cannot achieve that consensus. Philosophers and neuroscientists have recently suggested new methods for doing ethics as we begin to understand more clearly the relations between brain and behavior. Kwame Anthony Appiah's *Experiments in Ethics* insists that ethics is at its core an experimental discipline [1]. Richard Joyce's more radical *The Evolution of Morality* displaces ethics into the neurobiological and psychological sciences [2].

This essay examines critically the demarcation of ethics and science. While its method is theoretical rather than experimental, it proposes a research program as a logical next step to test its conclusions. It offers a conceptual foundation for a new ethics, a *survival ethics,* whose chief aim is the survival of life. Only a global understanding can challenge contemporary threats to life. The foundation of this new ethics is compatible with classical ethical systems developed over the past five thousand years. The essay's concluding sections will sketch the consequences of survival ethics for new definitions of "appropriate" technology. The conclusion proposes a new discipline called *teleonomics* that combines the strengths of philosophy, science, and technology. The conclusion also proposes a demonstration project to test the feasibility of this new discipline.

The foundation for a survival ethics springs from a comparison of rationality and ethicality. Richard Joyce collapses ethics into the neurobiological and psychological

sciences. These sciences attempt to explain the origins and development of ethics by means of evolutionary theory. The mainspring of this kind of explanation is genetic change and natural selection. More traditional philosophers like Kwame Anthony Appiah resist the conflation of science and ethics. For them, science is an instrument of generalized description. Scientific generalizations do not have the force of ethical prescriptions. The first two sections of the paper will compare rationality as the embodiment of contemporary science with ethicality to examine their separability.

RATIONALITY

Rationality's deepest meaning is to be discovered in its Proto-Indo-European root. The *ar* sound in *rationality* is linked with other words like *harmony, architecture, arithmetic, arm, art, ratio.* The sound *ar* means to join or to connect. Like all rationality, human rationality is connecting by means of abstractions. Abstractions are patterns common to environmental and brain states and accessible through transform mechanisms not now understood. The virtue of an abstraction is its generality, which enables us to predict and thereby control our environmental and brain states.

This essay engages an instrumental or pragmatic definition of *rationality*. Rationality evolves in the service of survival. To be rational, a belief or theory must correspond with experience, be consistent with other beliefs, be practical, be of wide scope, be generalized to an appropriate degree, call itself into question when appropriate, and be meaningful in both semantic and emotional senses.

The conditions of rationality are set by its survival function. Three common theories of truth express this relationship. The correspondence theory of truth derives its plausibility from the consideration that brain states must mirror environmental states so that the organism may make appropriate decisions about actions. The coherence theory of truth is based on the foundational principle of rationality as connectivity. A connection either exists or it does not exist; it cannot both exist and not exist at the same time in the same way. The pragmatic theory of truth reflects the evolutionary origins of rationality. A theory or belief as an expression of rationality must serve its intended use.

The remaining constraints of rationality follow from evolutionary mechanics. To be rational is to know all possible facts and theories pertaining to a decision. A rational belief or theory covers all pertinent belief and experience. The most perfect expression of the rationality of a belief or theory is its degree of generality. The test of generality is the ratio between the number of symbols required to express a belief or theory, and the area of experience covered by the theory or belief. Since the rationality of our beliefs and theories itself evolves constantly, a penultimate test is the propensity of a belief to call itself into question.

The final test is a function of the instrumentality of expressing our beliefs. We at present can only do that through symbols, literally in Greek "throwings-together." Symbols are aspects of experience that we choose to re-present other aspects of experience. The potentially arbitrary nature of the relation between symbol and symbolized means that we must constantly test that relationship—both for ourselves and our interlocutors.

With this definition, we can now ask whether there can be a science of rationality. At this stage of human evolution, there is no algorithm for making guaranteed decisions about what to believe in making the foundational choices that direct our lives in general, or our choices of theories and beliefs more particularly. The seven tests of rationality constitute a basket that must be sorted through in making rational choices. *In extremis*, one might create a hierarchy of values in the basket.

When faced with urgent choices upon which our survival might depend, practicality can become an overriding concern. Consistency is infamously the "hobgoblin of narrow minds." The simplicity or beauty of a theory might encourage its proponents to dismiss experiments that contravene the theory. Well-established theories become nearly impossible to question. Widely-shared symbols assumed to have meaning over long periods may acquire a false semantic stature.

Nonetheless, deeply seated theories that persist over time meet all seven tests of rationality to the degree possible given the historical limits of understanding. Perfect rationality implies total knowledge, the myth that animates Plato's definition of *philosophy* as love of wisdom or perfect knowledge. Philosophers through the ages have made their reputations through acts of hypertrophy—emphasizing one of the tests of rationality to the exclusion or diminution of others.

Thus Leibniz's "universal calculus" sets the stage for computation based on non-contradiction or consistency as the primary test of rationality. Locke, Berkeley and Hume exaggerate the role of empirical (rather than imaginary or calculative) experience. The eponymous pragmatists embellish the role of practicality in rationality. Idealists like Hegel, Spinoza, and Plato focus on the importance of generalization or simplification. Socrates makes his mark by emphasizing the hyper-reflexive character of rationality: "We know only that we don't know." Twentieth-century analytic philosophers like Wittgenstein make the most important if not the sole burden of philosophy the need to clarify meanings.

These European philosophers demonstrate the variegated nature of rationality. Given our historical perspective, it would be a grave mistake to imagine with them that one aspect of rationality is of overriding importance—or even to imagine that there is no more to life than rationality. Rationality is in fact itself a value. As the primary instrument of human survival, rationality's importance may appear to be paramount. Humans are weak, slow, dimly sensing, poorly naturally armed, tasty creatures that would yield to our competitors at the top of the food chain if not for our ability to think. Thinking is generalizing through abstraction in order to predict and control the future.

Philosophers like Plato, Aristotle, and Kant have exaggerated rationality's importance, declaring it to be the primary human value. However, rationality itself depends on our survival for its exercise. Pleasure also drives us toward survival, as do love, caring, and community bonding in our lives. Freedom, happiness, and contemplation as well are close allies of survival. Nevertheless, survival cannot be given a role as the preeminent value because many humans whom we respect and cherish over the ages have sacrificed their own survival for the sake of values they deemed more important than survival--love in the case of Christ, duty for Socrates, *satyagraha* for Gandhi.

Rationality and ethicality are analogous in that no single element or trait can encompass the whole of either characteristic, as I will show in the next section of the paper. The bridge to ethicality is to ask what the value of rationality is for life itself. Shall we use "rational" means to judge our fundamental values? Does rationality receive its own value through an instrumental analysis along evolutionary lines? Is rationality valuable as an end in itself, or only as it serves other ends, such as survival or freedom or happiness?

ETHICALITY

Ethicality first requires its own definition. *Ethics* has acquired the sense of a field distinct from morals. *Morals* refers to behavior that is customary or acceptable in a given

society. *Ethics* means the study of morals and more deeply the study of value itself. What is valuable is what is desired or, more strictly, what is desirable given some set of fundamental assumptions.

At its most basic level, ethics considers appropriate mechanisms for choosing principles or values to guide our lives. Rationality and ethicality are analogous in the sense that both are complex phenomena that cannot be given a single-factor analysis. Both are indispensable for choosing the directions of our lives. What I want to do in this section is to draw an analogy between tests for rationality and ethicality. Just as rationality cannot have a single defining criterion, so ethicality is expressed through a basket of values. The separate values have their champions in the history of philosophy. Each philosopher makes a case for a single value's having overriding status.

The history of African, Asian, and European ethics presents a medley of sometimes conflicting goods. Early African and Asian primary values appear to be commonsensical and grounded in the conditions necessary for human survival and flourishing. The oldest written philosophy, that of ancient Egypt starting around 2800 BCE, presents *Maat* as the highest good. *Maat* is variously translated as harmony, order, peace, justice, tranquility.

Other African cultures like the Oromo in Ethiopia emphasize a similar overriding ethical principle. The principal ethical good of the Borana, the Oromo group in the southernmost part of Ethiopia bordering on Kenya, is *Nagaa*, translated as peace or harmony. The Oromo ensure a community-wide harmony among themselves, their neighbors, and the environment through a democratic system called *gaada*.

The ancient Chinese philosophy of Taoism, canonized by Lao-Tzu and Chuang-Tzu around 600 BCE, enjoins the ethical principles of *wu-wei*, translated as passive non-doing. The Taoists, as their name suggests, believe that the universe is comprised of a single principle, the *Tao*, which is a balance of complementary principles striving for harmony. As the *Tao* or nature seeks its balance, humans live well if they follow nature's guiding principle of harmony rather than forcefully imposing an artificial system of control on nature.

The common-sense principles of *Maat, Naaga*, and *Wu-Wei* contrast sharply with the ethical maxims of other ancient traditions. Hindu philosophy enjoins a value of *moksha* or liberation from our common-sense conviction that this life we live daily is real rather than a dream. The primary ethical practice of this tradition is meditation, known through the practices of yoga, or the union of Self with God. Buddhism dispenses with the metaphysical presuppositions of Hinduism to focus on a single practical problem—how to eliminate suffering or achieve *nirvana*. Like Hinduism, however, Buddhism focuses on meditation as the instrument of liberation from suffering.

Plato's concept of the good is the very idea of good itself. For Plato, the whole point of life is to contemplate the perfect model of all that is good. Plato stands out among Greek ethicists for making the contemplation of the good by an immortal soul the overarching end of humanity. Other Greek ethicists are much more down to earth. The hedonists notoriously make pleasure the end of all ends. Aristotle rejects pleasure and substitutes happiness. He defines happiness as activity in accord with excellence. Excellence is a function of the nature of an organism. As thinking beings, our highest activity is thinking, and the greatest kind of thinking is thinking about thinking itself, defined by Aristotle as contemplation or philosophy.

Subsequent European philosophies lose this passion for pure abstraction, but make abstraction the ground for more practical pursuits—the enslavement and colonization of large portions of the world's populations. Augustine carries on the theoretical Christian

tradition of universal, unconditional love as the primary ethical principle. However, this principle, first enunciated by the now little known Chinese philosopher Mo Di (or Mozi) in the fifth century BCE, is honored more in the breach than in the observance.

Subsequent ethicists in the European tradition subscribe to more common-sense ethical principles: pleasure for Bentham and Mill; duty expressed through universalization for Kant; freedom for Hegel, Marx, and the existentialists; and the return to the basics of survival and flourishing by "American" pragmatists like James, Dewey, and Rorty.

These apparently quite diverse and seemingly random ethical "goods" or values can be reduced to a basket of seven fundamental values. My reduction here is provisional. The basic values are survival, rationality, pleasure, love, happiness, freedom, and contemplation. They cut across African, Asian, and European traditions, and they are associated with the most illustrious philosophers in the traditions of these continents. The common key values are the following: survival for Darwinists, pragmatists, Taoists, and Africans; pleasure for hedonists, Bentham, and Mill; rationality for Kant, Hegel, and Spinoza; love or caring for Christians, Mohists, and feminists; happiness for Aristotle; freedom for Hegel, Marx; and contemplation or meditation for Hindus, Buddhists, and many Judaic, Christian, and Muslim sects.

Can these disparate values be ranked or does each hold an independent status, as is the case with the basket of values comprising rationality? As the pragmatic criterion for believing a theory may sometimes take precedence over other rational values, so survival may under certain circumstances trump all other values—particularly for communities or for the whole earth population when survival is at risk. To be good, after all, is first to be. If survival is not an issue, however, it may deserve little consideration in choosing the fundamental values that are to serve as guidelines for one's life.

Nonetheless, the six values other than survival may be given an explanation through evolutionary considerations. Rationality is the primary instrument of human survival. Pleasure is the stimulus for the behaviors most necessary for the survival of the species--breathing, temperature control, hydration, eating, reproduction, and the like. Love is indispensable for human survival, given the long maturation period of humans and the need for community bonding for group survival. Variation is key to survival, and the value of freedom promotes variation. Contemplation may seem to be quite disconnected from the immediate concerns of survival. However, the primary focus of contemplation or meditation is the control of the attention. Ordinarily, random environmental circumstances dictate the attention's direction. Survival under this condition is a matter of luck. Meditation gives the individual rational control of her attention.

The fact that basic human values may be grounded in considerations of survival does not confer a privileged status on survival. In fact, we may deliberately choose to dismiss survival as a ground value. We may very well be the kind of species that sets up the "ethical" conditions for its own extinction. Powerful historical slogans point in this direction: "Live free or die!" "Give me liberty or give me death!" "*Patria o muerte*!" Religions like Hinduism, Buddhism, Judaism, Christianity, and Islam proclaim that this life is merely a test. "Real" life starts only after death or transcendence of life.

However, the fact that the survival of the species is now at risk makes survival an issue of overriding contemporary concern. The key question is whether enough humans believe that a primary mission of our lives is pass life on to our successors in better condition than we have received this gift. If this proves to be the case, we need a new "technology" to furnish the grounds for continuing life. This technology must synthesize three disciplines: ethics or philosophy, science, and technology itself. The technology must find a common ground for a "whole earth" ethics that the majority of humans,

regardless of their individual cultures and religious beliefs, can subscribe to. This new ethics must have as its primary focus the survival of the species.

TELEONOMICS: A NEW STRATEGY FOR A SURVIVAL ETHICS

My proposal for a new discipline assumes that basic human values or ends are naturally defined. Just as we are born to be grammatical, so we are conceived to be ethical [3]. Nevertheless we can assign hierarchies to naturally ordained values as well as subvert them. The enterprise of selecting our deepest ethical ends, interpreting what they mean, and assigning weights to them is a basic task of philosophy or more specifically ethics. This task includes highly theoretical proposals for achieving ends or values in ways that are consonant with other ends.

A quite separate enterprise is the task of actually achieving these ends. This part of the enterprise must be both scientific and technological. I define *science* as the system of generalizations and explanations that we use to understand, anticipate, and control experience. *Technology* is defined as the art of translating our understanding of experience into action. I call the fusion of philosophy, science, and technology *teleonomics* after the Greek terms for ends and laws.

The point of teleonomics is threefold: to choose ethical ends consonant with survival; to propose general means for achieving those ends through scientific reflection; and finally to propose practical means for realizing those ends through a synthesis of appropriate technologies.

The epistemological status of teleonomics must be comparable to that of economics, the “rules of the house” in Greek. Scientific generalizations about “what happens when” with respect to human behavior are notoriously statistical and often unreliable. However, the less general aspects of teleonomics are based on experience, and are quite reliable. Appropriate technologies exist to translate scientific or common sense generalizations into practical arts. The statements of teleonomics are hypothetical rather than categorical. Ethics tells us "Thou shalt do thy duty!” or “Thou shalt survive!” or “Thou shalt maximize pleasure!”

Teleonomics phrases its commands in hypothetical form: "If you wish to survive, then you must breathe, regulate your temperature, drink, eat, sleep in descending orders of urgency." Techniques for survival have been worked out over perhaps hundreds of thousands of years. Teleonomics is a synoptic discipline in that it relies on all other sciences to project its conclusions. It is an evolving science because it must change its hypothetical imperatives to fit altered circumstances. Weapons of mass destruction and global warming provoke unprecedented calls for ethical action.

Teleonomics is a bridge between ethics and science in unique ways. All sciences have a philosophical component—the extreme assumptions that drive research in the sciences in different directions, assumptions that cannot be tested given the current state of knowledge and their degrees of generalization. The Duhem-Quine hypothesis holds that theories can neither be refuted nor verified, because we cannot test the deepest assumptions. Parallax serves as an example. Geocentrists held that the failure to detect parallax meant the earth could not be moving. But geocentrists assumed that the distance between the earth and the stars was not sufficient to make parallax detection difficult. The falsity of that assumption required better instruments for measuring stellar distances.

All sciences face this difficulty. However teleonomics must not only cope with our inability to test deep ethical assumptions, but also translate scientific generalizations into appropriate technologies. *Appropriate* here means *ethically* appropriate—productive

of global peace and sustainable with respect to the rights of future generations. Teleonomics must bridge the spectral divides between science and philosophy as well as between science and technology.

The relations among the three disciplines are not hierarchical. Working with appropriate technologies may in fact show that our philosophical choices of ends or our basic scientific understanding of their realization have been wrong. The current hypertrophy of technology ("things are in the saddle and ride mankind," as Emerson declares) illustrates this claim. Choosing to focus on rationality and using complex technologies to realize basic human values have threatened our survival.

In translating philosophical assumptions into scientific generalizations, and those generalizations in turn into ethical and sustainable technologies, teleonomics is neither philosophy nor science nor technology, but a fusion of all three disciplines. The sciences should furnish the chemistry, physics, and biology of alternative renewable safe energies and other resources. The technologists or engineers using these fields should propose appropriate techniques for survival. By reason of its synoptic character, teleonomics is not a discipline that can be exercised by a single researcher.

CONCLUSIONS

This paper sketches a theoretical instrument for assessing technologies that are *ethically* and *practically* appropriate in the largest possible sense of ensuring human survival and sustaining our environment. Implementation would entail recruiting interdisciplinary teams to collaborate on the planning of appropriate micro- and macro-technologies. The first phase of a practical execution of this research proposal will select a small-scale demonstration project on water treatment and management to be developed by an interdisciplinary team of philosophers (Charles Verharen), scientists (George Middendorf, biology, Howard University) and engineers (John Tharakan, chemical engineering, Howard University). Because the appropriateness of a technology is inseparable from reflection on local culture, the team will include anthropologists (Bruce Dahlin, Shepherdstown University) and critical members of the community (to be selected from the Global South) where the project is to be implemented and tested.

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