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Preamble

African Journal of Science, Technology and Engineering **(***AJSTE) is an academic multidisciplinary peer-reviewed yearly publication that seeks to publish original, innovative research and academic scholarship that contributes to the growth of knowledge in Science, Technology and Engineering and related fields. Her key audiences are: Scientists in academia and industry, researchers, students, government agencies/policymakers and citizens with a passion for "STEM".*

This third edition is aligned with the newest research, interspersed with contemporary concerns and latest global transposition in Science, Technology and Engineering. It carries original and full-length articles that reflect the latest research and developments in both theoretical and practical aspects of global science. It promotes research awareness and compatibility platform through a concise and methodical interface to cater for all categories of scholars in science, while encouraging innovativeness and quality research work.

The topical issues in this Journal include : Application of aquacrop model yield optimization or prediction of optimal sowing dates under alternative soil moisture regimes in Laikipia, Kenya; influence of anthropogenic activities on Nyangongo wetland ecosystem in Nyaribari Chache Sub-County, Kisii County, Kenya; use of ICT in the classroom: The teacher and learner; optical and electrical characterization of tin sulfide; factors influencing utilization of library e-resources in academic delivery: the case of Multimedia University of Kenya.

The Journal is both in print and online versions.

Chief Editor

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Application of AquaCrop Model Yield Optimization for Prediction of Optimal Sowing Dates under Alternative Soil Moisture Regimes in Laikipia, Kenya.

Mutonga, M.W[1], Kipkorir, E.C[2], Ng'etich, W.K[3].

[1]Kirinyaga University, KENYA [2]Moi University, KENYA[3]University of Eldoret, KENYA

Correspondence: *mmutonga@kyu.ac.ke*

Abstract

This study presents the use of AquaCrop model in predicting optimal onset dates for wheat crop grown under ASAL conditions in Laikipia County, Kenya. Modeling of onset dates was done through simulation of root zone moisture content to reduce yield losses from crop failure. The optimal sowing date(s) for rain-fed wheat was based on AquaCrop rainfall criterion for generation of onset dates and optimization analysis of AquaCrop simulated grain yields. Cumulative rainfall of 10 mm in 4 successive days' onset criteria equivalent to the calculated Readily Available Water (RAW) required at 10 cm soil depth was adopted. Based on the onset criteria, a total of 57 simulations (19 years rainfall record and three onsets: early, normal and wet) was run using AquaCrop model and frequency analysis applied to the simulated yields to get the yield levels expected at varying levels of probability of exceedance. The set threshold was incremental at 0.5 ton/ha level from 0-12 ton/ha. The probability of exceedance was zero for threshold mean yields beyond 5.5, 11.0, 11.5 ton/ha for early (SD1), normal (SD2) and late (SD3) onset respectively. At 20%, 50% and 80% probability of exceedance, the average expected yield was less or equal to 4.5, 0.5 and 0.38 ton/ha for SD1, 4.5, 0.75 and 0.38 ton/ha for SD2 and 6.0,0.75, 0.38 ton/ha for SD3 respectively. Results indicated that zero tillage optimized the yield in all the sowing dates selected. In conventional tillage, early onset had high yield advantage for the viable early onset, but the risk of failure was high representing 22.11%. It is recommended that sowing date, which is a technology problem, be given a lot of attention.

Keywords: *Optimization Analysis, Staggering Onset Dates, Frequency Analysis, Zero Tillage, Climate Change.*

Introduction

Prediction of sowing dates have been done using science and religious cum traditional methods like Ramadhan (Ati *et al.,* 2002), the use of plant phenology such as flowering of the Acacia trees that mark the end of a dry period (Sekhwela and Yates, 2007), use of accumulated rainfall totals using the Walter's and Sivakumar's method (Ati *et al.,* 2002; Sivakumar, 1988), use of rainfall evaporation method, and historical analogues approach (Hansen and Indeje, 2013). These approaches have varied levels of accuracy, often characterized by yield losses. While traditional methods reportedly perform poorly, the other methods are not without challenges. Walter's method predicts quite early onset, while Sivakumar's predicts late onsets (Ati *et al*., 2002). Similarly, the use of plant phenology is threatened by deforestation and depletion of indigenous species.

Although the scientific methods are fairly reliable, there are other constraints which affect accuracy of predicting onset of sowing dates especially in arid and semi-arid areas (ASAL). Climate change is a major threat to accuracy of predicting onset of sowing dates (FAO, 2015). Most agricultural production takes place in an environments with risks and uncertainties especially in ASAL areas where water supply to crops from rainfall is variable and unreliable (Fereres *et al.,* 2007). According to Onyari *et al*., (2010), ASAL areas are characterized by temporal and spatial variability of rainfall. The rainfall is usually low and unreliable limiting productivity (Wamari *et al*., 2012). As a result, the timing and relative lengths of each crop growing period vary substantially with location (Mujdeci *et al*., 2010) and this leads to reduction in yields by up to 75% (Barron *et al*., 2003).

Further, most rain-fed farmers depend on hired agricultural machinery which also contributes to delay in land preparation. This overdependence on contracted agricultural machinery among other factors further cause delay in sowing (Monroy *et al*., 2013). However, even when the machines are available, other constraints among them land sizes, machine breakdowns, labor availability often hinder farmers from sowing their entire crop at the first onset of sowing period (Mhizha, 2010). Mhizha, (2010) recommended staggering the sowing dates to accommodate the above challenges and other uncertainties (Raes *et al*., 2004) which are difficult to predict or control.

Modeling of onset dates through simulation of root zone moisture content can be used to reduce uncertainty and manage risks of crop failure from a false start of the sowing period or delayed sowing which significantly shortens the growing period. If properly modeled, initial soil water (left over from the previous season) can influence early establishment of the crop and contribute to water use and yield later in the season, particularly in low rainfall seasons (Kipkorir *et al*, 2007).

Laikipia County is among the main wheat growing regions and falls under ASAL area of Kenya whose seasonal rainfall according to Huho *et al*., (2012) has been marked by delayed onsets, declining number of rain days and increased intensities altering farming calendars with negative impact on the yields. To increase and sustain production in this area, improvement in farm management practices, soil and water conservation, farming systems and timely sowing from weather prediction need to be encouraged.

In this study we used the AquaCrop model (Asseng *et al*., 2008) to generate onset dates by appraising the rainfall data file for the region. Rainfall data consideration was best suited for this rain-fed farming where sowing onset is determined by rainfall event(s). Optimal sowing time corresponds to adequate soil water content at the root zone to support crop growth. This is what was simulated to determine and generate the sowing dates with low risk of failure.

Materials and Methods

Optimization analysis was applied to obtain the algorithm that allocates the best acreage proportion to the generated sowing dates for maximum total yield taking care of the mentioned constraints over the simulation period. Microsoft Excel Solver® tool was used for optimization analysis of simulated yields.

Study area

According to Mutonga *et al.,* (2019) Laikipia County is characterized by the ASAL climatic conditions despite being a major potential grain producer. The area receives mean annual rainfall of 650 mm per year, but often very unreliable with the onset of the rains highly variable and can be delayed by up to two months in some seasons (Ojwang' *et al*., 2010).

Experimental site and design

The study was carried out in Lengetia farm in Laikipia County. The farm of approximately 4500 acres in area is located in a wheat growing zone, and has been under zero tillage for more than ten years and the dominant soil texture in the farm is clay soil (Mutonga *et al.*, 2019).

The field trial was laid out in randomized complete block design in split plot arrangement during the short rain season of 2015/2016. Tillage treatment formed the main block factors in the split plots (zero tillage (ZT) and conventional tillage (CT)), while sowing dates representing the early (SD1), normal (SD2) and late sowing (SD3) onsets (Table 1) formed the sub-plot factors randomized and replicated thrice on each of the split plot.

Table 1: Sowing dates representing the three sowing season characteristics determined by onset of rainfall an adjustment of rainfall criterion in AquaCrop (Raes *et al.*, 2004, Raes *et al.*, 2012).

Sowing Date	Occurrence	Symbol	Sowing time Characteristic	
			Onset time	Type of sowing
29th September	1st	SD1	Early	Dry
21st October	2nd	SD2	Normal	Wet
21st October	2nd	WTSD2	Normal (irrigated)	Wet
31st October	3rd	SD3	Late	Wet

Generation of onset dates

Sowing dates were determined using the onset of rainfall and rainfall depth criterion in AquaCrop model using historic daily rainfall data (Raes *et al*., 2004, Raes *et al.,* 2012) (Table 1). Generation of the onset of growing period using AquaCrop Model was based on historical farmer's practice of sowing (to establish the normal (wet) planting date and sowing window), historical climatic data and criteria for selection of dry sowing date(s) by the AquaCrop Model based on 19 years' historical rainfall data. The onset dates were generated based on soil moisture at the root zone to match the requirement for wheat to germinate.

The Raes *et al.,* (2004) rainfall criterion was used with little adjustment because the accumulated rainfall of 40 mm was limited under ASAL climate. The adjustment was that germination was triggered by received rainfall of at least 10 mm for four consecutive days. This is the amount of rainfall that was required to raise the soil water content at wilting point to field capacity in a profile of 10 cm of the top soil. This was based on the calculation of Readily Available Water (RAW) from the analysis of sampled soil. Also considering that there was stored soil water from zero tillage practice over the years, this rainfall was sufficient to trigger germination and the stored soil water would support crop growth until the next rainfall event was received.

A soil water balance analysis by the AquaCrop model and yield simulation was used to determine whether the generated date was a false start based on yield and risk of failure of the crop after germination. The soil moisture content was the limiting factor and therefore the rainfall criterion was preferred.

The historic daily maximum and minimum temperature data for the region was used as input file in AquaCrop model when generating initial onset dates and for scenario analysis. This was meant to take into consideration the temperature effect of the project site. To achieve calibration and validation of the AquaCrop Model for the local condition, a temporary weather station was set up equipped with a maximum and minimum thermometer for measuring the daily temperatures and data collaborated with those obtained from Lamuria Weather Station approximately about 1.5 km from the project site. Temperature was assumed to have a direct effect on soil water content through evaporation and was assumed to vary substantially with variation in tillage practice and therefore captured when monitoring the root zone soil moisture content (Mutonga *et al.,* 2019).

From experience, the farmers sowing window lies between 15th September and 15th October of every calendar year. The search window in AquaCrop was stretched by fifteen days on both sides to between 1st September and 31st October to take care of probabilities of early onset or very late onset of rainfall which trigger the onset of sowing. The first date to be generated within the search window comprised the early (dry onset date) while the first generated onset date after seven days from early sowing represented the normal sowing date. Finally, the first generated date after seven days from the normal sowing date was considered as the late sowing date.

The four sowing onset dates (Table 1), representing the three onset dates under rain-fed condition, and one water regime control treatment (with supplemental irrigation) were randomized among the subplots as; one dry onset (sowing date one-SD1), one normal onset (sowing date two- SD2), one late onset (sowing date three-SD3) and one normal onset under supplemental irrigation (water regime treatment - WTSD2). The effect of rain days was not investigated because it was assumed that rainfall had a uniform and direct effect of raising the soil water content in the root zone and was the sole source of water for rain-fed trials.

The sub-plots were 24 m^2 (4 m × 6 m) each and consisted of 12 rows, 6 m long and 0.3 m between rows, separated by 1.5 m to ensure that the treatments in the plots were independent of each other. The total number of sub-plots was 24: two tillage treatments (ZT and CT (2TT)), by four onset-dates treatments (4SD) replicated thrice (3) i.e. (2TT × 4SD × 3=24). The control treatment (WTSD2) in both the conventional and zero tilled plots was meant for calibration of the AquaCrop model, while the remaining trials were for validating the model.

Optimization analysis

Optimization analysis on the simulated yield results for every year and for different generated planting dates over the 19 years of available historic daily climate data was applied to obtain the optimal allocation of acreage to the various sowing treatments with the best maximum yields every year. This was achieved using Microsoft Excel Solver Tool and simulated yields in validated AquaCrop model.

For purposes of developing the optimization objective function, a total yield term (Y_T) was defined as the weighed summation of the grain yield simulated for each of the three sowing options for each year and over 19 years of available historic data (Equation 2.4.1)

$$\boldsymbol{Y_T = \sum_{s=1}^{3}(A_i\, Y_{S_i})} \qquad \textbf{(Eqn 2.4.1)}$$

The aim was to maximize mean grain yield for all the 19 years (Equation 2.4.2) (Mhizha, 2010). Therefore, the objective function which formed the target cell was;

$$\mathbf{max} \sum_{j=1}^{N}(\mathbf{Y_T/n}) \qquad \textbf{(Eqn 2.4.2)}$$

$$for\ j = 1\ to\ N$$

Subject to constrain on area; $0 \le A_i \le A$ and

$$A_1 + A_2 + A_3 \le A$$

$$for\ i = 1,2,3$$

Constraints on the changing cell; $0 \le A_1 \le 0.4A$

$$0 \le A_2 \le 0.6A$$

$$0 \le A_3 \le 0.6A$$

The values, 0.4, 0.6 and 0.6 are the weight factors corresponding to 25%, 37.5% and 37.5% proportional area allocation recommended for the early, normal and late sowing dates respectively. This was obtained from expected target yields and frequency of failure at 50% probability of exceedance.

Where,

S_i, is the respective simulated onset date (i.e. SD1, SD2 and SD3 representing the early, normal and late season onset), for i=1, 2, 3; Y_s, is the simulated grain yield of the S^{th} sowing date (ton/ha); A_i, is a weighted factor, a proportion of area (acreage) allocated through optimization to sowing date S_i.

A, is the total area (unit or 100%) to be considered and allocated to the three sowing seasons based on the proportions obtained in the frequency analysis while, N, is the total number of years of simulated yield considered in the optimization (based on available historic climate data, 19 years). The A_i weighted factor given to each yield term in the summation was aimed at allocating more land to desirable treatments and less (or even none) to undesirable treatments not likely to contribute positively to average yield.

Thus, the weighting factor formed the changing cells of the optimization procedure while the target cell was the mean of total yield (Y_T /n) over the 19 years. The target cell was maximized for highest stable yields (Equation 2.4.2). By means of constraints, the number of options selected in the optimization was restricted.

Data analysis

Frequency analysis and homogeneity test using RAINBOW was applied to secondary climate data and simulated yield data to check and ensure that they belonged to the same statistical population (Raes *et al.*, 1996; Raes *et al.*, 2006). Additionally, the Excel spreadsheet (windows 2007) and SPSS statistical software (Version 20) were used for tabulation, descriptive statistics and graphical representations.

Results

Yield as a function of tillage

Zero tillage plots had significantly high yields at $p<0.05$ than conventional tillage for all the rain-fed sowing treatments. The respective mean grain yield in both tillage treatments and varied sowing dates are presented on Table 2.

It is apparent that all the onsets in zero tillage yielded higher with a mean grain yield of 8.69 ± 0.54 ton/ha for the rain-fed trials which was above the plant breeders target yield of 8.5 ton/ha as compared to 5.70 ± 1.08 in conventional tillage (Table 2). The variation in mean grain yield for conventionally tilled rain-fed trials and the varied sowing dates was higher than that of zero tillage under the rain-fed trials (Table 2). This affirms the effect of sowing dates on grain yield and the need for accurate prediction of sowing time and confirms the effect of zero tillage in enhancing high grain yields (Mutonga *et al.*, 2019).

Table 2: Analysis of the wheat grain yields for the two tillage practices under the four sowing onset dates.

	Independent variables Mean Yield ton/ha		Levene's Test for Equality of Variance		T-Test for Equality of means		
Onset date	ZT	CT	F	Sig.	T	$LSD_{0.05}$	St.dev
SD1	8.21	4.196	1.30	0.32	8.50	0.001	2.84
SD2	8.41	6.681	3.08	0.15	1.98	0.118	1.23
SD3	9.45	6.226	0.12	0.75	18.62	0.000	2.28
WTSD2	12.92	13.607	6.35	0.07	-0.83	0.453	2.12
Mean	9.75 (8.69)	7.68 (5.70)					
St.dev	1.95 (0.54)	3.66 (1.08)					

KEY
CT-conventional tillage
ZT-zero tillage
SD1,2,3-Sowing dates one, two & three respectively
WTSD2 –water regime treatment
( )-mean yield and standard deviation under rain-fed condition

Similarly, the variation of yield between the two tillage treatments under similar sowing dates was high both for the early onset and late onset. This variation is relevant and also serves as an indicator of the effectiveness of zero tillage practice coupled with proper timing of the sowing onset dates. Further analysis of the grain yield result indicated that, farmers practicing conventional tillage are likely to produce less than the target yield of 8.5 ton/ha by 50.64%, 21.4% and 26.75% respectively for early, normal and late sowing, while those practicing zero tillage, the deviation from the mean target yield is not significant ($p<0.05$).

Using the field results of the water regime trial plots (WTSD2), the AquaCrop model was satisfactorily calibrated and validated under conventional tillage but was not satisfactory in zero tillage (Calibration details not discussed in this paper). This limited the application of the AquaCrop model only to the conventional tillage. However, as evident from the grain yield results for the three rain-fed onset dates, the yields were above the target yield, without a significant variation between them (Table 2). It is therefore apparent that, zero tillage had optimized the sowing onsets and all the dates falling within the sowing window were considered appropriate and optimal. That means, zero tillage practice as a soil and water conservation practice, can be used to support staggering strategy without significant yield variations.

Generated onset dates

The 40 mm in 4 successive days' criterion (Raes *et al.*, 2004) was very severe generating only one sowing date in some years while in some no onset within the sowing window. An attempt to use the less strict AREX criterion (25 mm in 7 days but with longer period of 10 days instead) (Raes *et al.*, 2004), was not successful because it also generated very few days (at most two and in some years none) occurring either too early or too late in the season. The two conditions could not be met for this ASAL region and therefore it was relaxed to 10 mm in 4 successive days. This was based on the calculation of Readily Available Water (RAW) (6.7 mm up scaled to 10 mm to cater for any losses) at 10 cm soil depth and through the observation during the experiment (the received rainfall which germinated the seed for SD1 was 8.8 mm which was less by 1.2 mm). The generated onsets were selected based on their occurrence as SD1, SD2 and SD3 representing the early, normal and late season as presented in Table 3.

Table 3: Average sowing date occurrence determined by the relaxed rainfall depth criterion.

Characterized season onset dates			
Number of onsets	Early Onset	Normal Onset	Late Onset
1	6-Sep	4-Oct	15-Oct
2	8-Sep	5-Oct	17-Oct
3	10-Sep	6-Oct	19-Oct
4	14-Sep	8-Oct	20-Oct
5	20-Sep	10-Oct	26-Oct
6	30-Sep	14-Oct	31-Oct

The result of multiple yield simulation with the generated dates was then subjected to frequency analysis.

Frequency analysis of simulated yields

Frequency analysis was performed to give insight on how often the simulated yield was below the threshold yield (frequency of failure). Considering the model parameters specified for each season, 3 sowing onsets; early onset, normal onset and late onset for the 19 years of historic climate data, a total of 57 simulations was run. A frequency analysis using Microsoft Solver tool was applied to the simulated data to determine the yield levels expected at varying levels of probability of exceedance and with a set threshold incremental at 0.5 ton/ha level from 0 yield to maximum 12 ton/ha as presented in Figure 1. Beyond a threshold mean yield of 5.5 ton/ha, the probability of exceedance is zero percent for SD1, zero percent for threshold mean yield of 11 ton/ha for SD3 and zero% for mean yield greater or equal to 11.5 ton/ha for SD2 (Figure 1).

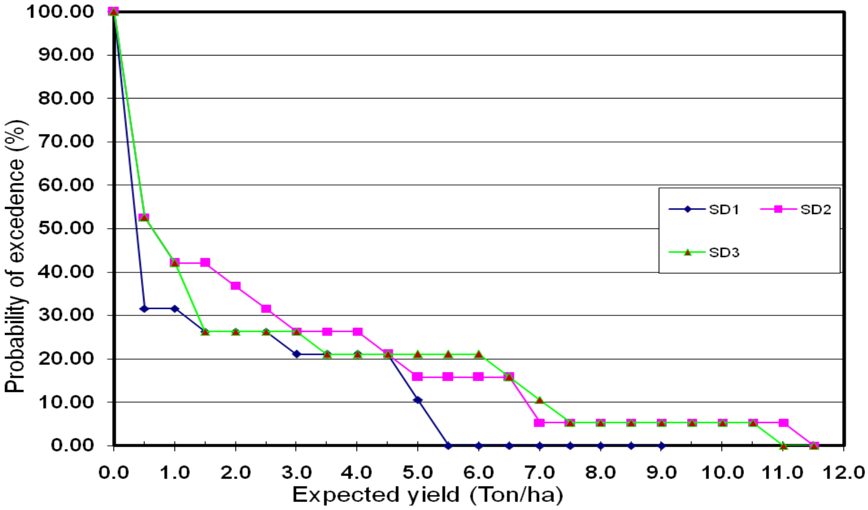

Figure 1: Probability of exceedance of wheat specified by planting dates (SD1, SD2 & SD3) obtained using validated AquaCrop model.

Further analysis of failure rate results indicated that early onset had the highest failure rate followed by the late and finally the normal. The Early onset had a high yield advantage for the viable early onset as compared to both the normal and the late onset only that the risk of failure of such onsets was high.

Similarly, in years without an early onset, the normal onsets had higher yield advantage than the late. Results also demonstrate a high failure rate for the early onset and late onsets as compared to normal onset depending on the characteristic of the rainfall in the season and not the occurrence, that is, neither too early nor too late into the season but the general wetness of the season.

At 20%, 50% and 80% probability of exceedance, the average expected yield was less or equal to 4.5, 0.5 and 0.38 ton/ha for the early onset (SD1), 4.5, 0.75 and 0.38 ton/ha for the normal (SD2) and 6,0.75, 0.38 ton/ha (SD3) respectively (Figure 1 and Table 4).

Table 4: Expected yields (ton/ha) for specified probability of exceedance

Probability of exceedance		Expected yield (ton/ha)	
(%)	Early Onset	Normal onset	Late onset
20	4.5	4.5	6.0
50	0.5	0.75	0.75
80	0.38	0.38	0.38

The 20%, 50% and 80% probability of exceedance can also be linked to probability of a season being wet, normal and dry respectively with respect to received rainfall.

Optimization analysis

Due to the prevailing constraints in wheat production and the need to stagger the sowing dates to minimize the constraints such as labor resources availability and land size, optimization analysis was carried out aimed at allocating the maximum possible acreage proportion to the dates with the best yields. The idea of failure rate was applied at 50% probability of exceedance (considered as the normal or average) such that the normal onset and the late onsets were set to receive 37.5% of the acreage each with the early set to receive 25% due to the high risk of failure associated with it (Figure 2).

The maximized mean grain yield results of optimization allocated 12.63% to the early, 34.74% to the normal and 30.53% to the late onset (Figure 3). This accounted to 77.89% of the total area to be sown with the remaining 22.11% not allocated due to the nature of the season with only two or one onset and the constraint on land size. This 22.11% could also represent a false start of the sowing period, where the crop germinates but does not get to full maturity because of low or no rainfall later in the season.

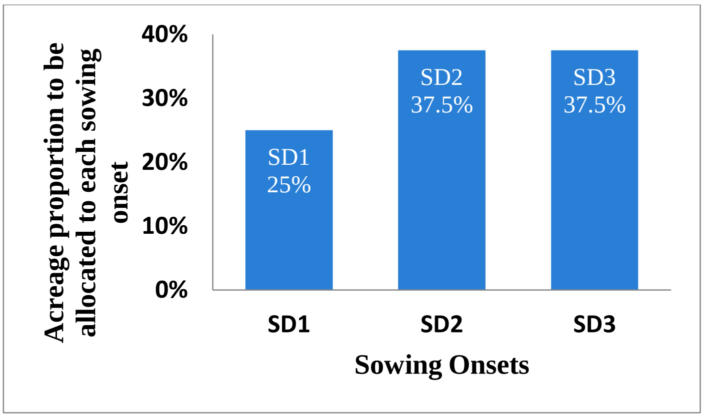

Figure 2: Bar graph representing the area to be allocated to each sowing onset based on Land size constraint (Weighed factor) at 50% probability of exceedance.

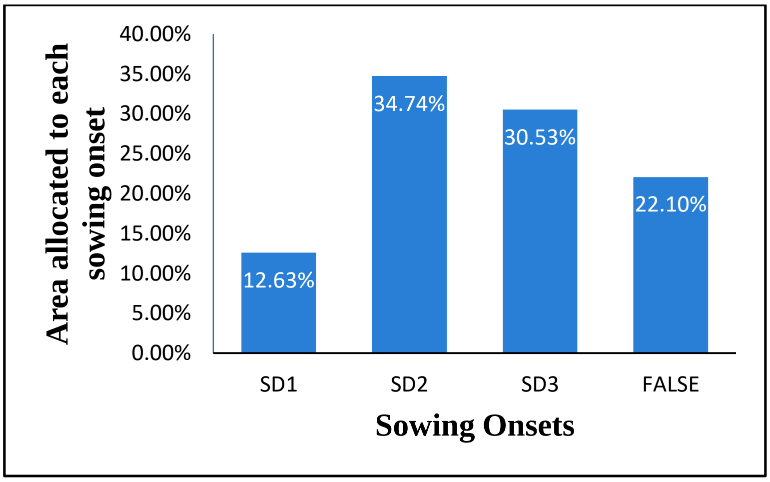

Figure 3: Bar graph representing the optimal sowing strategy (area allocation) indicating the possibility of false start after performing the optimization analysis based on simulated yield.

The farmers in Laikipia County, should through aim at doing most of their sowing during the 1st -14th of October under the normal season proportional to 34.74% of their total land area, 12.63% of the land area between 1st-30th September and 30.53% between 15th- 31st October (Figure 3).

Discussion

Zero tillage optimizes the sowing dates through retention of soil water (Buffer) from the long rains and advancement of sowing time through reduced time for land preparation by 20-30 days (Chandna *et al.,* 2004). Thus, it only requires a rainfall event or an irrigation event enough to trigger germination and the stored soil water will support crop growth until the next rain event. This is unlike in conventional tillage where the crop fully depends on received rainfall for germination, growth and development of the crop. This means that when the received rainfall results in seed germination and then a dry spell occurs for longer period than the crop can withstand water stress (moisture depletion to permanent wilting point), it eventually dies and this is regarded as a false start (Sen *et al.,* 2014). In this study, results of optimization analysis demonstrated that the probability of false start under conventional tillage was approximated 22.11% (Figure 3).

According to Tripathi *et al.,* (2013) research in India, a delay of every successive day in planting from the optimal sowing window decreased wheat grain yield progressively as was reported by Ali *et al.,* (2010). Consequently, farmers in India started practicing conservation technologies such as zero tillage to cut down on their production costs and avoid planting delays (Tripathi *et al.,* 2013).

Despite the high temperatures in ASAL areas, sowing date influences the yield of rain-fed crops like wheat due to erratic and unreliable rainfall especially at the onset of the rainy season. This is because rainfall directly influences soil water content which should be maintained at or near field capacity in conventional tillage. This is however not possible under conditions of erratic and unreliable rainfall. Based on the observed s differences in yields under conventional tillage, proper timing of the onset of the growing season has to be made.

In this study, a delay in sowing by ten days resulted to a loss of 6.7% while an early onset led to a loss of 37.1% under conventional tillage. This is attributed to the high evaporation and associated water stress. However, under zero tillage, an early onset resulted in a loss of 2.4% which is not significant ($p<0.05$), and a positive variation under delayed onset resulting in an increase of 12.4%.

These results demonstrate that under zero tillage, optimization of yields is possible through staggering of sowing dates within the sowing window. On the other hand, under conventional tillage in the study area, early onsets had high risks of crop failure or significant reduction in yield. Similarly, waiting for the wet season would complicate operations under this heavy clay soil and lead to soil degradation, (erosion, compaction and formation of hard surface hindering infiltration).

Conclusions and Recommendations

This study compared conventional and zero tillage practices against AquaCrop model generated sowing dates and wheat grain yields. In conventional tillage, timing and staggering of sowing dates had significant effect on grain yield, although with risks of high crop failure especially for the early onsets. Normal onset was the most appropriate sowing period. In zero tillage, crop yield was optimum in all sowing dates tested though early onset was better due to optimal soil moisture and early maturity of the crop.

Zero tillage can be embraced as a strategy to promote staggering of sowing dates without compromising grain yield or acreage under crop especially in ASAL areas. Finally, AquaCrop model is recommended as a useful tool for use with acceptable level of accuracy for scenario analysis in ASAL areas to optimize wheat crop yield production especially under rain-fed condition.

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Influence of Anthropogenic Activities on Nyangongo Wetland Ecosystem in Nyaribari Chache Sub-County, Kisii County, Kenya

Ogechi, B, Ngetich, J.K & Kiplagat, A
University of Eldoret, KENYA

Correspondence: *ogbent@gmail.com*

Abstract

Wetlands are among the most productive ecosystems in the world as they perform diverse functions including; flood attenuation, recharge of underground aquifers, climate regulation, erosion control; water provision for human use as well as acting as habitat for wildlife. Nyangongo Wetland in Kisii County in Kenya covering an area of 825 hectares of land is a key life support system to communities in Lake Victoria Basin. The study was informed by the theory of tragedy of commons on free access to environmental resources .The main objective of the study was to assess the effects of human activities on Nyangongo wetland over the last 30 years. The study adopted a mixed-method consisting of Remote Sensing and GIS-based analysis, to determine Land Use and Land Cover dynamics and associated human-induced alterations in the wetland. 251 respondents were randomly selected for interviews in order to gather data on their overall perception of the wetland, which were corroborated by six Key Informant interviews conducted. The respondents observed that the wetland has been adversely affected by the high demand for agricultural products and pollution of water sources leading to limited access to clean water. Based on image analysis, we established that the areal extent of the wetland in the year 1984 was 72.85ha which had since shrunk to 17.37ha by 2017 demonstrating a drastic reduction of 76%. On the other hand, the area under vegetation reduced from 609.07ha (73.8%) to 148.86ha (18%) by 2017, while Farmland area increased from135.65ha (16.4%) to 473.85ha (57.4%). Built-up area which used to be 7.65ha (0.9%) in 1984 expanded to 185.14ha (22.4%) by 2017 due to population pressure. Loss of biodiversity was identified as the most significant negative environmental effect of Nyangongo wetland as it lost more than 460.21ha of vegetation due to agriculture expansion and for settlement. It is recommended that the County and National governments should intervene by declaring the wetland an Environmental Sensitive area and implement interventions to regulate restoration and relocate land uses that are injurious to the wetland and promote appropriate use of the wetland for posterity.

Keywords: Restoration, Spatio-Temporal, Wetland

Introduction

Wetlands are vital natural ecosystems which contribute significantly to the natural and human environments through the history of mankind (Tego, 2010). They are most diverse and productive ecosystems and were defined as areas of marsh, fen, fringes of lakes, rivers, flood basins, estuarine deltas, ponds, river fields and marine water areas either permanent or periodic inundation, whether natural or artificial, with water that is static or flowing, fresh, brackish or salt the depth of which at low tide does not exceed 6 meters (Ramsar Convention in 1971).

According to Ramsar Convention, there are more than 1900 designated wetlands around the world covering 186 million hectares. Ramsar mission entails conservation and appropriate use of all wetlands through local, regional, national and international cooperation to achieve sustainable development globally (Ramsar, 2007).

Despite their importance in providing ecological services and supporting livelihoods of local communities, wetlands are currently threatened by degradation. The estimated inland wetland loss in some parts of the world is placed at more than 50% as a consequence of human activities leading to loss of wetland flora and with resultant wetland species loss and negative impact on the livelihoods of local communities (*EANHS, 2018;* Springate-Baginski *et al., 2009*; Millennium Ecosystem Assessment, 2005; Otieno *et al., 2001).* This is because many developing countries depend heavily on exploitation of wetland biological resources to support life among very poor rural communities whose livelihoods depends solely on the exploitation of these resources (IUCN, 1996). Lack of appreciation of the value of wetlands and their subsequent low priority in decision-making process has led to perpetual destruction or modification of wetlands causing an uncalculated social cost. The existence of wetlands is under threat due to alarming human infringement and it is estimated that more than 50% of the world's inland wetlands have been lost mostly due to agricultural activities. In a profound sense, it is estimated that the loss of 56-65% of existing wetlands in Europe and North America, 27% in Asia, 6% in South America and 2% in Africa is due to agricultural activities (O'connel *2013*).Wetlands are considered sustainable when they have the ability to cope with and recover from stresses and shocks which allows them to maintain or improve their capabilities in future.

Kenya has a rich heritage of wetland ecosystems accounting for 3-4% or 14,000km^2 of the total land area coverage (*Raburu et al 2012; GoK 2013)*. This rich heritage is due to her diverse climatic and topographical conditions. The country hosts six wetland types; riverine; lacustrine; palustrine; estuarine; marine; and a few constructed wetlands. The area covered by Inland wetlands in Kenya is 2,641,690 ha, far outstripping that covered by marine and coastal wetlands which occupy 96,100 ha. However due to increased rates of wetland and catchment degradation, the total percentage of wetland area is estimated to have gone below 2% (GOK, 2008).

Kenyan wetlands were the first ecosystems to receive international attention through the Ramsar Convention which was ratified in 1990. Lakes Nakuru, Naivasha, Bogoria, and Baringo which cover a combined area of 1,045km^2 have since been designated as wetlands of International importance. In addition Lake Elementaita and Nakuru were added to the UNESCO World Heritage List during its 35th session (2011) in Paris, France. The government of Kenya (2013) through a ministerial statement acknowledged that, Wetlands are key to socio-economic development of Kenya.

Though perceived as 'wastelands', wetlands are crucial in provision of goods and services that are of ecological or socio-economic in nature to rural communities surrounding them. The perception has encouraged their continued degradation and loss through conversions to farmlands, settlement areas, waste disposal areas, development of industries and overexploitation of its biodiversity. The dependency by riparian rural communities who are faced with poverty, food insecurity and poor living standard and the existence of small-wetlands such as Nyangongo in communal lands have further encouraged their degradation hindering their sustainable management (Raburu *et al.,* 2012). The impacts are expected to increase with increased population reducing the areal extent of wetlands' ecosystem. The impacts may result in an ecosystem disruption destroying the wetland beyond repair. This study aimed at examining some of the anthropogenic activities and their environment impacts on Nyangono wetland ecosystem and establish their importance to local community and determine appropriate land use practices applicable to Nyangongo wetland.

Literature Review

In Kenya, many wetlands have been threatened by emanating natural events and anthropogenic activities since 80% of the wetlands occur on lands which are privately or communally owned and without any serious conservation measures (Ndungu, 2013). The main threats to wetlands are unsustainable human practices such as extensive agriculture, overgrazing, fires, industrial use and infrastructure development which could result in drying-up, siltation and pollution of wetlands. However natural factors which are inevitable like drought and aridity may also affect wetlands (Chipps *et al*., 2006).

Drivers of Wetland Loss and Degradation

Planning Policies and decisions in most cases do not take into account the many services that wetland provide hence the rapid degradation and loss of wetlands globally (Grabl *et al.,* 2012). This rapid worldwide wetlands loss and degradation has been the basis of Ramsar Convention and initiatives.

The increasing human population, coupled with the growing need for increased food production for subsistence and commercial purposes to meet the high demand, have put tremendous pressure on wetlands around the world (O'Connell, 2003). Globally, human activities pose the greatest threat to the well-being of wetlands, resulting in either their loss or degradation (Bierstadt, 2011). Wetland loss is defined as "the loss of wetland area due to conversion of wetlands to non-wetland areas as a result of human activity". Degradation refers to impairment of wetland functions as a result of human activities (Moser *et al.*, 1996). Degradation leads to loss in wetland area leading to change in quantity of wetland resources around a baseline. This is usually manifested by loss of biodiversity, change in wetland water quality/ flow patterns, scarcity of wetland resources, loss of aesthetic, cultural and spiritual values of wetlands and the appearance of new species (Schuijt, 2002).

Some of the drivers include agricultural activities, infrastructural development, growing of alien tree species such as eucalyptus, pollution and urbanization. Although cultivation is taken as a remedy to cushion the poor and landless to secure their food security to sustain their livelihood needs in a short-term, it leads to direct loss of wetland due to drainage and conversion to agricultural land; indirect loss as a result of water abstraction from rivers and streams for irrigation; salinization, sediment deposition, eutrophication and pollution from pesticides and chemical residues. Poor agricultural practices in the upland areas may also lead to soil erosion and sedimentation or runoff of agricultural waste, both of which can affect wetlands. The subsequent pressures may lead to degradation of that wetland (Houlahan *et al*., 2006; Makalle *et al.,* 2008).

Rapid population growth compels the landless to encroach on fragile ecosystems like wetlands. Population projections predict that the population of developing countries will increase to about eight billion by 2025 and nine billion by 2050, (UNEP report, 2015).
Eucalyptus plantation has high impact on the storage function of wetlands because a lot of water is lost through transpiration. The water uptake is high compared to other trees such as polar trees which shade their leaves in winter and support vigorous growth of indigenous plants resulting in habitat loss (MEA, 2005; Hein *et al*., 2006; Gonzales, 2009)

Theoretical Framework

This study adopted theoretical approach of Garret Hardin 1968 tragedy of the commons depicting a scenario where a group of pastoralists grazed their animals on common fields without restrictions on how grazing land should be utilized. In this open access regime, individuals sought to maximize private gains from the common property where every herder increased his stock to foster individual wealth, social prestige and a status symbol. Such actions result in overexploitation of the grazing land and eventual degradation of resources. Arguably, if he did not increase his stock, the other grazers would and would hence be wealthier than him. In this competitive, all herders tended to add as many animals as they could to the common grazing lands. The land carrying capacity was exceeded resulting in collapse of the pastoral economy and impairment of productive ecosystems.

Based on this theory, residents in the study area have resorted to encroachment of Nyangongo wetland as it is a common resource open for easy access for settlement, crop farming and other land use activities without restriction by relevant authorities. However, these activities have resulted to overexploitation and to impairment pf ecosystem resilience. Inadequate funding and lack of cooperation by the local government to facilitate conservation of this resource has led to accelerated environmental degradation. Figure1 presents the detailed situation in the study area.

Conceptual Framework

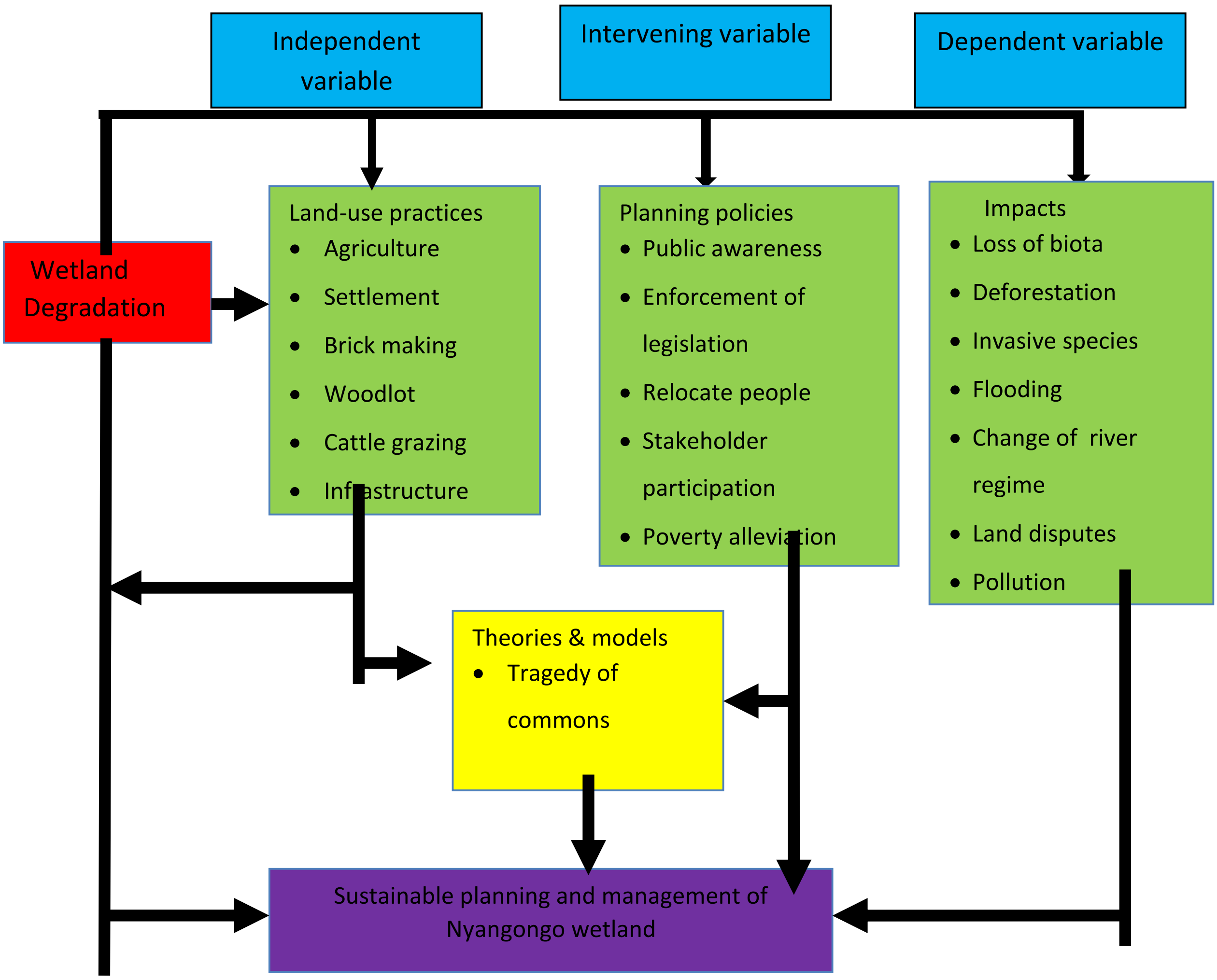

Figure 1: Conceptual Framework

The conceptual framework, depicts that the wetland is a key resource for poverty alleviation. Poverty on the other hand is a state of reduced or limited livelihood opportunities and leads to increased environmental degradation, either because people have no other variable options other than overexploiting natural resources. To contribute towards the realization of the MDG7, Kenya raised a poverty reduction strategy paper (2001-2004) that outlined key areas and measures necessary for poverty reduction and economic growth underscoring critical need for sustainable management of natural resources such as wetlands. Promotion and attainment of food security is recognized as the first step towards poverty reduction. Hence for the local community to sustain themselves they engage on exploitation of natural resource and since access to the same is not restricted by relevant authorities, overexploitation of the scare resources is inevitable. The community has moved into the wetland to engage in land use activities such as brick making, crop farming and livestock keeping, planting of eucalyptus trees and infrastructural development which enormously diminishes. For the locals to continue enjoying accruing benefits from the wetland, conservation should be key and this underscores the need for the implementation of policies that emphasize on resource management, monitoring and conservation by all interested parties. Therefore, there should be a concerted effort to educate the locals on the values of the wetland conservation and management to provide secure environmental services such as clean water and air for human use and provide insurance against risks of crop failure, market failure and natural disasters (Dechaineux (2015).

Materials and Methods

Study area

Nyangongo wetland (*Figure 2*) is situated about 10 km south of Keumbu market in Kisii County. The wetland covers an area of 825ha of land with a population density of 919.2 persons per square kilometer (Kisii CIDP, 2018). It is located at GPS coordinates 704,513.91m E, 9910989.53m S. A number of streams and rivers drain through the wetland with the main one being Rigathi river.

Climatic Conditions and Soils

The area exhibits a highland equatorial climate resulting into a bimodal rainfall pattern. Long rains are experienced between March and May and short rains between October and December with figures ranging between 1500mm to 2200mm with months of January and July being relatively dry. The mean annual temperature ranges between 16deg to 22deg. The high and reliable rainfall coupled with moderate temperatures are suitable for growing crops like tea, coffee, pyrethrum, maize, beans, and bananas as well as dairy farming. The area has red volcanic soils (nitisols), red loam soils, sandy soils and clay soils which have poor drainage (phaezems). In the valley bottoms, there exists black cotton soils (vertisols) and organic peat soils (phanosols).

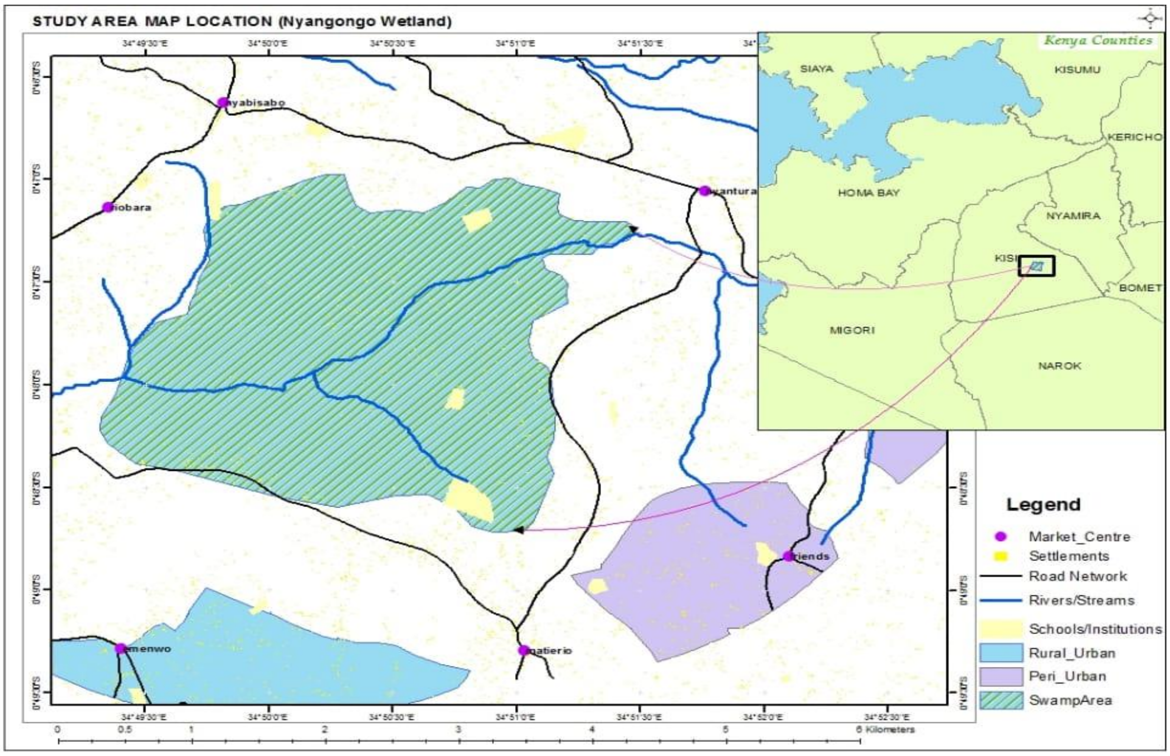

Figure 2: Map Showing Location of Study Area

Research Design

The study adopted action research design to interrogate the human activities in this setup and determine how they have impacted on the social and physical environment of this area. Action research can be defined as a reflective process of progressive problem identification and solving by individuals or groups to improve an issue in a community setup.

Data on human activities taking place on the wetland was collected and analyzed though their economic returns are high and short term and does not reflect sustainable utilization of this wetland.

Sample size and Sampling procedure

The research involved household interviews comprising of 251 respondents, key informant interviews, Focused Group Discussions, checklist, direct observation coupled with photographing to collect data.

Key Informant

The key informants were drawn from forestry department, agriculture, NEMA officers, WARM, County environment officers, who were purposefully selected to provide the desired information for the study. Key informants interview were carried out to corroborate the information obtained from household surveys to help gain a comprehensive understanding of nature and types of human activities, impacts, their relationship with land use and land cover in the wetland and the measures applied to promote conservation of the wetland.

Focus Group Discussions

Focus group discussions (FGD) were conducted as a follow-up to content analysis and individual interactions in interviews. Two focus group discussions were conducted with participants ranging from 8-12 both male and female. One group comprised of local farmers and brick makers and the other group comprised of members of administrative officers and elderly persons from the area.

Photography

Photography was used to corroborate the perception of results from other data collection sources to show the physical environment and land use practices as portrayed on the ground.

Sampling procedure

The main sampling procedures used included; Purposive sampling and Systematic Random sampling. Purposive sampling procedure was used in selecting key informants based on their knowledge of the study area. Systematic random sampling technique was used to select household respondents.

Research instruments

Primary data was collected using interview, to gain historical background of the wetland and data on wetland size and its users. Structured questionnaires were administered to individual household head/representatives. A total of 251 questionnaires from both wetland areas and its catchment area were duly filled and subsequently used for data analysis. The study focused on the communities living inside the wetland and within a range of 4km from the wetland boundary. The buffer zones were restricted to a distance of 4km because the propensity to use wetland resources is inversely related to travel distance (Odhengo et al.., 2018a; Abila, 2003). The questionnaires were complimented with photographs and data analyzed quantitatively using descriptive statistics.

Data Analysis

Data was analysed using descriptive and inferential statistics using SPSS Version 22. Descriptive statistics was used to assess the values the locals derive from the wetland to form a basis to develop a framework to enhance resource conservation. Data collected from key informant's interview and Focus Group Discussions (FGD) were analyzed and summarized as pertaining to wetland use, impending issues on its conservation, drivers of encroachment and emerging issues impacting on wetland loss and degradation. (Hsieh and Shannon, 2005).

Pearson Correlation analysis was used to describe the degree to which one variable relates to the other.

Results and Discussion

The study established Human activities in Nyangongo Wetland and quantified their importance to the Local Community as shown in Figure 3

From this study it was observed that the riparian communities derive a number of wetland values to sustain their livelihoods. Most of them are Supporting services which represents the ecological process that underlie the functioning of the ecosystem (MEA, 2005; Hein *et al*., 2006; Gonzales, 2009) such as wildlife habitat, grazing pastures, fiber and fuel, genetic materials for medicinal value, sand and clay for brick making, water abstraction for domestic use and watering their livestock, farmland for crop farming to enhance food security and for commercialization. Since the area receives rains most of the time, the locals engaged in agricultural activities all year round with Agriculture accounting for 91% as compared to other uses. This is followed by wood fuel at 75%, grazing 74.1%, hunting of wildlife at 24.3% and fishing which has since declined with only 28% of the locals obtaining fish from the wetland during wet seasons since breeding sites have been destroyed due to intensification of other agricultural activities and brick making.

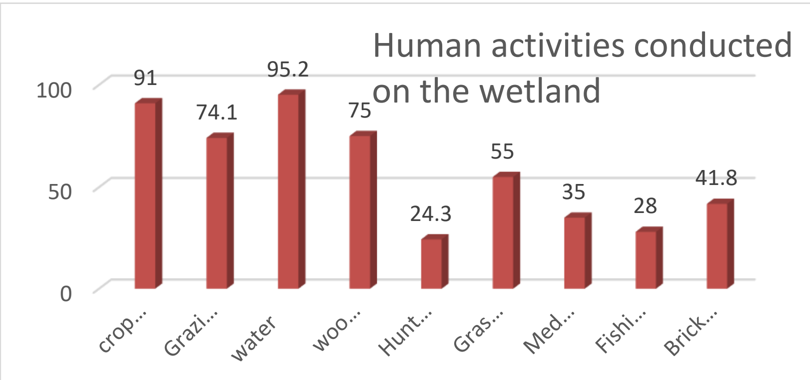

Figure 3: Human activities conducted on Nyangongo Wetland

Livestock Grazing

Grazing is one of the benefits locals derive from the wetland with 74.1% of the respondent reporting that they utilize the wetland for pasture to their livestock. Animals raised by the inhabitants included exotic and indigenous cows, sheep, goats and donkeys. The most common cattle breed is mixed hybrid animals and some zebu breeds. It was observed that free range and tethering grazing method of cattle rearing is practiced in the wetland. The P**late 1** below shows animals grazing on the wetland.

Plate 1: Livestock grazing on the wetland

The study revealed that land though under trust land has been segregated into individual grazing lands. Some farmers indicated that they converted their parcels into grazing land after crop yields declined which could lead to wetland regeneration as captured on satellite images of the area. The locals also indicated that the increasing demand for productive arable land and easier to work on, on the uplands is displacing grazing land to the valley bottom wetland areas. To determine the significant of grazing activity Pearson's correlation coefficient was used and results are as presented on table 1 below

Table 1: Model: Relationship between Households' Socio-demographic profile and Human activities on the Wetland

Land Use	R	R Square	Adjusted R Square	Std. Error of the Estimate
Grazing	.347[a]	.120	.026	.49657
Crop Farming	.308[a]	.095	.073	1.09071
Fishing	.154[a]	.024	.000	.16500
Water	.201[a]	.040	.016	.60941
Wood fuel	.227[a]	.052	.021	.07161
Medicinal Herbs	.257[a]	.066	.036	.75987
Thatch grass & Fibre	.227[a]	.052	.021	.07161
Brick Making	.175[a]	.031	.007	.49838

a. Predictors: (Constant), Gross income, Age of the respondent, respondent village, gender of the respondent, respondent marital status, educational level of the respondent, family size

Relationship between Households' Socio-demographic profile and grazing activity on the Wetland

The value of the R^2 =.120 (Table 1) shows that 12.0% of the independent variables was the predictors (gross income, age of the respondent, respondent village, gender of the respondent, respondent marital status, educational level of the respondent and family size as a result of grazing activities in Nyangongo wetland as explained by the model.

Crop farming

91% of respondents reported practicing agriculture hence agricultural expansion on the wetland. Other crops grown include sugarcane, bananas, tea, sorghum, finger millet, coffee, and beans, thus mixed cropping and agroforestry dominated most of the farms through the year round contributing to massive degradation of the wetland. Crops like sugarcane and bananas take a long time to mature and consume a lot of water resulting to wetland desiccation and lowering of the water table consequently impacting negatively on wetland function. Crop farming along riparian area had resulted to soil erosion and water pollution which over time will affect aquatic life and human health.

Plate 2 Agricultural Activities on the Wetland

Plate 2 above presents a sugarcane jiggery, a form of agricultural products extraction for commercialization. This has led to increased use of fertilizers to production for economic security. These agrochemicals get washed into the water resources and find their way into Lake Victoria.

Relationship between Households' Socio-demographic profile and crop farming on the Wetland

The relationship between Households' Socio-demographic profile and crop farming on the Wetland was analysed and results presented on table 1 above shows R^2 =.095, thus 9.5% of the respondents affirmed that crop farming in the wetland is significant for the local community.

Fishing

Fishing was also another provision services the locals benefited from the wetland though it was declining due to the loss of the wetland area. 28% of respondents indicated that they caught fish during the wet seasons when the wetland was waterlogged allowing for breeding. The Fisheries Department built fish ponds in the area to revitalize the same but the initiative stalled due to inadequate funding and poor management.

Relationship between Households' Socio-demographic profile and fishing activity on the Wetland

The value of the R^2 =.024 as indicated in the table 1 shows that 2.4% of the independent variables was the predictors (gross income, age of the respondent, gender of the respondent, respondent marital status, educational level of the respondent and family size which shows that fishing is significant for the local community as a benefit derived from the use of wetland.

Source of Water for domestic use

The common sources of water in the study area included; rivers, wells, protected springs and roof water harvesting. 95.2% of the respondents said they obtained water from the wetland for domestic use and to water their animals and crops including vegetables especially during the dry seasons and for making bricks. In addition, water is an important habitat for various biodiversity in the area such as mudfish which is harvested by the locals for consumption especially during rainy season when the wetland is water logged. Notably however, 5% of respondents harvested rain water and/or had sunk wells to obtain their water supply.

Relationship between Households' Socio-demographic profile and water use on the Wetland

A value of R^2 = 0.04 (table 1) shows that water obtained from the wetland is significant for the local community.

Source of Wood Fuel

More than 75% of the respondents interviewed indicated that they obtained fuel energy for firewood from among others *erythrina tomentosa, acacia mearnsii,* *croton macrostchyus* for domestic use. Wood fuel is used in processing sugarcane products from the sugarcane which is grown in the wetland and surrounding catchment areas. Satellite imagery shows that vegetation harvesting is carried out unsustainably resulting in drastic loss of habitat and biodiversity in the area. Indigenous vegetation continues to be replaced with exotic trees such as eucalyptus which brings high economic returns. However such trees impact on wetland ecology as they smother any undergrowth within the area.

Medicinal Plants as a Wetland benefit to the Local Community

Some of the indigenous trees in the area are useful as their roots, leaves or barks are harvested to supply medicinal herbs to cure various ailments such as mumps, typhoid, bloat, cough and sexually transmitted infections (STIs) as well as livestock diseases including foot and mouth disease, bloat and delivery problems. At least 5 plant species were associated with medicinal values and 35% of the respondents indicating that they obtained herbal therapy from the wetland. These medicinal plants were becoming rare due to the conversion of the wetland and adjacent vegetation cover into agricultural fields.

Table 2: Some Indigenous and Exotic Trees Grown in the Wetland Area

Botanical name	Common name	Indigenous/exotic	Use
Psidium guajava	Guava	Exotic	Firewood, human, animal feed & timber
Erythrina tomentosa	Omotembe	Indigenous	Medicinal, firewood &wood carving
Acrocarpus fraxinifolia	Omokina bwango	Indigenous	Medicinal& firewood
Sesbania sesban	Omosabisabi	Indigenous	Water filtration
Cassia didymobotrya	Omobeno	Indigenous	Medicinal
Triumfetta flavescens	Omomiso	Indigenous	Medicinal/firewood
Croton macrostachyus	omosocho	Indigenous	Timber/firewood

Relationship between Households' Socio-demographic profile and medicinal harvesting activity on the Wetland

A value of R^2 =.066 (Table 1) shows that medicinal herbs derived from the wetland are a significant benefit for the local community. WHO estimates that about 80% world population relies on herbal medicine for their primary health care needs. De Luca et al., (2012) asserted that more than 300,000 plant species exist globally and that only 15% have been screened for possible therapeutic potential. In light of this observation, the ministry of environment and Forests, India, documented more than 9500 plant species with pharmacological values adding value to India's healthcare system.

Thatch Grass and Fibre

The type of grass which is common and visible in the study areas is common cattail grass (Phragmites communis). It has numerous uses like covering fresh unroasted bricks from direct sunlight, thatch traditional houses and construction of brick sheds.

55% of respondents affirmed that they use thatch grass for various purposes and that this product was continously declining hence preference for use of other materials like iron sheets for construction. Thatch grass is also used as handcraft material for making mats and sometimes for fencing around homes and makeshift bathrooms. According to Abagusii customs, leaves from fibers were used to cover food (Ugali) prepared from wimbi during payment of dowry. Such fibers are also used to fasten rafters when making mud houses and to fasten thatching grass in form of (reeds) to prevent it from being blown away by strong winds hence preventing roof leakages during rains.

The R^2 =.052 (Table 1) shows that thatch grass and fiber is a significant wetland derived benefit for the local community.

Brick Making

41% of respondents depended on brick making as an economic activity and that a kiln of 5, 000 bricks after baking, would yield approximately 4,000 complete bricks excluding the damaged ones. The cost of one brick at the time of the survey sold at Ksh. 10 translating to Ksh. 40,000 providing higher economic returns compared to other economic activities such as tea farming which generate less income for a similar period of time.

The relationship between Households' Socio-demographic profile and brick making had R^2 =.031(Table 1) demonstrating that brick making is a significant wetland derived economic activity for the local community.

Though there are laws and regulations protecting wetlands from being used indiscriminately(Swallow et al., 2003; GOK, 2014) they are continually being ignored by riparian rural populations who have no alternatives' due to socio-economic stressors leading to unsustainable use of the natural resource. Similarly, several researchers have attributed agricultural expansions in various parts of the world to depletion of land covered with natural vegetation (Bewket, 2002; Amsalu et al., 2007; Dessie & Kleman, 2007; Prakasam, 2010; Schneider & Pontius, 2001).

It is therefore clear from the findings that agricultural expansion is the major land use activity impacting more on wetland ecosystem resulting in intense vegetation clearing hence degradation and loss. Similar observations have been made in other developing countries (Rosolen et al 2014), Zsuffa et al 2014). The increase in wetland cultivation may be attributed to the integral role agriculture plays in rural livelihoods of semi-arid areas in Zimbabwe (Victoria et al, 2012).

Conclusions and Recommendations

Although land use activities account significantly to the sustenance of livelihoods of the riparian communities in Nyangongo wetland, land use changes and poverty coupled with rapid socio-economic dynamics of the increasing population as well as lack of elaborate planning framework has curtailed sustainable management and development of Nyangongo Ecosystem for both present and future generations.

That agriculture is the main type of land use on the wetland ecosystem has led to increased surface runoffs, erosion, flooding, and sedimentation which has resulted in catchment degradation, water pollution, loss of biodiversity and other important socio-economic and cultural benefits.

Recommendations

There is need to advance policies to advise appropriate utilization of wetlands to ascertain sustainable use of such resources and limit environmental degradation to encourage rehabilitation of the wetland and restore the declining values for the benefit of the current and future generations. Communities around the wetland should be involved in sustainable wetland management strategies with the view restoring and conserving the wetland integrity. Planting of environmental friendly plants like the bamboo and other indigenous trees should be encouraged, controlled livestock grazing, apiary farming and Soil-less cultivation be encouraged to reduce the pressure on arable land to turn the wetland into a sustainable base for rural economy without altering the ecosystem characteristics.

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Use of ICT in the Classroom: The Teacher and Learner

Ngumbi, E [1], Wasike J[2]

[1] *Catholic University of Eastern Africa, KENYA*

[2] *Kirinyaga University, KENYA*

Correspondence: elizabeth.ngumbi6@gmail.com

Abstract

The use of ICT in classroom teaching and learning is critical for success of any education system. However, without proper implementation strategies and foundation in place for the use and application of ICT, the education agenda for any county or organization is bound to fail. This study sought to examine the current status of ICT in classroom teaching and learning, ICT integration in the classroom, educational Policy and Planning, teacher and learner attitudes, availability of hardware and learning e- resources, administrative support and internet connectivity with a view to making recommendation for improvement. Existing literature was reviewed and personal experiences used as educators and observations documented to guide in developing the research. Results showed that ICT covers a whole range of applications, techniques and systems and is key in effective facilitation of classroom teaching and learning, information dissemination and sharing and thus impacting the learner's life skills. It was further established that ICT plays an integral part in teaching-learning interactions through use of interactive digital whiteboards, smartphones and "flipped classroom" model that enables students to practically view live lessons. Training is recommended for teachers especially in the creative use and application of ICT tools in teaching, especially using the learner participatory approach.

Keywords: Information Communication Technology (ICT), Classroom, Teaching, Learning.

Introduction and Background

ICT in Teaching and Learning

The term Information and Communication Technology (ICT) was introduced in the early 1990's to replace Information Technology (IT) in recognition of the communicating abilities and facilities offered by the computer. However, while most people have adopted the term ICT, people in higher education use the term Communication and Information Technology (CIT) to refer to the same concept.

ICT covers a whole range of applications, techniques and systems (Clarke, 2006). Lallana and Margaret (2003) argue that ICT refers to abroad field encompassing computers, communications equipment and services associated with them. ICT is not just considered as applications and systems, but also as a skill for life. In this sense, it is regarded in line with literacy and numeracy as a fundamental skill which every individual needs so as to live confidently, effectively and independently in a modern society (Clarke, 2006). Use of technological skills in learning and teaching have been proven important during COVID – 19 pandemic due to lockdowns and cessation of movement forcing learners and teachers to learn remotely (UNESCO, 2021). Both teachers and learners were in high need of basic ICT tools and Internet connectivity for learning to continue remotely.

ICT is as a key skill, underlies learning in different subject areas, while it is developed through each subject (Tanner & Jones, 2003; Kennewell, 2004). This identification of ICT as a skill for life formed the basis of its introduction in the institution curriculum in the developed nations. ICT has three positions in the curriculum, namely: learning about ICT, learning with ICT and learning through ICT. Learning about ICT refers to ICT concept as a subject of learning in the institution curriculum, while learning with ICT is concerned with the use of ICT as a medium to facilitate instruction. While supporting the same view, Pelgrun and Law (2003) maintain that learning through ICT refers to the integration of ICT as an essential tool into course /curriculum. It implies that ICT can be learnt as any other subject in the curriculum but can also be integrated in the learning process so that learning takes place through the learners' interaction with the facilities.

Education has traditionally been a process of impartation of knowledge, skills, attitudes, values and other dispositions in order to produce a better and productive individual. However, modern technologies expect education to go beyond traditional impartation to enabling learners to engage in a life-long acquisition of knowledge by their own efforts especially through the use of ICT. In ancient Greece, Socrates argued that education is a slow and skilful process of extracting the latent potentialities which are already within a learner hence it is a life-long process that begins at birth and ends with death (Wosyanju, 2009; Teklemariam & Nam, 2011; Teachers Mind, 2012). Integration of ICT refers to seamless incorporation of ICTs to support and enhance the attainment of curriculum objectives, to enhance the appropriate competencies including skills, knowledge, attitudes and values and to manage education effectively and efficiently at all levels (Republic of Kenya, 2012b). Institutionalization of technology represents the degree to which ICT technology becomes a routine and pervasive commodity within the institution so that ICT uses become the acceptable ways of doing things.

Using and integrating ICT in institutional management, teaching and learning helps to shift learning from the traditional approaches to modern including online learning. For instance, knowledge is transferred from teachers and textbooks to learners with little space and more time is given to critical analysis of issues by learners (Republic of Kenya, 2012a). In addition, ICT is a key tool of modern technology used in the training and acquisition of various skills both in education and in other areas of focus by professionals. Thus ICT in education is considered as a discipline, resource and key skill. Within these broad areas, ICT offers enormous benefits to society based on the fact that ICT education in education is not only imparting knowledge and skills for the information age, but also in boosting the economic and political status of the country. Besides harnessing the potential of ICT, nations can greatly expanding economic growth, dramatically improved human welfare and stronger forms of democratic governance (Chandrasekhar, Kumar & Kamik, 2004). It is in this regard and in view of education objectives of providing the learners with opportunities to acquire necessary knowledge, skills and attitudes for the development of the self and the nation, build a foundation for technological and industrial development, that makes it necessary to integrate ICT in education.

Study Objectives

This study sought to stablish the current status of ICT in classroom teaching and learning, the principles of ICT integration in the classroom, educational Policy and Planning, and determine teacher and learner attitudes, availability of hardware, electronic learning resources, administrative support and internet connectivity with a view to making recommendation for improvement.

Methodology

The study reviewed existing literature and used personal experiences of educators.

ICT Use in Classroom

It is necessary to develop a thorough rationale before beginning to use computers in classrooms. This would be of little significance providing computers in institutions unless a valid rationale has been established. With the increasing availability of computer hardware, it is important that teachers do not become engrossed in the machine, but focus on their primary role as educators. Since the 1960's the computer has been heralded by some as the solution to many problems in education. According to Lee (2006), many early computer scientists saw the possibility of the computer replacing teachers in institutions. However, this has not been the case in the mainstream institutions (Collis, 1989). There are three main rationales for ICT in institutions, thus the organizational productivity of the Institution, technological literacy and support for student learning. Dest (2002) presupposes the need for ICT competent students and for ICT rich environments that enhance students' learning across the curriculum.

Historically, technology has been developed to solve problems, improve living standards and increase productivity. If the most appropriate educational technology is selected by teachers, then students learning should be optimized which through increasing the value of the outcomes. However, the cost of technology may be a factor to consider. ICTs are be relatively expensive to procure, install, maintain and support users and this should be compared with the outcomes (Lankshear & Synder, 2000). Besides productivity, technology is used because it solves a major problem in teaching or learning (Lankshear & Synder, 2000). This could complement the aspect of productivity, for if a part of the curriculum is not completed due to lack of technology, then the associated value of the outcomes is zero and therefore, the productivity is zero.

A nationwide survey of teachers commissioned by Josten Learning Cooperation (1997) indicated that the computer revolution has had a tremendous impact in the classroom. The emphasis was on student access to information outside the classroom and improved student motivation, not on specific academic achievement. The study found that fewer than half of the teachers used computers for instructional purposes, rather they used word processing, spreadsheets or graphics for personal productivity only. Differing priorities showed that teachers would rather use additional funding to increase the number of computers in classrooms while principals felt that teacher training would improve effectiveness of computer use in learning. Other surveys (Bosch, 1993; Niess, 1991; Trotter, 1997), while reporting strong computer usage by teachers, pointed to lack of integrated use with the curriculum. In many instances, it has been a case of fitting the curriculum to the computer rather than the computer to the curriculum.

Working in an appropriately designed ICT rich environment has the potential of producing a variety of positive outcomes, improved patterns of social interaction, and changes in teaching styles, more effective teaching, increased student and teacher motivation. Achieving this potential is a challenge and requires the correct vision of ICT and its integration (Tiene & Luft, 2001). Education Week magazine (1999) examined the state of

ICT in public education in the United States and reported that; (i) 43% of the respondents in a survey felt that introduction of computers into public institutions was not happening fast enough, (ii) that despite the lack of research evidence, 74% of the public and 93% of educators agreed that computers had indeed improved the quality of education, teaching and learning (Trotter, 1997, p. 8) (iii) that placing computers and software in the classrooms is not enough, rather, discovering whether ICT "works" is not the point and that the real issue is when and under what circumstances. Like any other tool, teachers have to come up with a strategy or pedagogy to make it work (Viadero, 1997, p. 16), (iv) that wise use of technology takes adequate training, time planning, support and teacher ownership (Viadero, 1997, p.16) and that (v) money spent on technology is wasted without an equal effort to help teachers with its use and integration into the curriculum (Zehr, 1997, p. 24). Thus despite the general feeling that the computer revolution of the last decade has had a major impact in institutions, the nature of this impact seems to be limited to access and information retrieval rather than improved teaching methods or revitalized institution and classroom structures (Hativa & Lesgold, 1996).

According to Pelgrum, 2001 challenges have been acknowledged by a number of scholars with;

i. Access to hardware and software as well as funding.
ii. Time for planning, personal exploration, online access and skill development
iii. Technical and administrative support and resources.
iv. Resistance, passivity, institution cultures and traditions of teaching
v. Vision and leadership
vi. Support for integration of technologies into instruction and the curriculum

Ertmer (1999) grouped these challenges into two categories: first order challenges or barriers extrinsic to teachers (access, time, support, resources, training) and second order challenges intrinsic to teachers (attitudes, beliefs, practices, resistance). She asserted that even if every first order challenges/barrier were removed, teachers would not automatically use ICT/technology and in fact, rather than being eliminated completely, such barriers will continue to ebb and flow throughout the evolutionary integration process.

Principles of ICT Integration in the Classroom

Integration does not mean placement of computers or hardware in classrooms. If computers are merely add-on activities or fancy work sheets, where is the value? (Hadley & Sheingold, 1993). ICTs must be pedagogically sound. They must go beyond information retrieval to problem solving; allow new instructional and learning experiences not possible without them; promote deep processing of ideas; increase student interaction with subject matter; promote teacher and student enthusiasm for teaching and learning; and free up time for quality classroom interaction.

Wager (1992) argued that the educational technology that can make the biggest difference to institutions of learning and students is not the hardware, but the process of designing effective instruction which incorporates computer technology and other media appropriately. Integrating technology is not about technology, it is primarily about content and effective instructional practices. ICTs involve the tools with which we deliver content and implement practices in better ways. Integration is defined not by the amount or the type of ICTs used, but by how and why it is used. Successful technology adoption and integration requires concerted focus on the mission of improving education for all students. It grows from the mission. Bernauer (1995) captured a significant insight when he stated that it is not ICT as such that has resulted in improved student outcomes, but rather how the technology was used and integrated into instructional processes.

In addition, Munoz (1993) described herself as a technophile, emphasized the prudent, ethical use of ICT and warned us to resist the seductive force of technology to replace rather than enhance. Fullan (2000), in a review of educational reform, reminds us that since technology is ubiquitous, the issue is not whether, but how we contend with it. He stressed that as ICTs become more powerful, good teachers become more indispensable.

Lewin (1951), the author of force field analysis theory, illustrates the dynamics at work in the change process. This Movement from the present level of performance to a desired level is facilitated by driving or encouraging forces, while at the same time, it is hindered by restraining (or resisting, discouraging) forces. The present situation usually represents a state of equilibrium or balance between these driving and restraining forces.

The Driving forces for technology integration might include the power and potential of new developments, rapid availability, creativity, internet access, ease of communication, or the promise of impact on learning. Restraining forces might include barriers and constraints such as technical support, teacher expertise, and time for planning or pedagogical applications. ICT does, indeed, hold a remarkable promise for changing the quality of teaching and learning in our institutions. It is indeed a catalyst for transformation, but this does not mean that we merely need more computers in our classrooms. We spent resources on installing equipment, which soon begin to gather dust, because we neglected the process components –learning, teaching practices and curricula. Thus, ICTs are valuable resources, but only when used in a systematic process for developing human competence (Earle, 1992).

Teacher Use of ICTs

According to Fullan (2000), integration includes a sense of completeness or wholeness and incorporates the need to overcome artificial separations by bringing together all essential elements in teaching and learning process. Change starts with individual teacher, who, upon catching the vision, is willing to take risks, experience confrontations or encounters in rethinking, teaching, and learning and to model for and be a mentor to peers. It involves preparation of the teacher (building relationships of trust, helping teachers feel and recognize the power of teaching with technology, personalizing, training, and finding out teacher needs, interests and concerns), commitment by the teacher, following up on that commitment by the support team and resolving teacher concerns arising during the change process. Teachers move through at least three levels in the change process: confidence, competence, and creativity. It is the gradual nature of the process as they progress from learner to adopter to leader.

Kafu (1976) noted that teachers tend to lag behind in adaptation and adoption of new technologies that they are nervous and unwilling to adopt these innovations and hence find themselves unprepared to meet the new demands of the accelerating educational technology that confront them including introduction of computers. Tinio (2003) argued that although valuable lessons may be learned from best practices around the world, there is no one formula for determining the optimal level of ICT integration in the educational system. Significant challenges that the policymakers and planners, educators, education administrators and other stakeholders need to consider include educational policy and planning, infrastructure-hardware availability, software and content development, capacity building/training, administrative support, and teacher attitude.

Makewa (2002) stated that teachers in institutions encounter a number of problems as they attempt to implement computer use in their institutions. These problems include insufficient number of software, lack of adequate computer knowledge and maintenance competence, training opportunities, lack of modern computers, and inadequate funds for computer implementation.

Educational Policy and Planning

Tinio (2003) points out that attempts to enhance and reform education through ICTs require clear and specific objectives, guidelines and time-bound targets, mobilization of required resources and political commitment at all levels to see the initiative through. Some of the essential elements of planning for ICT are listed as:

i. A rigorous analysis of the present state of the educational system. ICT-based interventions must take into account current institutional practices and arrangements. Specifically, drivers and barriers to ICT use need to be identified, including those related to curriculum and pedagogy, infrastructure, capacity building, language and content, and financing.

ii. Specification of educational goals at different education and training levels as well as the different modalities of the use of ICTs that can best be employed in pursuit of these goals. This requires of the policy maker an understanding of the potential of different ICTs when applied in different contexts for different purposes and an awareness of priority education needs and financial and human resource capacity and constraints within the country or locality as well as best practices around the world and how these practices can be adapted for specific country requirements.
iii. The identification of stakeholders and harmonizing efforts across different interest groups.
iv. The piloting of the chosen ICT-based model. Even the best designed models or those that have already been proven to work in other contexts need to be tested on small scale. Such pilots are essential to identify and correct, potential glitches in instructional design and implementability.
v. The specification of existing sources of financing and the development of strategies for generating financial resources to support ICT use over the long term.

Teachers' and Students' Attitudes

Rogers (1995) asserted that attitude determines whether a person is willing to try a new innovation or not. With the explosion of information in all areas of our lives, the growing need for a more competent workforce increases the need for the integration of ICT in classrooms.

In large part, then, the responsibility for preparing highly qualified workers who are up to the challenges of a global economy rests on teachers. In order for teachers to integrate technology successfully in their classrooms, it is crucial that they cultivate and maintain positive attitudes toward technology and attain computer skills (Hignite & Echternacht, 1992). Some teachers do not believe that ICT's are relevant to either student improvement or to their professional development. As a result, there is a slower shift in teachers' attitude towards ICTs than planners had expected and hence student attitude is affected.

Hardware and Learning Resources

According to Tinio (2003), a country's educational technology infrastructure sits on top of its national telecommunications and information infrastructure. Before any ICT- based programme is launched, educators must carefully consider whether or not;

i. There appropriate rooms or buildings available to house technology. In countries where there are many old buildings, extensive retrofitting to ensure proper electrical wiring, heating/cooling and ventilation, and safety and security would be needed.
ii. Electricity and telephone are available. In developing countries large areas are still without reliable electricity and the nearest telephones are miles away. Experience in some countries in Africa point to wireless technology (such as VSAT or very small aperture terminal) as possible levers for leapfrogging. Although this is currently an extremely costly approach.

It is cheaper and easier to introduce a form of technology into education and keep it working where education is riding on the back of large-scale developments by governments or private sector. Television works for education when it follows rather than precedes television for entertainment. Computers in institutions can be maintained once commercial and private use has expanded to the point where there is an established service industry. Thus, it is not always necessary to have one computer per student, but they need sustained access to appropriate computer systems. The hardware requirements of the computer system will depend on the type of software required.

Capacity Building

Various competencies must be developed through the educational system for ICT integration to be successful. According to Tinio (2003), teacher professional development should have five foci: skills with particular applications, integration into existing curricula, curricular changes related to the use of ICT, changes in teacher role, and underpinning educational theories. Ideally, these should be addressed in pre-service teacher training and built on an enhanced in-service. In some countries, teaching accreditation requirements include training in ICT use. ICTs are swiftly evolving and even the most ICT fluent teachers need to continuously upgrade their skills and keep abreast of the latest developments and best practices. Most teachers' professional development in ICT is heavy on "teaching the tools" and light on "using the tools to teach."

Administration Support

According to Hope (1997), leadership plays a key role in ICT integration in education. Many teacher or student-initiated ICT projects have been undermined by lack of support from the administrators. For ICT integration programs to be effective and sustainable, administrators themselves must be competent in the use of technology and must have a broad understanding of the technical, curricular, administrative, financial and social dimensions of ICT use in education. Thus, successful implementation of ICT in education would to an extend depend on the principals or education managers. ICT in education is a target oriented innovation which is very demanding in terms of financial, material and human resources. The huge financial involvement makes it necessary for the principal to understand clearly the essence of ICT in education, its benefits to human beings especially in education sector and how ICT in education can be developed and implemented. The Scottish Executive (2000) presents some ideas which a principal who is in the process of starting ICT in education should consider. These include;

i. Finding out where the institution is now, what is the current provision in the curriculum, resources for training and other needs?
ii. Finding out where the institution needs to be?
iii. Deciding how the institution will get there.
iv. Creating an ICT section in the institution development plan.
v. Conducting a staff training ICT needs assessment.
vi. Reviewing the curriculum.
vii. Considering approaches to teaching and structuring of tasks.
viii. Considering how ICT can impact on a range of learning approaches.
ix. Considering the ICT present learning environment and what is needed to deliver the curriculum.
x. Determining how assessment, recording and reporting for ICT is done.
xi. Considering developing a policy statement for ICT across the institution.
xii. Determining how monitoring and evaluation of ICT performance is carried out.

The Scottish executive also presents indices of ICT successful implementation as a guide to principals. According to the Scottish Executive (2000) ICT in teaching and learning is successful where pupils are:

i. Motivated, challenged and required to think for themselves.
ii. Encouraged to be independent and confident users of technology.
iii. Set tasks, encourage cooperation and collaboration, solve given problems and more responsive in the context of support for learning activities.

These indices of successful ICT in education should guide every principal during the development and implementation phases of ICT in education in his/her institution. At the planning stage, they guide selection of learning content and resources, while at the implementation stage, they guide the process of evaluation. One underpinning requirement is that every institution principal should endeavor to be competent in the use of technology. Tinio (2003) this observed that for effective and sustainable ICT in education, the leader or administrator must have a broad understanding of the technical, curricular, administrative, financial and social dimensions in education.

Technical Support

Tinio (2003) continued to argue that technical support whether provided by in-institution staff or external service providers, or both, technical support specialists are essential to the continued viability of ICT use in a given institution. Thus, while the technical support requirements of an institution depend ultimately on what and how technologies deployed and used, general competences that are required would be in the installation, operation and maintenance of technical equipment (including software), network administration and network security. Without on-site technical support, much time and money may be lost due to technical problems.

Content and Software Availability and Internet Connectivity

Tinio (2003) continued to argue that content development is a critical area that is too often overlooked. The bulk of existing ICT based educational material is likely to be in English or of little relevance to education in developing countries, Kenya included. There is therefore, need to develop original educational content e.g. radio programs, interactive multimedia learning materials on CD-ROM or DVD and web based courses. An estimated 80% of online content is in English hence a large proportion of the educational software produced in the world market is in English. For developing countries in the Asia-Pacific countries where English language proficiency is not high, especially outside metropolitan areas, this represents a serious barrier to maximizing the educational benefits of the World Wide Web-WWW. Thus, even in countries where English is a second language (such as Kenya, Singapore, Malaysia, the Philippines, and India) it is necessary that teaching and learning materials that match national curriculum requirements and have locally meaningful content, preferably in the local languages, be developed. This would ensure that the World Wide Web is a genuinely multicultural space and that people from different cultures have an equal stake and voice in the global communities of learning and practice online.

Conclusion and Recommendation

Use of ICT in teaching and learning is critical for success of any education system. Its impact on education is encouraging because students are taught practical IT skill which can be used in working life as well since it is a life skill. ICT allows students to monitor and manage their own learning, think critically and creatively, solve simulated real-world problems, work collaboratively, engage in ethical decision-making, and adopt a global perspective towards issues and ideas, allowing the teacher to produce and modify information resources quickly and easily for access and use by learners. It allows access to a wide range of information in various formats, and interactive whiteboards (IWBs) have become essential tools in the classroom enabling learners to engage in a life-long acquisition of knowledge using their own efforts and subsequently recognizing their readiness, attitudes, motivation, barriers, and learning styles. They also significantly enhance learner human and social capabilities and have a positive role on their well-being. ICT further necessitates greater communication, resource sharing, and improved practice so that the education agenda is owned by helping every individual in the system improve teaching and learning. It is a time of great possibility and progress for the use of technology to support learning. However, to maximize on the use of ICT in classroom, there is need to establish a starting point where each students' ICT learning and embed in key learning areas such as literacy and numeracy is established; planning for progression in ICT learning progression in the Learning Continuum of the curriculum, and employing evidence based ICT teaching strategies that support ICT learning alongside subject learning.

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Optical and Electrical Characterization of Tin Sulfide

Okinyi, D.O[1], Gwaro, J.O[2] , Munji M[3], Njoroge, W[4].

[1,3, 4] Kenyatta University, [2]Maasai Mara University

Correspondence: dokinyi@gmail.com

Abstract

Alternative sources of clean and more efficient energy are desirable to replace fossil fuels for sustainable development. Photovoltaic technologies have become major players in the development of renewable sources of energy using thin film solar cells. In this study, tin sulfide (SnS) films were prepared and deposited using chemical bath. The preparation of tin chloride was done by weighing different masses to obtain various concentrations in the range (0.05 - 0.25) M. Tin chloride was then dissolved by adding HCL (5mL). Addition of HCL made the solution to be transparent. 20mL of 0.1M NA2EDTA acting as a complexing agent was added into the transparent solution in the beaker and the solution stirred using a glass rod for 4 minutes. Next 20mL of 0.6M of sodium thiosulfate (source of sulphide) was added and the solution stirred for 4 minutes. Ammonium was added to the solution to make it alkaline and clean glass slides were vertically placed in the solution without disturbing it. Optical properties of thin film samples prepared such as transmittance, absorbance and reflectance in the range of 200nm to 1200nm were measured using UV-VIS NIR Solid Spec 3700 DUV Spectrophotometer in the range 200nm to 1200nm. The optical measurements were calculated using SCOUT software to determine absorption coefficient and band gap for all the thin films that were prepared. The sheet resistivity of all the thin films prepared were measured by using 4-point probe. The tin sulfide films were prepared at a concentration of 0.1M of tin chloride with a thickness of 62 nm used to fabricate the photovoltaic solar cells. The optical and electrical properties measurements showed that the fabricated solar cell has low transmittance, high absorbance and suitable narrow band gap for an absorber layer. Based on the optical and electrical values obtained, a p-n junction was fabricated suitable for solar cell applications.

Keywords: Band Gap, Photovoltaic, P-N Junction, Solar Cell.

Introduction

The photovoltaic industry is experiencing a lot of research activities that are directed towards the development of new alternative ways of meeting energy demands, since more energy is expected to be consumed by industries and domestic use (Kui-Jui, 2010). Solar energy is available in plenty naturally from the sun hence it has high potential of meeting a large fraction of renewable energy demands. Conversion of solar energy into electricity will be crucial to ever increasing energy demands (Mohd *et al.,* 2011).

Solar energy is an environmental friendly and economically viable clean source of renewable energy. Its tapping is crucial in obtaining an environment free from carbon emissions (Makori, 2013).

Ongoing research on thin film solar cells is mainly on CdTe-CdS and CIGS-CdS due to its high achieved efficiencies of 22.1 % (De Elisa, 2016) and 23.4% (Gedi *et al.,* 2021) respectively. The research has a major setback due to presence of harmful elements (cadmium and selenium) and Tellurium, Indium and Gallium being scarce and expensive (Gedi *et al.,* 2021). In view of the above factors, efforts have been made in developing an environmental friendly absorbers and buffers that are not harmful and abundant in nature. Tin sulfide has drawn much interest in research due to its abundance being non- poisonous and cost effective. It is viewed as a favorable absorbing layer for thin film solar cells because of its magnificent optical and electrical properties. It is a double compound semiconductor comprising of non-poisonous and earth bountiful materials. The band gap energy is 1.35 eV which is near to the optimum value 1.5 eV for maximum absorption of solar energy. The absorption coefficient in the visible region is high (greater than 104 cm-1) (Jacob *et al.,* 2015). The theoretical efficiency is about 32% which is almost equal with silicon based sunlight cells (Araujo *et al.,*1994). The efficiency recorded so far for SnS based solar cells is merely 4.6% (Sinsermsuksakul *et al.,* 2014). Subsequently, a superior comprehension of the underlying structural, chemical and actual qualities of SnS is expected to accomplish higher efficiencies.

Tin sulfide films have been prepared and deposited using a number of techniques such as thermal evaporation (El-Nahass *et al.,*2002), successive ionic layer deposition (Ghosh *et al.,* 2011) Chemical bath deposition (Sinsermsuksakul *et al.,*2013), spray pyrolysis (Ninan *et al.,* 2016) and atomic layer deposition (Sinsermsuksakul *et al.,* 2014). Films deposited by atomic layer deposition have recorded the best efficiency so far, though the method is slow and expensive. The chemical bath technique has been reported to be a favorable substitute method of deposition (Chao *et al.*, 2011) because it is simple in depositing the low cost of constituent materials of SnS and the fact that the films obtained can occupy large areas. Optimizing growth conditions (time for deposition and concentration of the solution) is important in order to avoid unnecessary precipitation and any loss of materials during deposition (Higareda-Sanchez *et al.*, 2021).

This research focused on investigating the effect of concentration of tin chloride on the thin films deposited. Effects of varying the concentration on the precursor on optical and structural aspects were studied. Concentration was varied from 0.05 M – 0.20 M and deposition time maintained at 50 minutes. SnS thin films of better crystallinity were obtained at 0.1M SnCl2.
The tin sulfide thin films were prepared by chemical bath technique.

Methodology
Chemical bath technique was used in depositing the tin sulfide thin films. The films prepared by this method were of high quality. This technique of preparing thin films can be deposited on a broader area. The set up below of chemical bath technique was used in the deposition of SnS.

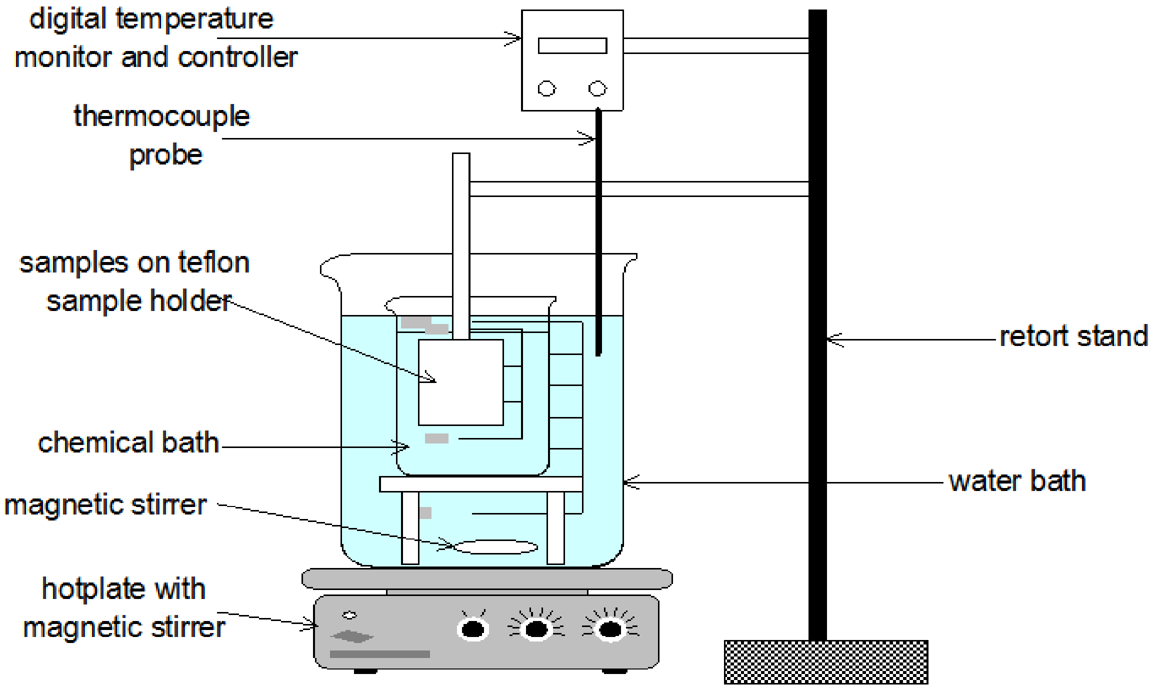

Fig. 1: Set up of Chemical Bath Technique

The following chemicals were used for preparation of SnS thin films; sodium thiosulfate, tin chloride and di-sodium ethylene diaminetetraacetic (Na2EDTA), ammonia and HCl.

Tin was obtained from tin chloride. Tin chloride was dissolved by adding hydrochloric acid. Sulfide ions were obtained from sodium thiosulfate. Di-sodium ethylenediaminetetraacetic (Na2EDTA) was used as a complexing agent. Ammonium was used to change pH of the precursor solution. The complexing agent was to chelate with tin ions. The microscopic substrates were cleaned before deposition by immersing them in ethanol for 10 minutes and later cleaned using distilled water for another 5 minutes.

In order to prepare SnS, specified amount of tin chloride was weighed in a beaker to obtain different concentrations (0.05 M to 0.20 M). The tin chloride was dissolved by adding 5 ml of HCL making the solution transparent. 20 ml of complexing agent (0.1M Na2EDTA) was then added and the mixture stirred well for 2 minutes, 20 ml of sodium thiosulfate of 0.1M concentration added and the solution stirred by using a magnetic stirrer. To change the pH of the solution 1 ml of ammonium was added and obtained solution kept at a constant temperature of 80oC. The substrates were kept vertically for a duration of 50 minutes for deposition to take place. After 50 minutes of deposition, the substrates were removed and cleaned by immersing in distilled water and cleaned deposited films dried for analysis.

Table 1 below shows summary of deposition parameters

Table 1: Deposition parameters of SnS

Parameters/Chemicals	**Quantities/Conditions**
SnCl2.H2O	25 ml
Na2S2O3	25ml
Na2EDTA	25ml
HCL	5ml
NH3	1ml
Deposition temperature	80oC
Deposition time	50 min
pH	12

Results and Discussions

Optical characterization

The solid spec DUV spectrophotometer was used to obtain reflectance and transmittance data in the wavelength range of 200 nm to 1200 nm. The transmittance data was used in the Scouts software to obtain band gap energy, absorption coefficient and refractive index. Results recorded from Scouts Software were used to determine absorption. The absorption results were also used to determine band gap using equation
(1) below,

$\alpha h\upsilon = (h\upsilon - Eg)1/2$ (1)

where α is absorption coefficient, h is planck's constant (h = 6.63 x 10-34 Js) and υ is frequency of incoming photon.

From the graph of (αhυ)2 against hυ, band gap was obtained by extrapolating the region that is linear in the graph.

Electrical Characterization

Resistivity of films were measured using 4-point probe method connected to Keithley 2400 source meter. Sheet resistivity was calculated from sheet resistance.

a. Transmittance

The graphs of transmittance against wavelength are as shown in the figure 2 below;

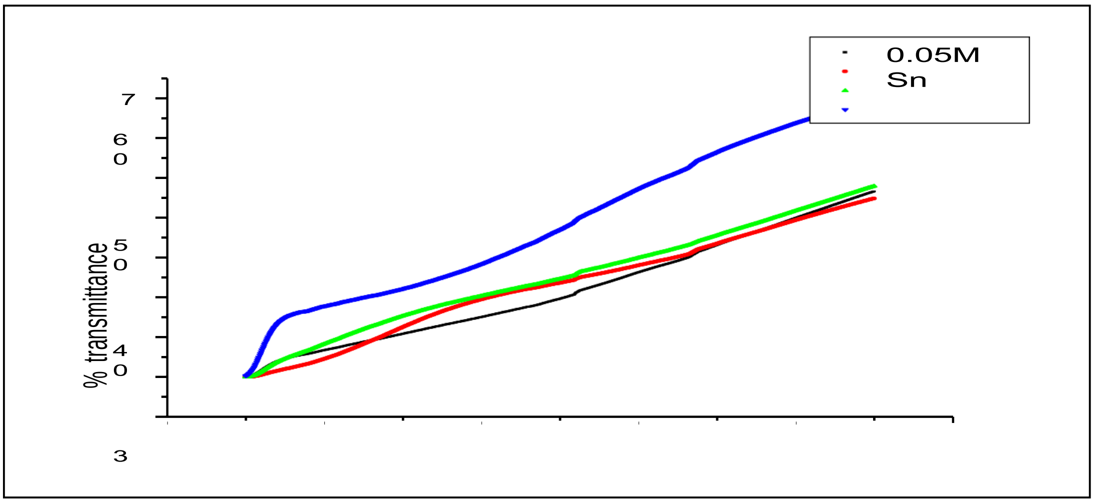

Figure 2: Graphs of transmittance against wavelength at different molarity

From the data obtained, transmittance was changing as the molarity of the tin chloride was changing. Generally, transmittance was between 0.2 – 44% for photons of wavelength between 200 – 1200 nm. The lowest transmittance was obtained for the films deposited with 0.1M SnCl2 and highest was achieved with 0.2M SnCl2. The results can be explained in terms of surface 'roughness'. When the concentration increases, surface 'roughness' increases which reduces transmittance but increases for higher concentrations. The increase in surface roughness is caused by increase of optical scattering that is caused by rough surface morphology.

b. Reflectance

The graphs of reflectance against wavelength at different concentrations is as shown in figure 3

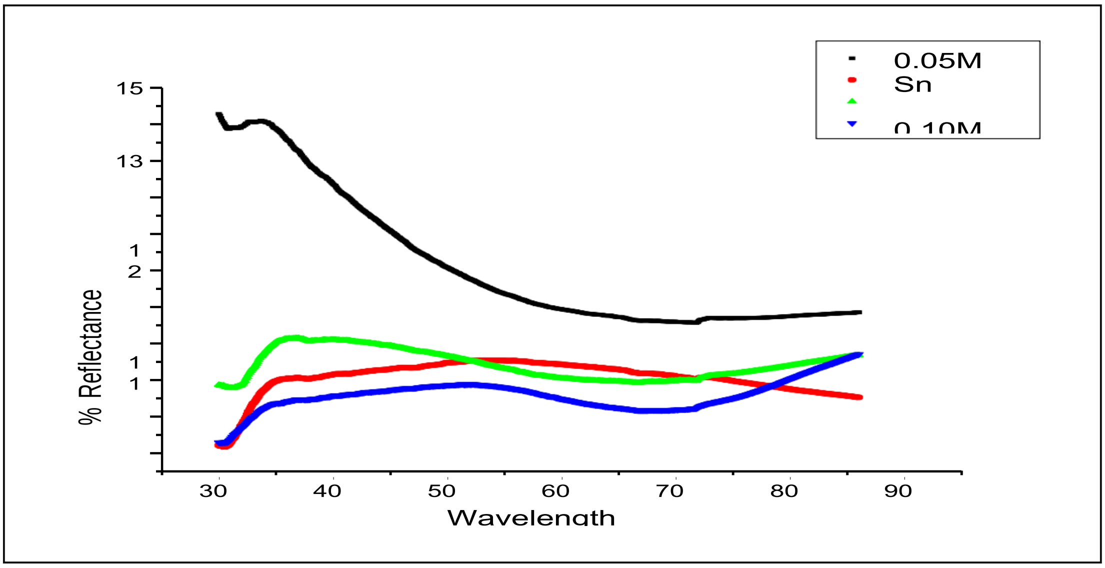

Figure 3: Reflectance versus wavelength at different concentrations

The films obtained showed reflectance ranging between 3- 12%. There was a slight increase within the visible region and decreased beyond this region. The lowest

c. Absorption

Absorption of the films samples decreased as the wavelength increased. Absorption of the films was high when the photon energy was greater than the band gap energy. Graphs of absorption against wavelength are as shown in figure 4

The values of absorbance were tabulated within the visible region and recorded as presented on the table 2.

Table 2: Average absorbance and molarity values

Molarity of SnCl2	Average absorption within VIS	Film thickness
0.05	62.45	45.5
0.10	65.98	62.3
0.15	63.68	73.2
0.20	54.31	86.70

The graph of average absorption within the visible region versus concentrations was plotted as shown in figure 5:

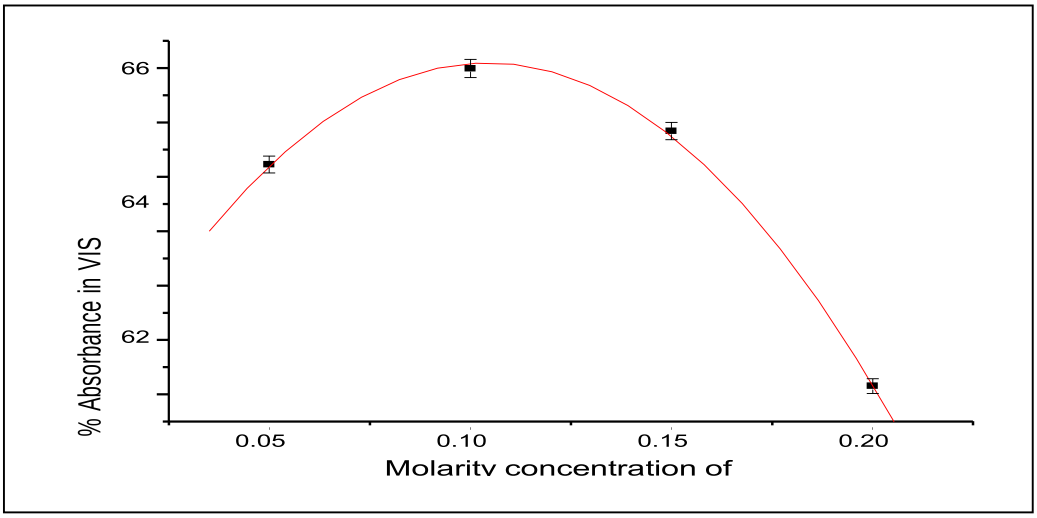

Figure 5: Average absorption versus concentration.

Average absorption is highest at 0.1M SnCl2 which is suitable for an absorber layer.

d. Band gap energy

The band gap energy was obtained by use of equation (1) at various concentration as shown on table 3 below,

Table 3: Band gap energy values at different molarity

Concentration of SnCl2	Band gap, eV
0.05M	1.68
0.10 M	1.61
0.15 M	1.33
0.20 M	1.27

The band gap energy was decreasing as the concentration was increasing. This was due to increase in density of localized states which increases due to increase in film thickness. Band gap against concentration graphs was as shown in figure 6.

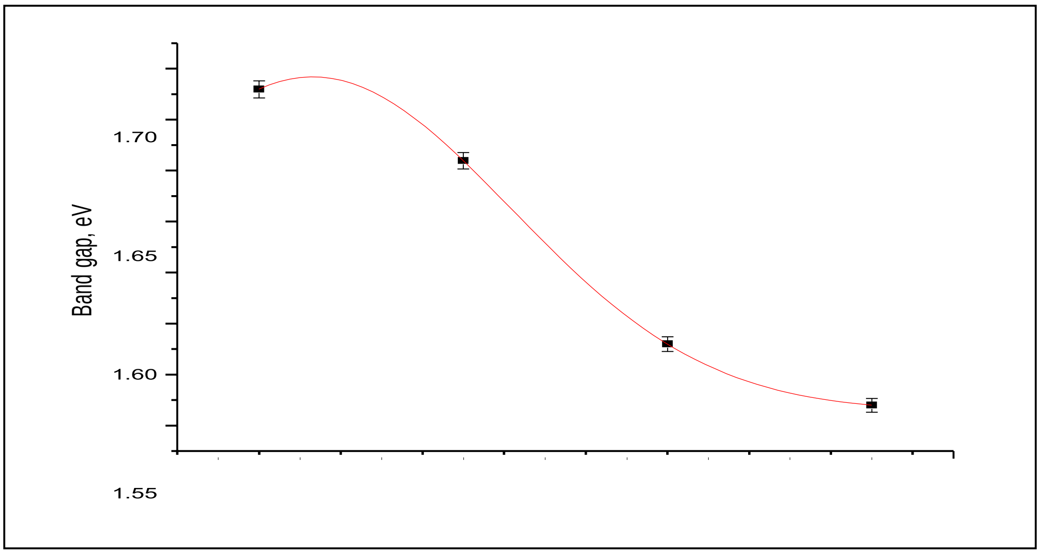

Fig. 6. Band gap energy against molarity for SnCl2.

Table 4: Optimum parameters used in fabrication

Parameter	Unit
Temperature of deposition	80oC
Concentration of SnCl2	0.1 M
Time of deposition	50 minutes
pH	12

e. Resistivity

The 4-point probe method connected to Keithley 2400 source meter was used to obtain resistivity values and recorded on table 5. Conductivity was obtained from resistivity values.

Table 5: Values of resistivity and conductivity

Concentration of SnCl2	Resistivity x 10 3 (Ω cm)	Conductivity x 10-3 (Ω cm)-1
0.05	4.078	0.245
0.10	2.081	0.481
0.15	0.337	2.967
0.20	0.335	2.982

From the values of resistivity and conductivity values obtained, the graphs were obtained as in figure 7

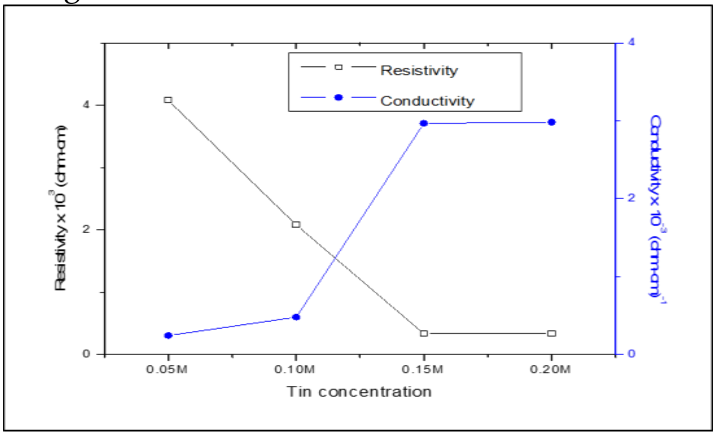

Fig.7: Resistivity and conductivity versus concentration of SnCl2 graphs

As the concentration of SnCl2 increased, resistivity of films decreased. The decrease in resistivity is explained by use of petritz barrier model. Petritz barrier that talks about crystallites not being able to grow large enough at low temperature and that the inter crystalline regions offer high resistance to movement of charge carriers. The decrease in resistivity is also due improvement of crystallinity of films at higher concentrations (Kumar *et al.,* 2012).

Conclusions

SnS films were successfully deposited on the glass substrate using chemical bath technique. Deposition was done under different conditions (varying concentrations of SnCl2). The electrical and optical properties were studied when molarity of tin chloride was varied. Transmittance of the films within the visible was between 2 – 44%. The films showed a decrease in band gap energy (1.68- 1.37eV) as molarity of tin chloride was increasing (0.05M – 0.20M). Resistivity of deposited films was decreasing (4078Ωcm - 335Ωcm).

Recommendation

0.1 M tin chloride was chosen for fabrication of the solar cell due to high absorption and low band gap which is suitable for an absorber layer.

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Patterns and Drivers of Land Development in (Greater) Eastern Bypass Peri-Urban area of Metropolitan Nairobi

Kinuthia, H[1,2], Majale, C[2], Letema, S[2].

[1] Kenyatta University, KENYA [2] Kirinyaga University, KENYA

Correspondence: ***hkinuthia@kyu.ac.ke***

Abstract

Peri-urban areas are transitional zones characterised by subdivision of agricultural land to urban plots which foreruns sprawled development. Whereas forms of urban sprawl and patterns are well articulated in the literature, the drivers are not explicitly linked to the patterns. This paper asserts that in absence of systematic planning, development control and provision of basic environmental infrastructure to guide development; peri-urban land development is shaped by different drivers at different developmental period depicted by organic growth patterns. This paper examines pattern and drivers of land development in (Greater) Eastern Bypass peri-urban areas of Nairobi Metropolitan area over the last two decades. Overlay of subdivision shape files and satellite images for the period 2000 to 2020 at intervals of five year intervals are used to depict pattern of development. Leapfrog measure for the land abutting the major roads is calculated to determine the rate of development. Maps on development patterns are overlaid with utility and amenities maps to relate patterns and drivers. The different patterns of development observed at different period are attributable to drivers such as developed road infrastructure, history of the place, availability of amenities and utilities. Leapfrogged development characterized by clustered and dispersed settlements marks onset of development in the peri-urban area, but decreases over time depending on development of basic infrastructure. Increased land subdivision triggered by speculation does not imply readiness of land for development, but it foreruns land conversion and leapfrog development. Land development should be preceded by planning of land use and provision of basic infrastructure, amenities and services to reduce the effects of sprawled urban expansion.

Keywords: Peri-urban, leapfrog development, drivers, development patterns

Introduction and Background

Peri-urban areas are transitional zones that are shaped by political, economic and social factors that are specific to each country (Kombe, 2005; Doan & Oduro, 2012; Jimu, 2017; Varkey & Manasi, 2019). These zones are areas where cities and rural villages merge through integration of urban and rural economies and expansion of urban infrastructure (Varkey & Manasi, 2019). The process of peri-urban land development is seamless, but sometimes characterized by discontinuous and leapfrog development (Heim, 2001; McGregor et al., 2012; Doan & Oduro, 2012). The changing patterns in land development shapes the character of peri-urban land (Webster & Muller, 2009; McGregor et al., 2012). Population pressure due to rural-urban migration and inadequate land use planning are viewed as causes of leapfrog development in peri-urban of African cities (Doan & Oduro, 2012; Dekolo et al, 2015; Cobbinah & Aboagye, 2017). On the contrary, cities in China experience leapfrog expansion due state-led extension of urban infrastructure to increase land under investment leading to oversupply of land for urban use in the peri-urban (Yue, 2013; Tian et al., 2016). That urban expansion in developing countries is perceived to be amorphous due to reduced capacity of governments to plan and provide infrastructure (Doan & Oduro, 2012; Dekolo et al., 2015) partly explains the growth of informal settlements in the peri-urban of African and Latin American cities (Doan & Oduro, 2012; Cobbinah & Aboagye, 2017; Baye et al., 2020).

Development patterns, ribbon, dispersed, radial, cluster and compact, are discernible and attributable to various growth drivers (Doan & Oduro, 2012; Baye et al., 2020). Several scholars have described the peri-urban of African cities as characterized by leapfrog development that is reminiscent of non-contiguous and unplanned growth (Cobbinah & Aboagye, 2017; Dekolo et al., 2015; Doan & Oduro, 2012; Salem, 2015). Leapfrog development is defined as sporadic physical development induced by commercial and residential activities in the peri-urban causing inefficient use of land (Doan & Oduro, 2012; Yue, 2013). Leapfrog, strip, non-continuous low-density development are viewed as the major spatial forms of urban sprawl (Aldosary & Khan, 2010; Heim, 2001) attributed to lack of systematic planning of peri-urban land (Baye et al., 2020; Varkey & Manasi, 2019; Webster & Muller, 2009). The character of peri-urban land is shaped by three attributes, spatial appearance resulting from land development, peri-urban life i.e. interplay between land uses and activities, and peri-urban change i.e. drivers and temporal aspects of change (Varkey & Manasi, 2019; Kleemann et al., 2017; Woltjer, 2014). In many African cities, peri-urban space is on demand for residential use to cater for rural-urban migration (Nuhu, 2019). Management of growth in the peri-urban areas require an integrated approach of all activities, land uses and the changes happening on the available land (Clawson, 2013; Tian et al., 2016). Leapfrog, ribbon, clustered and low density development seen during urban growth is temporary, transitional and its extent depends on drivers that trigger development in a given area (Heim, 2001; Aldosary & Khan, 2010; Zhang et al., 2017). Land speculation, zoning policies and expansion of urban infrastructure have been viewed as key drivers of leapfrog development in peri-urban areas (Yue, 2013; Kleemann et al., 2017; Zhang et al., 2017; Varkey & Manasi, 2019). However, different authors have also attributed it to high urban poverty leading to search for cheaper shelter in the peri-urban (Kombe, 2005; Doan & Oduro, 2012; Dekolo et al., 2015; Salem, 2015; Baye et al., 2020). History of a place, customary land tenure system, rural land reclamation and global investment are also described as having significant influence on peri-urban leapfrog development (Kombe, 2005; Doan & Oduro, 2012; Kleemann et al., 2017; Baye et al., 2020).

Extension of government programs and subsidies into the peri-urban in areas of technology, transport and industries, has largely contributed to leapfrogging and in most cases, the land speculators and developers are not fully confronted with social costs and benefits of their decision (Triantafyllopoulos, 2017). Speculators opt for peri-urban land where there is minimal development control (Ayonga, 2015) compared to urban land. This leads to unregulated land fragmentation which accentuates leapfrog development. Infrastructure development and subsidization of infrastructure such as water supply and roads in the peri-urban promotes conversion of agricultural land into urban use (Archer, 1973; Heim, 2001; Clawson, 2013). Local and national governments have major roles in rezoning of land in peri-urban areas originally used for agriculture to allow for residential, commercial and other urban use after extension of urban infrastructure such as sewer lines (Zhang et al., 2017). Absence of prior planning of the peri-urban land, speculators and landowners determine preceding land uses through subdivision of agricultural land into more residential units at the expense of other urban uses (Napier et al., 2013; Byamugisha, 2013; Clawson, 2013). This paper asserts that land subdivision does not necessarily lead to development of land, but contributes to conversion of peri-urban land from agriculture to urban use. The focus of the paper is to analyse land development after land subdivision and relate patterns to drivers of development in peri-urban Northland of Nairobi Metropolitan defined by the Greater Eastern Bypass.

Methods

Pattern of development, change in land use/cover, leapfrog measure were used as key components to quantify urban growth. GIS techniques were used in land use/cover analysis, classification, buffering and analysis of land parcel development between 2000 and 2020 based on five-year time series. The timing is pegged on the period before and after construction of Eastern Bypass between 2008 and 2012 and planning for Greater Eastern Bypass and Link Road in 2009. The study period from 2000 to 2020 represent a time when most public infrastructure policies and programmes were planned and initialized as part of Kenya Vision 2030, Millennium Development Goals and Sustainable Development Goals. This period is important as it enables observation of development pattern before planning and construction of major transport infrastructure in the area that are perceived to influence land development.

Satellite images for 2000, 2005, 2010, 2015 and 2020 were used to analyse change in land use/cover and pattern of land development. Pattern of development was analysed through overlaying satellite images with subdivision shape files using ArcGIS 10.5 where developed plots are identified using parcel numbers and labelled using colour coding. Details of developed plots such as year of development are entered into the attribute table. The subdivision shape files are generated through digitizing Registered Index Maps (RIMs) sourced from Survey of Kenya (Figure 1). Registered Index Maps used for the study were based on parcellation and land adjudication carried out between 1988 and 1996. Buffering to measure leapfrogging was done along five major roads in the study area; Thika Highway, Eastern Bypass, Link Road, Greater Eastern Bypass and Juja Farm Road, two of which were planned and were yet to be constructed. Maps are then used to show the pattern of development every 5 years.

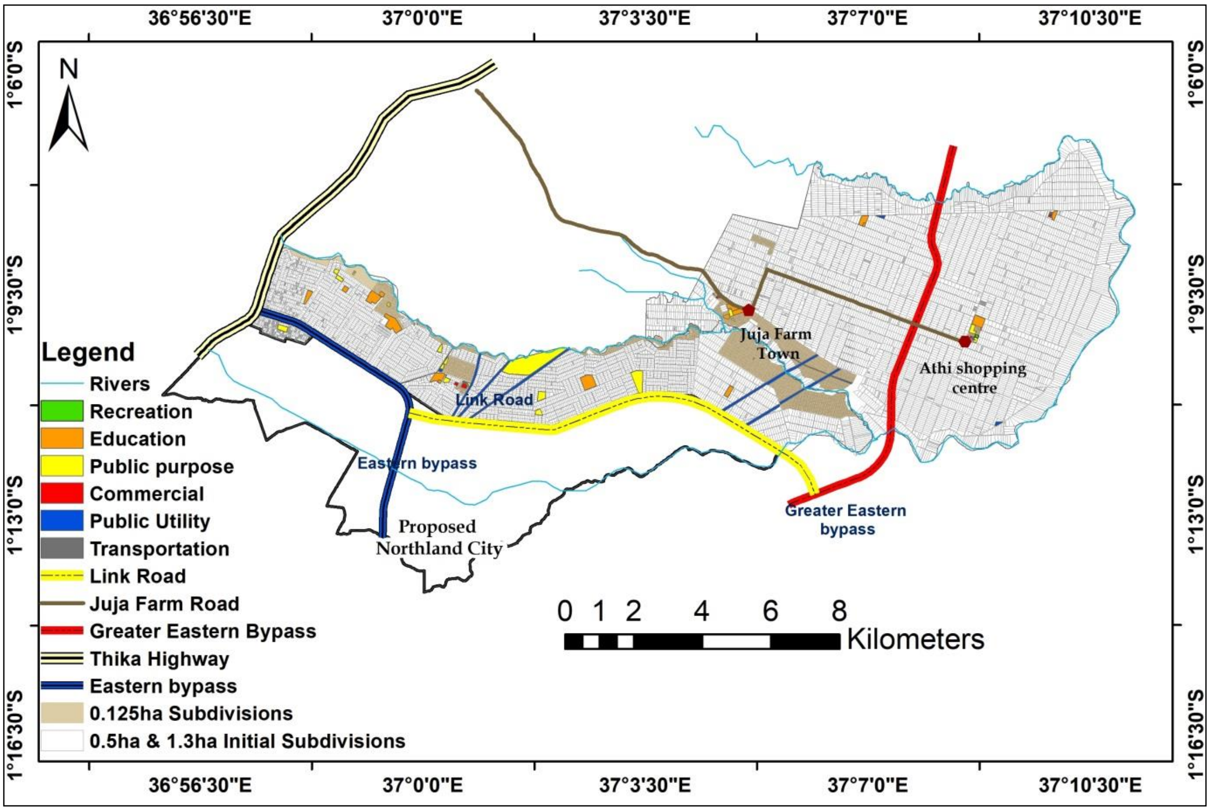


Figure 1: Characteristics of the Greater Eastern Bypass Peri-Urban Area

Leapfrog measure for 2000, 2005, 2010, 2015 and 2020 was carried out on buffers of 250m, 500m and 1000m established around Thika Highway, Eastern Bypass, Link Road, Greater Eastern Bypass and Juja Farm Road since they are perceived to be the growth nuclei. In order, to calculate the proportion of leapfrog development, total area of leapfrogged parcels in a given buffer and year is divided by total area of developable land within the buffer, which includes all undeveloped land and total area of developed land as expressed in the equation:

$$\text{LFjts} = \frac{Undeveloped\ land\ in\ Time\ s\ in\ Buffer\ j\ in\ Year\ t}{All\ Undeveloped\ Land\ and\ Developable\ land\ in\ Time\ s\ in\ Buffer\ j\ in\ Year\ t} \ldots.1$$

Leapfrog measure or index is expressed as a percentage of total amount of vacant land to quantity of developable land within a given period and distance from the road (Yue, 2013). The value varies between zero (no land available for development) and one (all land is developable). The index measures intensity of leapfrog development, where an index is greater than 0 indicates leapfrog development has occurred (Yue, 2013). Leapfrog development measure that combines spatial and temporal aspects which other measures of urban sprawl have forgone is used to explain leapfrog patterns and extent of urban expansion (Tian et al., 2016; Yue, 2013). It is used to account for developed land at given location and timing and corresponding leapfrogged land along expedient commuting routes (Zhang et al., 2017). The land abutting the five roads was originally subdivided into parcels of 0.5Ha, 1.3Ha and 0.125Ha for small-scale farming. The parcels are used to examine development patterns and measure leapfrog development. 0.5Ha parcels are concentrated along Eastern Bypass and Link Road, 0.125Ha are close to the river and 1.3Ha are along Greater Eastern Bypass (Figure 1). Subdivision shape files and satellite images are used to identify vacant parcels falling in a given buffer and year. All the underdeveloped parcels are not developed are considered leapfrogged unless they are identified as reserved land for public purpose and other specified land uses (Figure 1).

Primary data was sourced through interviews to utility agencies such as Kenya Power and Lightning Company and Ruiru and Juja Water and Sewerage Services Company and Water Resources Authority. These agencies were interviewed on level of coverage of basic infrastructure in the peri-urban area. Layers of utilities and amenities in the peri-urban such as electricity, water, sewer distribution, schools, residential associations, boreholes, and motorable roads are used to identify possible drivers of peri-urban leapfrog development. Map on amenities and utilities distribution was overlaid with maps on development patterns, to link patterns to drivers.

Results

Land Use/Cover Change in (Greater) Eastern Bypass Area

Analysis of land use indicates that grassland had the highest coverage, followed by farmland and riparian reserve while the lowest was built up area (Figure 2). Table 1 shows analysis of change in land cover from one period to the other, where the built up experience the highest positive growth while farmland experienced negative growth from 2000 to 2020. Grassland accounts for the highest coverage possibly because part of the land is owned by absentee owners who are residing elsewhere. The collapse of large scale farms that occupied the study area between 1907 and 1970 led to increase in growth on natural vegetation on the abandoned land hence increasing the area under grassland. Small scale sisal farming that began after subdivision of land accounts for the percentage of land under farming (Figure 2), which declined as more land was either taken out for development or sold to land entrepreneurs who kept it idle, waiting for development. Decline in farming is also attributed to the fact that the study area is located in semi-arid area and most of the farming relies on rains. The poor performance of market for sisal products may have contributed to reduction in farming. Concentration of the built up area is along Thika Highway, which was developed in 1970s, and partially along the Eastern Bypass which was planned in 1970s but part of development plans such as excavation works and clearing the road corridor began in 2003 but were later abandoned until 2008 when construction of the road started again (Figure 2). Construction of Eastern Bypass between 2008 and 2012 coupled with upgrading of Thika Highway to a super highway between 2007 and 2009 further increased the built up area along the two roads. Concentration of development into the interior and along the other three roads is less dense is characterized by scattered and clustered development. This could be attributed by the fact that the Link Road and Greater Eastern Bypass have not been developed to open up the area while Juja Farm Road which links the study area to Thika Highway is not an all-weather road hence reduced transport connectivity into the area. Though farming declined by 3% from 2015 to 2020 (Table 1), there are commercial farms developing along rivers possibly taking advantage of the improving transport connectivity to allow transportation of produce to towns closer and increasing population in the study area.

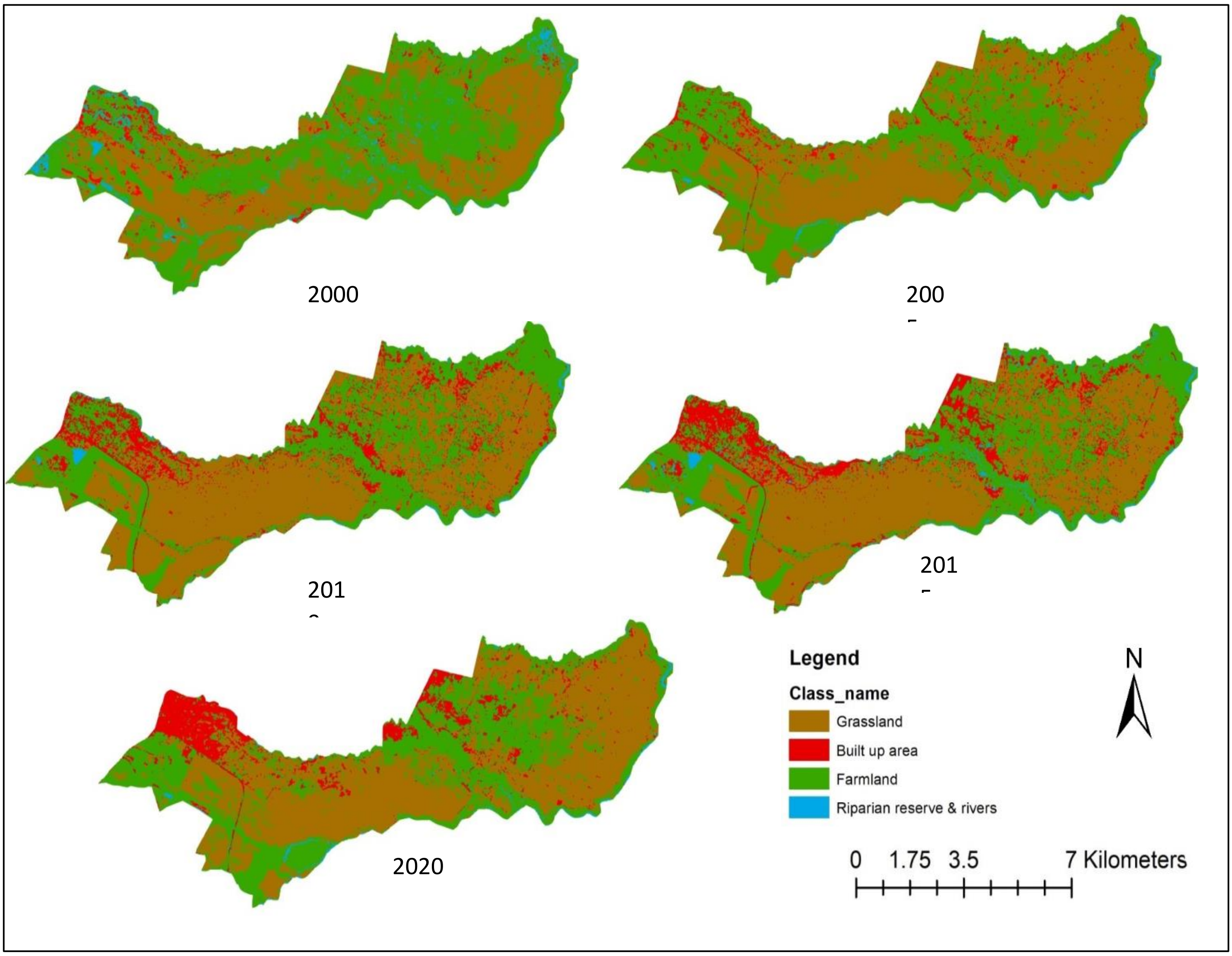


Figure 2: Land Use/Cover Change for 2000-2020

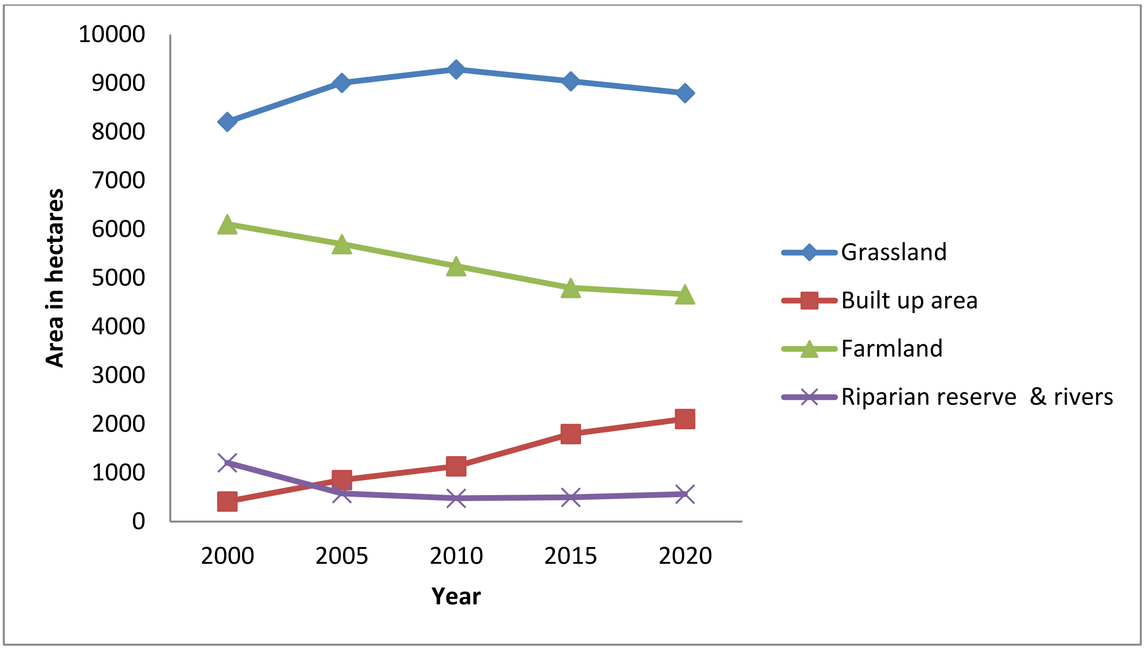


Figure 3: Land Use/Cover Trends between 2000 and 2020

From the summary in Figure 3, only the built up area has experienced positive change within the study period, which is attributed to urbanization that has been spurred by infrastructure development. Farmland declined within the same period and can be attributed to land subdivision where at least 45% of parcels originally used for small-scale farming have been subdivided into smaller plots for urban use, which are not economical for agriculture. In addition, the subdivided land was sold out to buyers whose interest is either to speculate on the land and sell it when land value increases or to hold the land until it is suitable for development. Grassland area increased between 2000 and 2010, possibly as a result of farmers abandoning farming while the decline between 2010 and 2020 is as a result of increasing built up area. There is an inverse relationship between the area under grassland and the built up area since as grassland decreases the built up area increases which suggests that grassland is a transitional use when land is converted from farming to urban use.

Land Subdivision

A spike in subdivision of 0.5ha and 1.3ha into urban and residential plots is observed between 2008 and 2012 the period which construction of Eastern Bypass began and planning the Link Road and Greater Eastern Bypass. The subdivision observed between 2005 and 2008 are characterized with structural speculators who had prior information on planning and development of the roads and deliberately bought and hoarded land before public notification. Structural speculators comprised of officers in road planning authorities and land companies associated with state officers.

There is a gradual decrease of subdivision along Eastern Bypass and Link Road between 2013 and 2018, the period after completion of Eastern Bypass construction while a sharp rise is observed within the same period along Greater Eastern Bypass because land in the area is more marginal hence less accessible. The 0.5ha parcels were subdivided into 10-14 plots while 1.3ha into about 24-26 plots of 0.035-0.042ha average sizes. Approximately 75% of land along Eastern Bypass had been subdivided between 2005 and 2018, 45% of land abutting the Link Road and 42% of land along Greater Eastern Bypass.

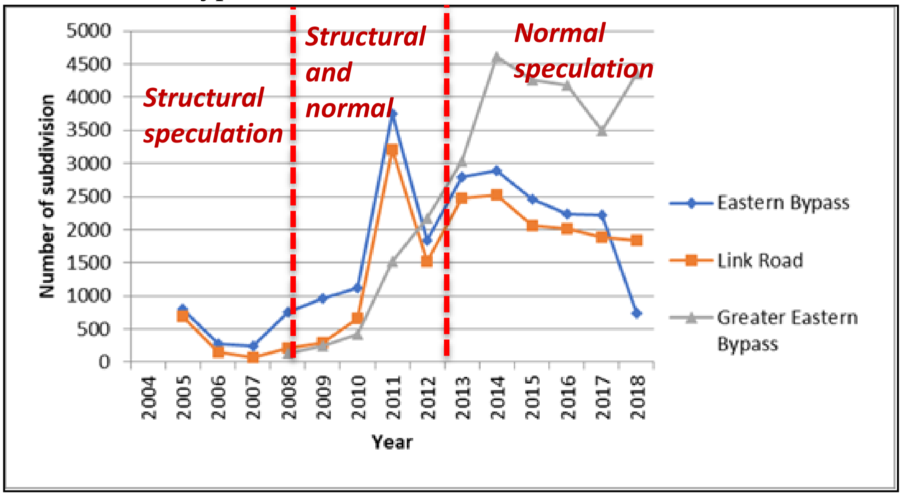


Figure 4: Trend in Land Subdivision in (Greater) Eastern Bypass Area

Development Patterns

Land development in 2000 is characterised by dispersed development with about 3% of the land developed with most of the development is concentrated along Thika Highway, which is the major transport infrastructure along the peri-urban area. The density per 0.5Ha parcel of land decreases as distance from the highway increases, with the number of settlement units reducing from 3-4 units to one unit per parcel. Figure 4 demonstrate that part of the land along Eastern Bypass and Link Road has leapfrog development while Greater Eastern Bypass area is characterised by cluster and ribbon development along rivers.

Development in 2005 is mostly concentrated on the land adjoining Thika Highway with scattered development on the interior (Figure 4). The density of developed parcels decreases as distance from Thika Highway increases. At 1Km buffer from Thika Highway the density per parcel are at least 4 buildings on a 0.5Ha parcel, while at 3-4Km buffer the density per parcel decreases with most parcels being vacant. Land abutting Link Road, Greater Eastern Bypass and Juja Farm Road is characterised by scattered development with 90% being undeveloped. Linear/ribbon development is observed along Ndarugu, Ruiru, Juja and Nairobi Rivers, where water from the rivers supports farming and household activities. There are clusters of development along Eastern Bypass concentrated on the interior. Development along Greater Eastern Bypass and Juja Farm Road is largely scattered, with clusters observed within 1Km radius of Juja Farm Town.

Construction of Eastern Bypass in 2010 triggered linear development along the road characterised by food eateries that were serving upcoming businesses and hardware shops were to support increased construction and land development in the catchment (Figure 4). Development on 250m buffer of Eastern Bypass is majorly mixed, comprising of apartments, shopping malls, shops and vacant parcels that are under farming. However, as one moves into 500m and 1000m buffer, the character changes to mixed density residential units built on different sizes of plots and vary from townhouses, detached, apartments and single units. High-density continuous development is observed at the road junction of Eastern Bypass and Thika Highway, which had been upgraded to a dual carriage way. Other road junctions such as Eastern Bypass and Link Road have no growth since the Link Road had not been developed. Development along the Link Road is largely leapfrogged with a few settlements along the 250m buffer. There is low density linear development along Juja Farm Road and radial development around Juja Farm Town.

By 2015, linear development along the Eastern Bypass is more pronounced with 80% of plots on 250m buffer being developed (Figure 4). Character of development is changing from retail shops, hardware's and eateries to high-rise office blocks and warehouses with lower floors being taken up by chain stores such as Naivas and Quick Mart. Beyond the 250m buffer, there is continuous low density residential which contrasts the linear high-density development on 250m buffer of Eastern Bypass.

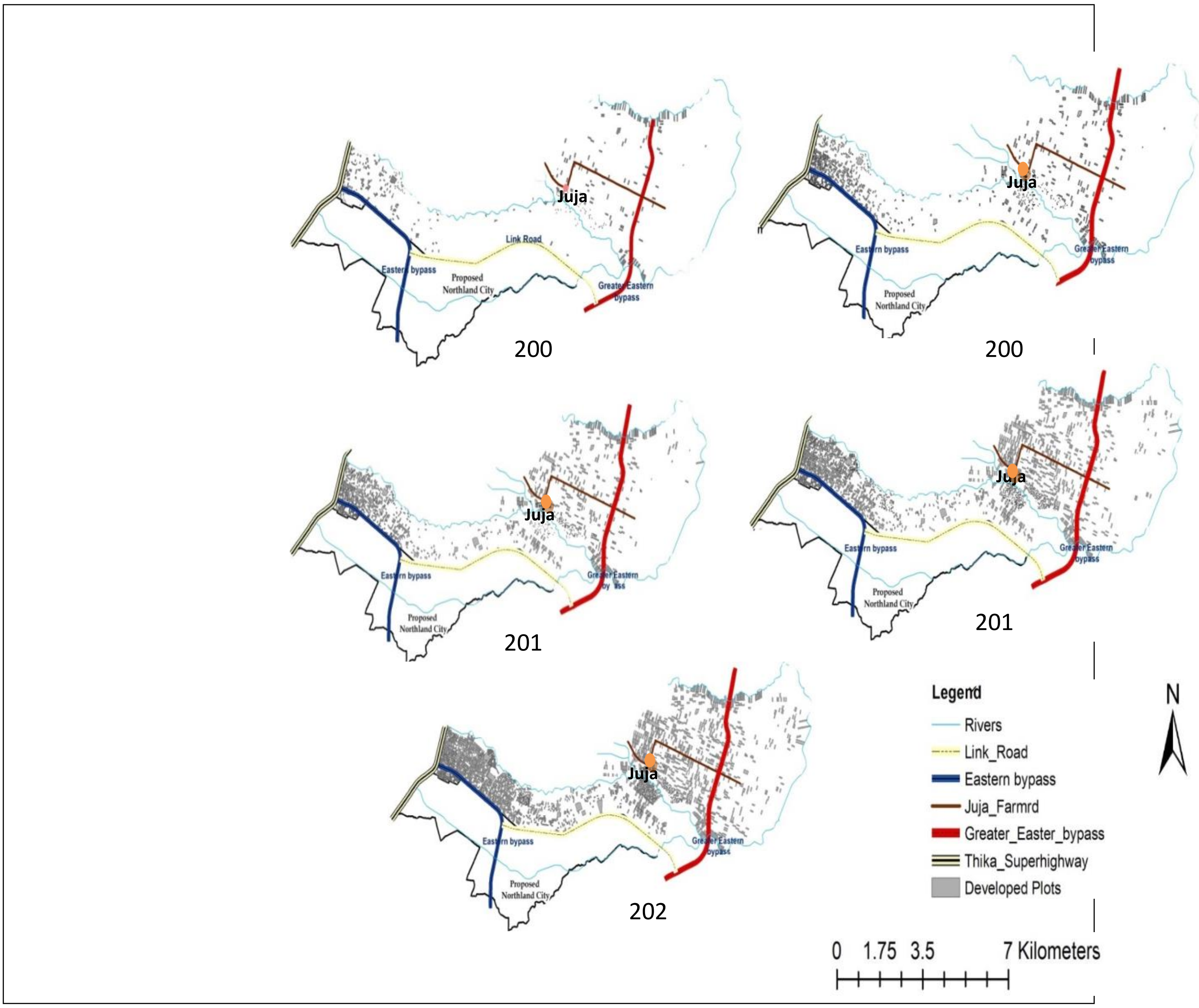


Figure 5: Land Development Pattern in (Greater) Eastern Bypass 2000-2020

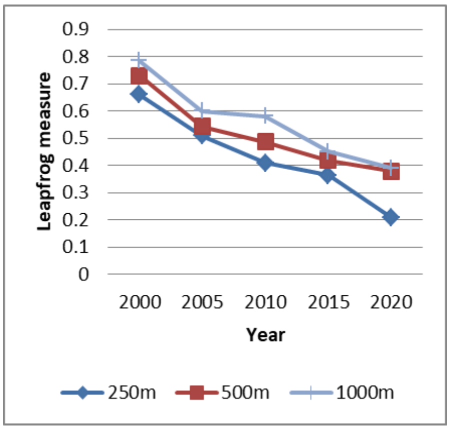
Partial linear development is observed along the Greater Eastern bypass and Juja Farm Road, while the land along the Link Road is characterized by cluster and dispersed development.

Between 2015 and 2020, the density of development increased to 85% along the Eastern Bypass and Thika Highway and is more continuous with a few undeveloped parcels (Figure 4). The land along Link Road and part of Greater Eastern Bypass is largely leapfrogged and development is low-density with a parcel of 1.3Ha having one settlement. Development is concentrated on the western side of Greater Eastern Bypass, along Juja Farm Road and around Juja Farm Town. Notably, the number of planned gated community developments increased along Eastern Bypass consisting of 10-15 residential units occupying 0.5Ha contributing to continuous, compact, low-density development pattern along Eastern Bypass. Partial low-density linear development is observed along the Greater Eastern Bypass, which had not been developed and Juja Farm Road, which is earmarked for upgrading to an all-weather road.

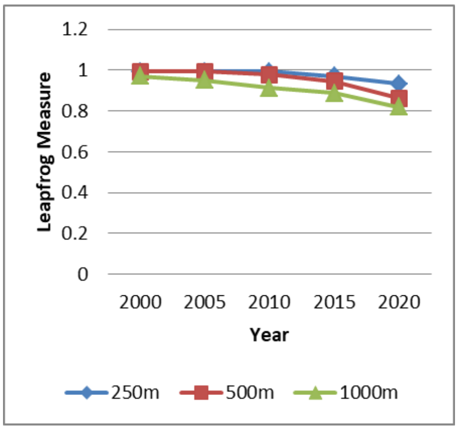
3.1 Measure of Leapfrog Development

Thika Highway has the lowest leapfrog index ranging from 0.91 in 2000 to 0.25 in 2020 on 500m buffer (Figure 5). Along the Eastern bypass, leapfrogging declined significantly after construction of the road between 2008 and 2012, with leapfrog measure of 0.4 in 2020 on 1000m buffer and drops to 0.25 in 250m buffer of the 2088 parcels analysed in 250m buffer of Eastern Bypass, approximately 60% of developable land had not been developed in 2005, 55% in 2010, 43% in 2015 and 25% in 2020. Steady growth is observed along the Eastern Bypass between 2010 and 2015 with a 20% decline in leapfrog measure compared to the Link Road, which experienced moderate growth with less than 10% change. The highest regression of leapfrog is observed on 250m buffer along Thika Highway between 2015 and 2020, with a change of 25%. Along Juja Farm Road a decline of about 30% was noted along the 250m buffer between 2005 and 2015, indicating there was significant development compared to land along Greater Eastern Bypass (Figure 5).

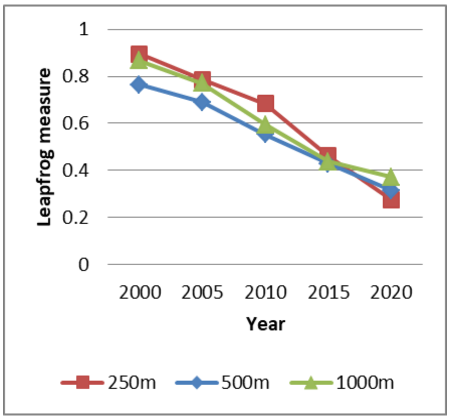
Leapfrog measure along the Greater Eastern Bypass and Link Road is significantly high ranging between 0.95-0.92 in 2000, with change from one period to the other being minimal. However, leapfrog measure for Juja Farm Road, which passes through Juja Farm Town, is lower in 2005 at 0.7 and it decreases to 0.4 in 2020. Leapfrogging on 1Km buffer along Link Road decrease from 0.95 in 2000 to 0.85 in 2010 while on the 250m the decline is from 0.92 to 0.90, which is less significant (Figure 5). This suggests that land closer to the proposed road is less accessible for development. Along Greater Eastern Bypass leapfrog measure decreases from 0.78 in 2010 to 0.65 in 2020 suggesting that planning and design of Greater Eastern Bypass between 2009 and 2013 may have influenced development to a greater extent. The land abutting the Link Road and Greater Eastern Bypass has been a hot bed for land speculation from early 2010 when planning and design of the roads were in process. However, the land along the two roads exhibit the highest leapfrog measure ranging between 0.9 and 0.75, thereby suggesting that presence of land speculation does not necessarily infer development of land. A notable observation is that leapfrog measure along all roads has declined over time albeit at different rates.



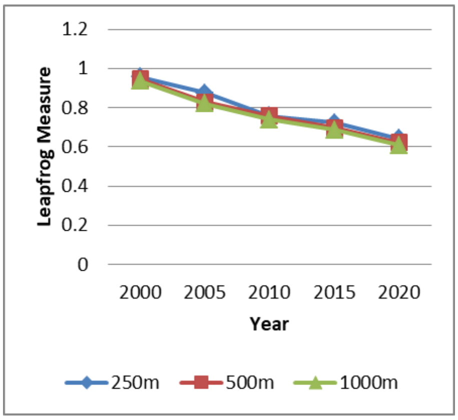
a) Eastern Bypass



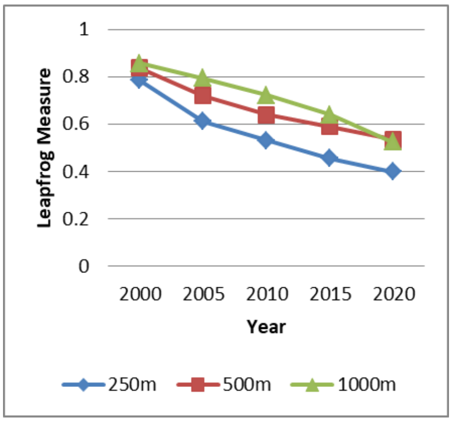
b) Link Road



c) Thika Highway



d) Greater Eastern Bypass



e) Juja Farm Road

Figure 6: Leapfrog Measure in (a) Eastern Bypass, (b) Link Road, (c) Thika Highway (d) Juja Farm Road and (e) Greater Eastern Bypass

Drivers of Land Development

Development in the Greater Eastern Bypass area is characterized by linear, clustered, low density and leapfrog development. Patterns of development observed between 2000 and 2020 are triggered by a myriad of drivers. Reliable source of water is identified as a key driver of land development in the Greater Eastern Bypass area and explains linear development along the rivers and cluster development around water sources, which characterizes initial development in the area. Nucleated development was also observed within radius of 500-700m from boreholes. This may explain the increase in number of private boreholes along the Greater Eastern Bypass peri-urban area. There are 3 county boreholes and 27 private boreholes in the area (Figure 6), suggesting that the municipal water is inadequate or absent. Interview with a technical staff in charge of regulating sinking of boreholes from Water Resources Authority (WRA), revealed that there are more illegally sunk boreholes in the area because selling of water in the neighbourhood is a lucrative business. Juja Farm area has the lowest municipal water connection and most homes get their supply from private boreholes and rainwater harvesting. The private boreholes are concentrated around Juja Farm Town where 60% of land development has occurred.

Juja Farm Town is a pre-colonial administrative and amenities centre with chief's office, land agents offices, a primary and secondary schools, hospital, police station and polytechnic. Development around this town was further influenced by settlement of Catholic Missionaries in 2003. The missionaries also have built a primary and secondary school, a convent, a monastery and sunk two boreholes that supply water to the neighbourhood. Radial development is observed along roads radiating from the town to other small centres of Juja Farm catchment. The historical nature makes it a growth nucleus due to availability of basic infrastructures and services.

Construction of primary roads such as Eastern Bypass triggered linear development along the bypass. However, there is no clear linear development observed along Greater Eastern Bypass and Link Road, the two major roads that have been planned, but not developed. Construction of primary roads opens up opportunities for upgrading and maintenance of access roads by local authority and private developers, which increases accessibility and prompts infill and continuous development. The growth seen on the 250m buffer along Thika Highway and Eastern Bypass between 2012 and 2020 can be attributed to infill commercial development, which is triggered by the upgrading of the roads. This explains why the land abutting Eastern

Bypass has 85% motorable roads and 80% of land developed by 2020; compared to 90% of roads along Link Road and Greater Eastern Bypass are impassable during rainy seasons (Figure 6) and only about 20-30% of land is developed. This is not uncommon in Kenya since the county governments focuses on improving roads and provision of services in areas with high development density and social and political pressure. Local access roads and streets in the peri-urban area are under Kiambu County Government while the major roads - Thika Highway, Eastern Bypass, Link Road, Greater Eastern Bypass and Juja Farm Road - are developed and maintained by the National Government. Maintenance of Juja Farm Road which links Juja Farm Town to Thika Highway and Juja town contributed to partial linear and leapfrog development along 1Km buffer between 2015 and 2020. Plans to upgrade the road to asphalt concrete, further triggered leapfrog development due to anticipated increased accessibility.

Electricity connectivity to towns like Juja Farm Town and other local centres like Athi and Mumba along the Greater Eastern Bypass has resulted to nucleated development characterized by small businesses such salons, welding, cereal millers and retail shops. Along Eastern Bypass increase in electricity coverage to 90% by 2020 led to infill development. Reticulation of electrical power lines follows road development in Kenya because way leaves become more clearly defined after primary and access roads are developed. This may explain why the land along Greater Eastern Bypass and Link Road has low electricity connectivity.

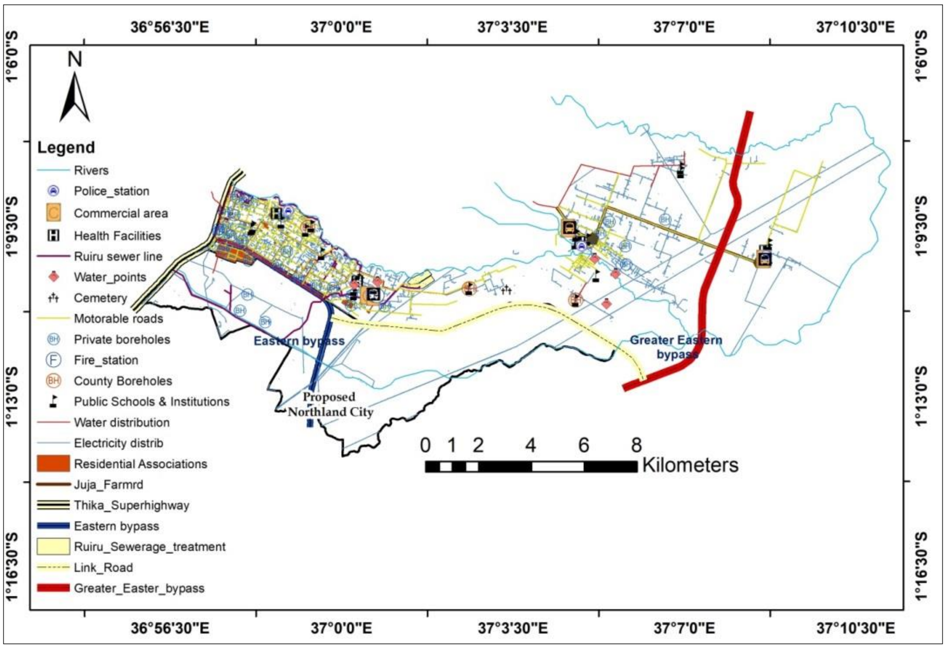


Figure 7: Infrastructure, Amenities and Services in (Greater) Eastern Bypass Area

Public schools in the Greater Eastern Bypass area were among the first developments in the area. Clustered settlements are observed between 2015 and 2018 around two primary schools along the Link Road and one along Greater Eastern Bypass suggests that they may have influenced development of land. The Last Mile Connectivity Program by Kenya Government, which commenced in 2015, led to schools in peri-urban and rural areas being connected to electricity. The transformers near the schools are designed to serve households within at least 600m radius thereby resulting into cluster development around schools.

Resident associations are associated with compact low density development in the peri-urban area. Of the 12 residential associations in the area (Figure 6), 5 are operating neighbourhood estates between 5Ha and 25Ha. These associations are formed by individuals either working together or those with common interest such as welfare groups commonly known as *"Chamas"*. They acquire large parcels of land then subdivide into urban use plots, majorly for residential use and sell to members who are required to adhere to bylaws on land development set by the association. Crime rate in Kenya is high, with the Annual Crime Report of 2019 rating Kiambu County (RoK, 2019), where the peri-urban area is located, third with a 0.37% increase from 4.93% in 2018. The high crime rate has led to increased security measures by associations and private developers by either developing within vicinity of developed land or pulling of numbers to develop together to be secured through numbers. Ten of the identified associations are concentrated along Eastern Bypass and two along the Link Road. These associations lobby for supply and improvement of infrastructure such as roads and sometimes work closely with county governments to ensure development control in the neighbourhood so as to safeguard the quality and standard of the neighbourhood estates. Cluster development observed between 2000 and 2010 along Eastern Bypass and along Link Road and Greater Eastern Bypass is associated with early settlers mainly comprising of urban poor in search of cheap shelter.

Discussion of Findings

Results show that peri-urban development patterns observed in the Greater Eastern Bypass are reminiscent to organic development occurring due to lack of structured and planned development. Scholars have pointed out that leapfrog development observed in peri-urban areas of African cities emanate from population pressure preceding provision of basic infrastructure and services due to low capacity of local governments (Doan & Oduro, 2012; Dekolo et al., 2015; Varkey & Manasi, 2019). Settlement in peri-urban land is informed by certain drivers depicted by development patterns. Infrastructure and utilities such as roads and water sources are viewed as primary drivers of peri urban land development while amenities such as schools and urban centres ride on presence of certain utilities such as electricity to trigger development. Construction of sewerage treatment plant along Eastern Bypass in 2017 did not prompt any further development, possibly because it was developed when 70% of land was already developed and most developers were accustomed to onsite sanitation. There has not been a push, sensitisation or requirement for connections to a sewer line as per the Public Health Act (RoK, 2012). Kleemann et al. (2017) highlighted that provision of infrastructure for sanitation and waste management is a general problem in most developing countries hence their low potential to drive peri-urban development. The linear pattern along the rivers is an aspect of agrarian civilization where rivers support small scale farming and are a source of livelihood (Soulard et al., 2017). Lack of development and extension of water programmes to the areas has led to people settling along the rivers due to reliable source of water. However, settlements along rivers are more clustered near Juja Farm Town which is an established colonial town and centre of amenities in the area.

Presence of non-governmental organizations have an influence of peri-urban development especially when they have a strong influence on decision making in relation to zoning, land use planning and provision of utilities and amenities (Kleemann et al., 2017). Private developers and residential associations manipulate provision of utilities and amenities through lobbying to favour their prospective developments, hence directing development through pulling numbers and structuring development in the peri-urban. The Catholic missionaries through provision of domestic water in an area where municipal water is absence contributed to clustered development. Historical towns, even with few amenities and utilities are growth nuclei which are likely to attract public investments more than newly developed towns. Kleemann et al., (2017) pointed out that development of the urban and peri-urban areas can be traced to the history and post-colonial administration and governance of a place.

Construction of roads triggers development on abutting land, first, because of increased connectivity to towns and urban centres. Second, construction of major or primary roads creates an opportunity for development of access roads by private developers or local government. Third, it spurs development of previously speculated land that was inaccessible. Leapfrogging along the Greater Eastern Bypass declined significantly during the study period. However, a higher regression was observed along Eastern Bypass after construction of the road between 2010 and 2015, suggesting that development of primary roads prompts more development in the peri-urban. Private developers ride on provision of primary roads, which are mainly developed by national governments, to develop their land since they are able to provide other basic services such as water and amenities such as schools, which county governments may take long to provide. Planned roads triggers leapfrog development and this explains why land along Greater Eastern Bypass and Link Road has high leapfrog measure (Figure 5). Development of un-serviced land is attributed to early settlers who develop land anticipating development of basic infrastructure. Planning of infrastructure such as roads may trigger speculative land subdivision in the peri-urban, but continuous land development and decrease in leapfrogging is prompted by construction of infrastructure.

The urban poor in search of cheap shelter buy and develop the un-serviced sub-plots in the peri-urban and wait for the local authority to plan and develop infrastructure such as access roads (Kombe, 2005; Poku-Boansi & Amoako, 2015). To ensure smoother settling process, they organize themselves in small groups mostly of close family members or workmates and then they buy and develop land together. Clustering by these groups act as a source of security and an avenue for residents to lobby and collaborate for supply of utilities such as electricity. As more clusters develop access to services becomes easier and small centres start developing to serve the incoming population. The residential associations, families and small groupings that drive development in the peri-urban have one aspect in common that they work together to bring people to develop a certain area as a source of security and access to utilities, amenities and services. The difference between the small groupings and residential associations is that the former is after cheaper shelter and whereas the latter can comprise of land speculators who aim to benefit maximally from the development of the peri-urban land. Kombe (2005) implied that the organic pattern of peri-urban land development in Sub-Saharan Africa is informed by urban poverty level. These initial settlers prefer cheap housing in the peri-urban where there is minimal development control that increases cost of development. Varkey & Manasi (2019) also pointed out that lack of cheap housing facilities in the urban areas and increasing demand for real estate development has led to rapid spatial expansion of peri-urban areas moving margin further into the rural areas. Although real estate developers look out for cheap land in the peri-urban, they ride on provision of primary infrastructure such as roads by government, to commence development.

Peri-urban planning plays a critical role in regulating the space to accommodate urban expansion and promoting space growth to attract investment (Tian et al., 2016). In absence of systematic planning of peri-urban, land development is dominated by political, social and economic forces resulting into mushrooming of informal settlements (Baye et al., 2020; Varkey & Manasi, 2019). Conversion of land use in peri-urban is stimulated by infusion of new investments such as infrastructure development by the local government and private developers (Ingram& Brandt, 2013). The conversion process is highly diffused and is made complex by actors involved that greatly impact on the decision making process (Clawson, 2013). Land use policies and provision of public infrastructure and services that accompanies peri-urban land conversion shapes land development and promotes rational land use (Baye et al., 2020; Tian et al., 2016). Municipal authorities are manipulated by the residential association and groups in extension of urban services and infrastructure causing infrastructure backlog in the peri-urban (McPherson & Guy, 2012; Woltjer, 2014).

Conclusion

Absence of development control and phased development in the peri-urban areas gives way to certain drivers like roads, water sources, schools, and towns to influence development patterns; which inform the organic character of peri-urban. Onset of unplanned development in peri-urban is characterized by leapfrogging depicted by cluster, dispersed and radial development patterns that are associated with some growth drivers. Some drivers such as roads and water supply influence development pattern more compared to electricity and sewer system. Utilities and services provided by local authorities are secondary drivers of peri-urban development. Planned development units, boreholes, associations/groups, and insecurity have emerged as new drivers of peri-urban developmental patterns; with no new developmental patterns. Initial developers collaborate and lobby to pull resources and influence provision of basic infrastructure. Leapfrog measure is high in peri-urban areas devoid of basic infrastructure. Planning of some infrastructure such as primary roads prompts a slight regression in leapfrogging, while development of major roads leads to infill development of adjacent land and reduced leapfrog measure. Planning of major infrastructure in the peri-urban leads to land speculation, which stimulates land subdivision and change of land use from agriculture to urban use. Increased peri-urban land subdivision does not imply readiness of land for development, but foreruns leapfrog development. This research underlines the need for controlled and planned development in the peri-urban to reduce organic growth spurred by certain drivers.

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Factors Influencing Utilization of Library E-Resources in Academic Delivery: The Case of Multimedia University of Kenya

Diki, P.M

Meru University of Science and Technology, KENYA

Correspondence: *pdiki@must.ac.ke*

Abstract

The study investigated utilization of library e-resources for academic delivery among faculty members of the Multimedia University of Kenya. The study sought to (a) Establish the benefit of library user education in library e-resources utilization; assess utilization frequency of library e-resources; explore the impact of utilizing library e-resources and identify the factors that hinder utilization of library e-resources. The study was informed by Technology Acceptance Model and Unified Theory of Acceptance and Use of Technology theoretical frameworks. The study used descriptive survey research design with a population sample of seventy-One. Data collected using questionnaires distributed to faculty and analyzed using; Statistical Package for Social Sciences (SPSS) software. Majority of the respondents rarely visited the library to access the e-resources since they have access to them from their offices or anywhere within the university. The study also revealed that the faculty members adopted e-resources for their teaching and learning and it greatly impacted their academic delivery. The major challenges faced when accessing and utilization of digital information was slow Internet, lack of adequate computers, lack of awareness and ICT skills. It is recommended that university stakeholders should formulate policies and ensure extensive training is offered to library users and provide hardware and software to increase reliability of internet connectivity and user awareness of e-resources services through effective marketing and promotion strategies to enhance utilization of e-resources by faculty to support academic delivery.

Keywords: Utilization, E-resources, Academic delivery

Background of the Study

In modern day academic libraries, electronic resources are crucial academic tools which compliment print based information resources as academic tools. Where library users are restricted because of geographical location and finances, e-resources still provide access to the information needed. There is currency in information contained in e-resources, because they are frequently updated (Perpetua, 2012). Instruction and research rely on what skills an individual has and the appropriate information is accessible to faculty members. Library user education takes more than good information searching skills (Allison, 2010). Availability and usage of library e-resources in the modern time has been made possible by the advent of Information Communication Technology (ICT). In this digital era the advent of ICT has posed challenges to academic libraries in their attempt to meet their library clients' user needs. Library users are thus exposed to various e-resources through the internet and for this, academic libraries are now investing a lot of monies on e-resources subscription (Swain & Panda, 2009). According to Shulling (2007), many university libraries have gradually adopted e-resources to become a major information resource.

Statement of the Problem

In universities worldwide today, access to library e-resources is a major requisite for academic delivery. Through learning, teaching and research, universities have become the centres for the propagation and generation of knowledge.

Multimedia University of Kenya library, like other academic libraries in Kenya, has invested heavily in acquisition of books, non-book materials and e-resources. To ensure access to e-resources the library has made significant investments with an annual budget for subscription and maintenance of the e-resources. The library has thus subscribed to thousands of e-resources through the KLISC programme. Despite the many advantages like authoritativeness, timeliness and accurate literature that are derived from adoption of e-resources in academic pursuits, there is low utilization of the e-resources by faculty compared to students and non-teaching staff. The library has rich e-resources package which include, journals and e-books, full text electronic, bibliographic databases and routinely conducts current awareness services on availability of the e-resources and training to its users on how to effectively access and utilize the resources. That utilization by faculty has not been optimal is a matter of concern to the university library management and other stakeholders. This study investigated utilization of e-resources for academic delivery by faculty of multimedia University with the view to identifying factors leading to utilization and to recommend the way forward.

Objectives of the Study

This study sought to; (i) determine the benefit of libra user education on library e-resources utilization by faculty at Multimedia University of Kenya (ii) assess frequency of utilization by faculty (iii) explore the effects of utilizing theresources for by faculty and (iv) identify the factors that hinder utilization by faculty.

Literature Review

Role of user education on e-resources, frequency of utilization and impact

Many researchers have conducted studies on awareness and use and of electronic resources. Interestingly, previous reports have indicated that search engines like Google were highly utilized compared to other electronic resources (Manda 2014, Rehman and Ramzy 2004). Use of these resources can presumably be enhanced through creation of awareness on existence and user training on retrieval and application of the said resources for research and academic delivery.

According to Deng (2010), Australian universities have effectively adopted utilization of e-resources into teaching, learning and research due to advancement of ICT infrastructed and the fact that adoption is and utilization of the said resources is a common practice in Australia.

Perception of the value of the e-resources is a major factor that determines whether or not the faculty would utilize the e-resources for research and academic delivery, in that one can only utilize what they find relevant to their needs. The purpose for which the library users utilized various resources is what has prompted many researchers to investigate the subject (Ali 2007, Madhusundan 2010). Use of these resources by faculty have been closely associated with availability of skilled library staff, technical support and security of e- resources as well as user education and availability of ICT infrastructure and reliability of internet (Armstrong 2011). A London-based

International African Institute (IAI) carried out a survey on the current situation of utilization of e-resources among universities in African and observed that use of e-resources was hindered by cuts in library budgets, insufficiency of ICT infrastructure, reliance on donor support and hosting or irrelevant resources (Kisiedu, 2009).

Technology Acceptance Model & Unified Theory of Acceptance and Use of Technology (UTAUT)

One of the theories associated with technology adoption and use is the Technology Acceptance Model, TAM (Davis 2003). The model postulates that user behavior towards adoption of technology is affected by external variables namely perceived usefulness and ease of use. Thus adopting technology is influenced directly or indirectly by user intentions, approach, anticipated usefulness and perceived ease of use as well as peripheral factors affecting objectives and actual utilization through communicated effects on intended purpose and perceived ease of use (Davis 2003)

This study was also informed by UTAUT model. Thus according to Oye (2012) indicated that the Technology Acceptance Model (TAM) is only able to predict the success of technology adoption by 30 percent and its expansion can only predict 40 percent, while UTAUT effects on moderating factors have increased the efficiency of prediction to 70 percent which is an important progress over the previous models.

Methodology

Research Design: A descriptive survey design was used. Quantitative and qualitative data was collected and used to establish a relationship between the study variables.

Population and Sample: The population in this study comprised five faculties of the Multimedia University of Kenya namely faculty of computing and Information Technology, Faculty of Engineering, Faculty of Business and Law, Faculty of Media and Communication and Faculty of Science and Technology (Table 1).

Table 1: Study population

Faculty	Total Members

Faculty of Computing and Information Technology	38
Faculty of Engineering	30
Faculty of Business and Law	56
Faculty of Media and Communication	60
Faculty of Science and Technology	19
Total	**203**

Sampling and Sampling Procedure: Sample population was 71 faculty (respondents) drawn from the five faculties of Multimedia University of Kenya (table 1) based on the Israel (2003) model. The model takes sample size for ±3%, ±5%, ±7% and ±10% for Precision Levels Where Confidence Level is 95% and P=.5. Going by the model, if ±10 was taken for precision when the population is 203, the sample was 71.

Data collection and Analysis: Data was collected using closed and open ended questionnaires physically distributed to faculty. Quantitative data was coded, analysed and analysed using Statistical Package for Social Sciences (SPSS) software and presented in form of graphs, charts, tables and percentages (tables 2,3,4 and figures 1, 2 and 3)

Results and Discussion

Demographic Information of Respondents

The study response rate was 81%, Seventy-One (71) questionnaires were distributed with a return rate of 58%. The distribution by gender was consisted of 47 (81.0%) males and 11 (19.0%) females. Faculty of Media and Communication and Faculty of Business and Law registered the highest number of respondents both at 15 (25.9%) respectively, Engineering 10 respondents (17.2%) Science and Technology 9 (15.5%), and Faculty of Computing and Information Technology 8 (13.8%) respondents (table 2).. 55.2% of respondents were lecturers and 1.7% professors

Table 2: Respondents teaching position

Rank	Frequency	%
Tutorial Fellow	12	20.78
Lecturer	32	55.2

Senior Lecturer	9	15.5
Associate Professor	4	6.9
Professor	1	1.7
Total	**58**	**100**

There are great benefits resulting from creation of awareness and training for faculty.. 10.3% of respondents indicated that they had benefitted from user training offered by library staff on how to access and utilize the e-resources. 25.9% indicated that they were made aware of the existence of the e-resources and the categories of e-resources the library has subscribed to. 13.8% respondents indicated that user education enabled them acquire the technical knowhow and skills needed to accessing and utilize the e-resources for research and curriculum delivery.

Table 3: Benefits of library user education

Benefit	Frequency	%
Access to knowledge	6	10.3
Created awareness	15	25.9
Tutored on how to access	8	13
Didn't indicate	29	50
Total	**58**	**100**

Frequency of access to library e-resources

The study sought to establish the respondents' rate of visiting the library to access and utilize electronic resources. Results showed that 37.9% respondents had never visited the library to access the e-resources, 10.3% visited the library on daily basis, 18.3% weekly and 7% monthly. Majority of faculty accessed the library e-resources from other places within the University but outside the library.

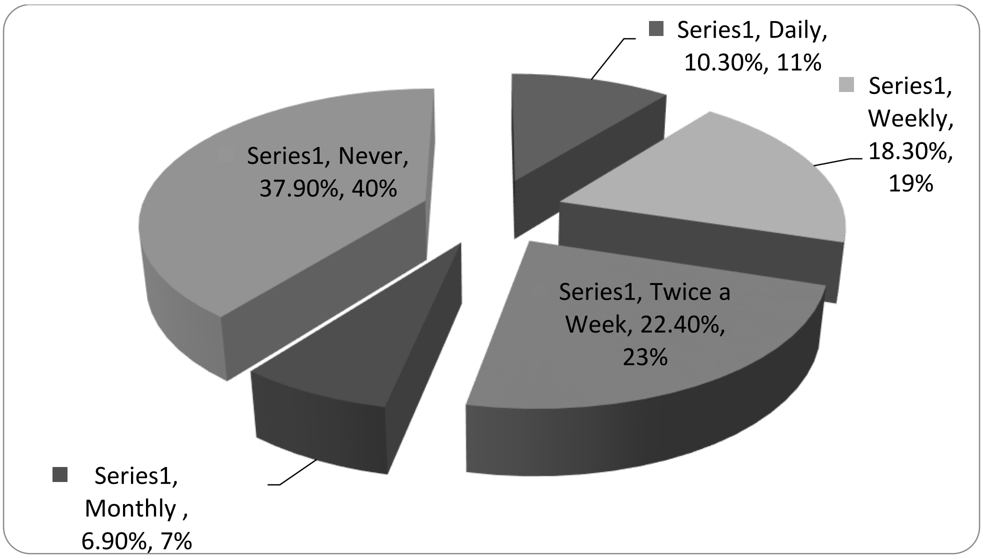

Figure 1: Frequency of the respondents visit to the library to access the e-resources

Effects of library e-resources on academic delivery

24.1% respondents indicated that the e-resources the university library has subscribed to were relevant and had served their academic delivery needs. 48.3% were satisfied with the e-resources and indicated that their academic delivery had improved with utilization of the e-resources, 6.9% less satisfied while 10 (9.6%) were dissatisfied with what the library had subscribed to. These finding are consistent with reports of Ansari and Zuberi (2010) that majority of the faculty were satisfied with adoption and utilization of the library e-resources in their daily teaching and learning practices.

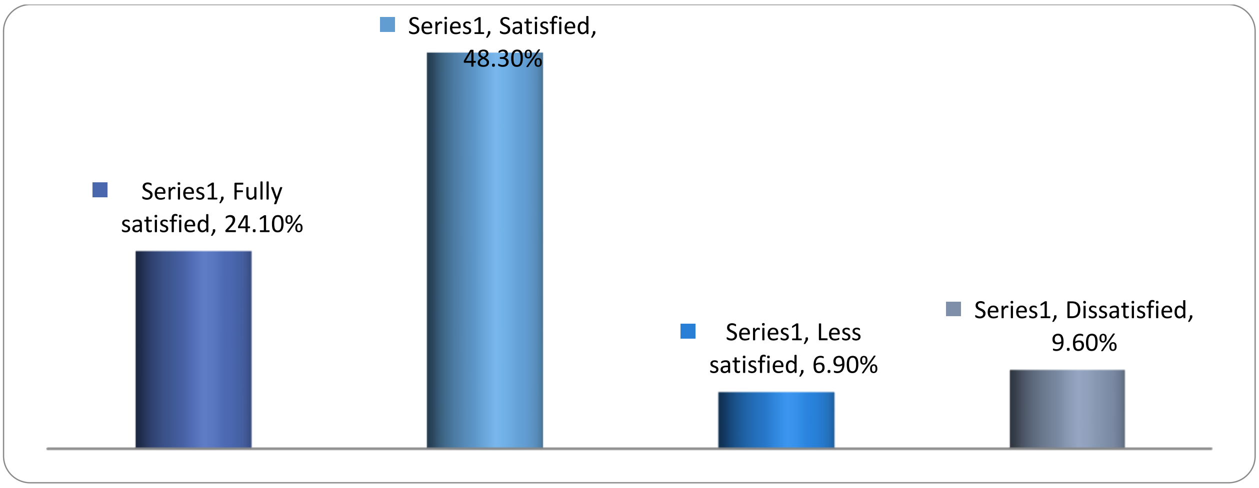

Figure 2: Satisfaction rating of the MMU library e-resources

Relevance of the e-resources MMU library is subscribed to and their impact on faculty academic delivery was investigated. It was noted that the relevance impacts on use and access. 48.3% respondents indicated that the e-resources the library had subscribed to were relevant while 22.4% stated that the e-resources were slightly relevant. One respondent indicated that the e-resources were not relevant for academic delivery. 25.9% were not aware of the e-resources relevance since they did not know of the existence of the services at the library hence were unable to attach any relevance of the e-resources.

Table 4: Relevance of library e-resources on academic delivery

Respondents Comments	Frequency	%
Very relevant	28	48.3
Slightly relevant	13	22.4
Not relevant	1	1.7
Don't know	15	25.9
Didn't indicate	1	1.7
Total	**58**	**100**

Factors that hinder utilization of library e-resources

46.6% respondents indicated that the major challenge to utilization of library e-resources was inadequate computers, slow internet at the University (29.3%), lack of proper ICT skills (6.9%). Unfriendly e-resources interface which are difficult to use while 1.7% respondents felt that the e-resources the library subscribed to were irrelevant to academic delivery.

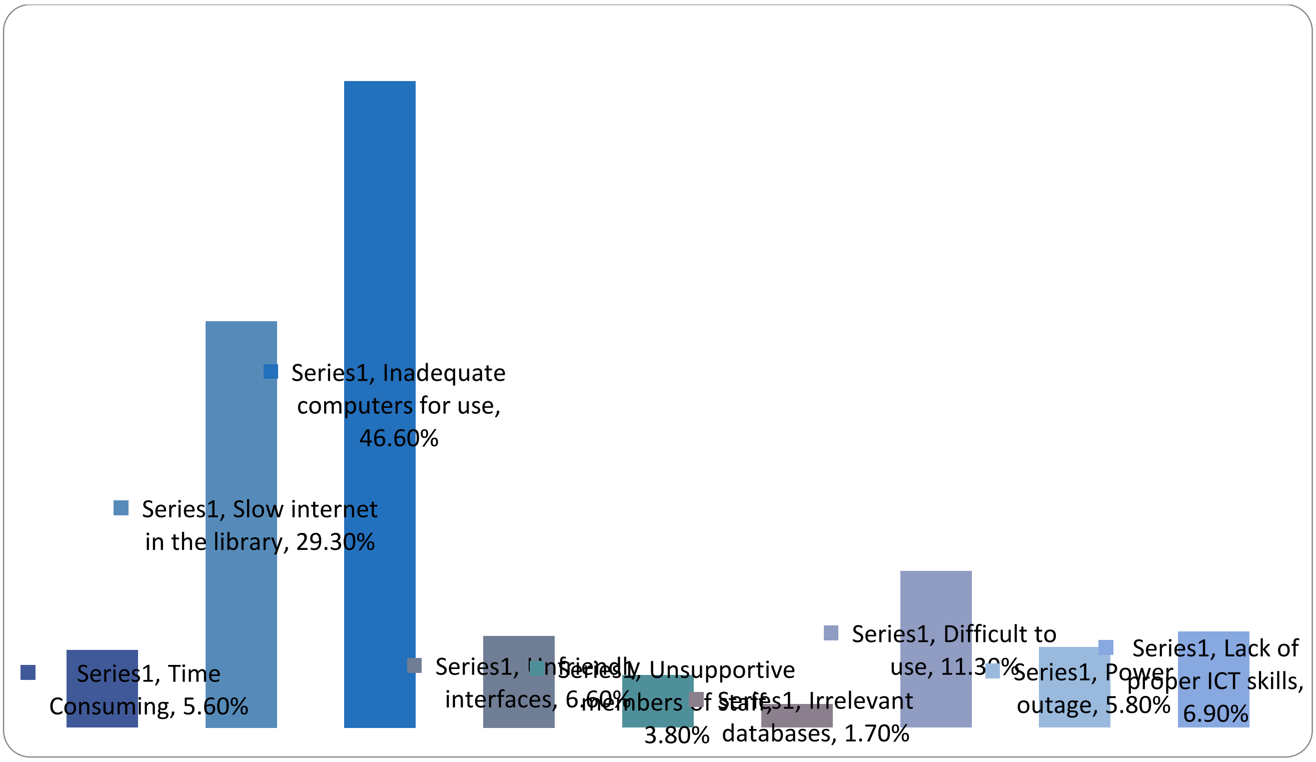

Figure 3: E-resources utilization challenges

Discussion and Conclusions

Results of this study study suggested that user education is a very important undertaking in the library, because through it, faculty were made aware of what e-resources the library has, and given skills on how to access and utilize them in their research and academic delivery. Although some faculty had never visited the library to use the e-resources indicating that they accessed the e-resources from anywhere within the University, a majority of faculty trained were well equipped with the necessary skills to navigate through the online content. The major one being inadequate computers for use with only fifteen computers allocated for use by both faculty and students. Slow internet was cited as a major impediment to utilization of the e-resources theoretically prompting the need for increased bandwidth. Other challenges that hindered the faculty from utilizing the library e-resources for research and academic delivery were frequent power outages at the university, unfriendly interfaces and lack of ICT skills.

Recommendations

It is recommended that faculty members be made aware of and trained on how to access, retrieve and utilize the library e- resources to support research and academic delivery. While the University should consoder improving budgetary allocation to secure library resources, ***Library management should strategize on how best to mobilize funds to support acquisition of additional infrastructure including computers, increased bandwidth, emergency power supplies, expansion of existing resources and further formulate policies to guide utilization of the resources***

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MOBILE +254709742000/+254729499650

Email: info@KyU.ac.ke

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