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Editorial Preface

It is giving me immense pleasure to launch this inaugural issue of the East African Journal of Science and Technology (EAJST) with the intent of providing an international forum for the researchers and scientists of the various fields of environmental topics including physical, life and health science; social science or any closely related fields. The EAJST is an international science journal hosted by **I**ndependent Institute of Lay Adventists of Kigali, Rwanda and promoted by Chinese Academy of Sciences and China University of Geosciences. With the support from such international bodies, it is expected EAJST to establish its international reputation.

The journal EAJST encourages researchers and scientists throughout the world to submit original research articles, critical review articles covering advances in recent research of such fields as well as technical notes.

In order to position EAJST as the most authoritative journal on doctoral studies, a group of highly valuable scholars have agreed to serve on the editorial board. The Editorial Board of EAJST is very committed to build it as one of the leading international journals in the area covering environmental topics.

As you read throughout this inaugural volume of EAJST, I would like to remind you that the success of our journal depends directly on the number of quality articles submitted for review. Accordingly, I would like to request your participation by submitting quality manuscripts for review and encouraging your colleagues to submit quality manuscripts for review. One of the great benefits we can provide to our prospective authors, regardless of acceptance of their manuscript or not, is the mentoring nature of our review process. EAJST provides authors with high quality, helpful reviews that are shaped to assist authors in improving their manuscripts.

The editorial board of EAJST and me are looking forward to receiving your valuable scientific contributions.

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Impacts of Anthropogenic Activities and Climate on Wetland Ecology: Case of Sitatunga(*Tragelaphus Spekei*) at Kingwal Wetland, Kenya.

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Abstract: The study carried out in Kingwal wetland in the Nandi north district of Kenya to investigate the effects of anthropogenic activities on biodiversity and habitat destruction in the area, as well as the implications of such activities for the future of the Sitatunga animal. The methodology involved questionnaires, interviews with a cross-section of the local people, the organization, and focus group discussions (FGD). Data from Meteorological Department Eldoret was analyzed and used to depict mean monthly rainfall patterns in the study area. Results indicated that Sitatunga is already under threat from the loss and fragmentation of habitat. Encroachment and invasion caused by anthropogenic activities are on the increase, while Climate change poses a new challenge as it often exacerbates the impacts of other pressures. The Kingwal wetland once an extensive wetland and an important breeding site for Sitatunga has been reduced to a narrow stretch of swamp (Ambasa, 2005). It also indicated that, among the various human activities undertaken in the area, cultivation, grazing, and Brick making had the greatest impact on biodiversity conservation through degradation of the wetland over the years. About 95% of the respondents were regarded to engage on major socioeconomic activity in the area. However, majority of the respondents (96%) are aware of the need to conserve the wetland which is the habitat for the rare Sitatunga (*Tragelaphus Spekei*). For the improvement of the current status of the wetland and its sustainable management, it was recommended: (i) enhancement of local participation in biodiversity conservation initiatives, (ii) initiation of public education and awareness campaigns, (iii) integration of traditional and modern knowledge system of biodiversity conservation, (iv) reforestation, (v) provision of alternative sources of income for the local population.

Keywords: Anthropogenic activities, Biodiversity; Climate change, Wetland ecology

1 Introduction

Over the past two decades a large amount of evidence has accumulated, showing that global climate is rapidly changing. Precipitation patterns have probably changed as well, with increased precipitation in some parts of the globe, and decreased rainfall in others (IPCC 2001). And in recent decades the frequency and intensity of droughts has been observed to increase in for instance parts of Africa and Asia (IPCC 2001). The link between climate change and biodiversity has long been established. Although throughout Earth's history the climate has always changed with ecosystems and species coming and going, rapid climate change affects ecosystems and species ability to adapt and so biodiversity loss increases (CBD, 2009).Changes in climate exert additional pressure and have already begun to affect biodiversity. Land and ocean surface temperatures have warmed, the spatial and temporal patterns of precipitation have changed, and sea level has risen. These changes, particularly the warmer regional temperatures, have affected the timing of reproduction in animals and plants and/or migration of animals, the length of the growing season, species distributions and population sizes. It's also noted that the risk of extinction will increase for many species that are already vulnerable, for example Species with limited climatic ranges and/or restricted habitat requirements and/or small populations are typically the most vulnerable to extinction. (IPCC 2001).

In recent times, biodiversity has become easy targets for human over-exploitation due to increasing human populations and the quest for a better life through improvements in science and technology. Studies have shown that Biodiversity is being exploited at much faster rates than ever before with negative implications for sustainable human livelihood (Turner et al., 1990).According to Wilson (1992) biodiversity is facing a decline of crisis proportions which could ultimately lead to mass extinctions in the very near future. In Kenya, increasing evidence indicates that the rate of environmental degradation has increased in recent times (NEMA, 2000), with previously Wetlands being converted to agricultural lands (Hawthorne & Abu-Juam, 1995).

In addition, human activities have affected, and will continue to affect, biodiversity, through land use changes, habitat destruction etc, with changes in climate exerting additional pressure on species, communities and ecosystems (Gitay *et al*. 2002). Current rates of climate change have already resulted in species composition changes. As the climate warms up or cools down, many local species have to shift from their current habitat to areas better suited to their needs. Changing temperatures will also influence their reproductive cycles, their growth patterns and, also as a result of range shifts, the interaction between species (ICLEI 2008). However, it's noted that the risk of extinction is likely to increase for many already vulnerable species; particularly those with restricted range (Gitay *et al*. 2002).Different studies have shown varying approaches to this concern, According to Global biodiversity outlook 3,may 2010 in its report compiled by IUCN the proportion of all species in different threat categories of extinction risk as per IUCN Red list based on data from 47,667 species(CBD,2010). The method use was based on prediction models under climate change requiring paradigm shifts which will not be able predict the future with accuracy, but instead need a strategy for using existing knowledge and bioclimatic modeling to improve understanding of the effects of future climate on biodiversity. A report by Local Government for sustainability (ICLEI,2008), based on Biodiversity Integrated management focused on reducing Co2 through deforestation and land use change as a result of human induced green house emission. This was managed by maintaining local biodiversity and increasing urban green space in particular forest areas which were of significant and effective contribution towards protecting the global climate. In addition providing regulatory framework for encouraging vegetation growth on private properties was done to enhance environmental protection.

Kingwal wetland is a massive wetland on the catchments of Yala River. The wetland is popular as a habitat for rare Sitatunga, crane birds and wetland forest of Syzygium spps. The wetland is a very important resource for both the community living in the catchment and those living downstream of Yala River. Cultivation in Kingwal wetland in time of dry season (food stress) is on increase and cause the biggest threat to the system. Extensive maize cultivation and vegetables poses a threat not only to the availability of alternative products from wetland but also to the ecological functions of wetlands and socio-economic wellbeing of the community who depends on them. The biggest threat to degradation of Kingwal is linked to dry season which encourages farmers to look to wetland cultivation and leads to burning of wetland vegetation. Another threat is planting of Eucalyptus trees in the wetland which lowers the water table. The once extensive wetland which is an important breeding site for Sitatunga has been reduced to a narrow stretch of swamp. The current situation, if allowed to continue, is likely to result in habitat destruction and loss from the wetland, consequently threatening the survival of the rare Sitatunga (Ambasa, 2005).

The main objectives of this study were (i) to investigate the impact of Anthropogenic activities (cultivation, hunting, grazing, and brick making) and climate change on biodiversity conservation and loss of habitat for Sitatunga and (ii) to obtain useful data/information to enable recommendations on how to Mitigate, reduce the effects of global warming and the impacts of Anthropogenic activities on Sitatunga habitat. This can be achieved through maintaining local biodiversity and increasing green space, in particular forest areas, therefore are significant and effective contributions towards protecting the global climate similar method was used in a report by Local Government for sustainability (ICLEI,2008) .This study focused on creating Awareness on the importance of biodiversity conservation. The methodology used involved questionnaires, interviews with a cross-section of the local people, the organization, and focus group discussions (FGD) together with obtaining data from Meteorological Department Eldoret this ensured original, accurate and reliable data is obtained to solve the problem on biodiversity loss. By doing so, it will help in slowing down extinction rates of ecologically, culturally, economically significant species such as Sitatunga. This study is important because no other study has been conducted,researched and documented on the impacts of anthropogenic activities on biodiversity and climate focusing on the rare sitatunga animal.

2 Materials and methods

Study area

The site chosen for study was Kingwal Wetland in Nandi North District. Kingwal swamp is 25 kilometers from Eldoret towards Kapsabet and almost 400 kilometers from Nairobi and is the habitat for the rare Sitatunga (Tragelaphus Spekei). Kingwal currently measures 2.73 square kilometers. The district is situated in the western part of the Rift Valley Province. It lies within latitudes 0^0 and 0^0 34'' North and longitudes 34^0 44''and 35^0 25''East. (Nandi district development plan 2002-2008).

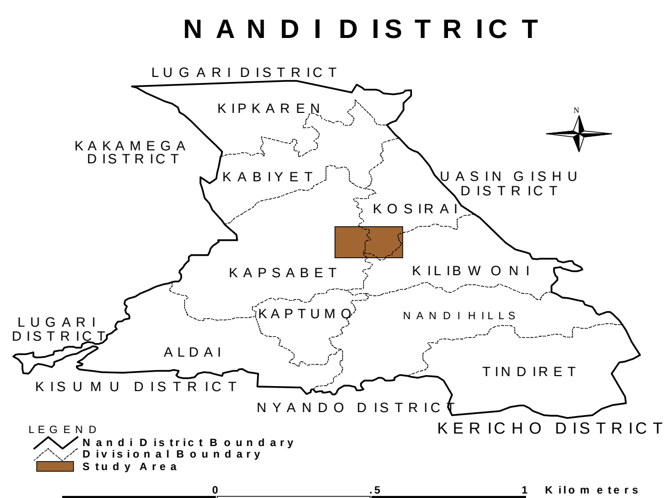

Figure 1 Location of the study area on the maps of Kenya and Nandi District

The vegetation of the wetland is consists of forests, derived grasslands, shrubs and scrubland, Kikuyu grass species is suited for cattle grazing. (Nandi district development plan 1994-1996).

Dominant grass species include *Andropogon gayanus, Hetero-pogon contortus, Panicum maximum,* and *Sporobolus pyramidalis*. About 40% of the area was converted into *Eucalyptus, Azadirachta indica* (neem), and teak plantations when parts of the area were designated as forest reserves (Yenku A and B). The major human activities in the wetland are Extensive maize and vegetable cultivation, grazing and Brick making). Other activities include hunting, Eucalyptus cultivation (Ambasa, 2005).

Data collection

A total of 80 questionnaires were administered according to human activities carried out by individuals within Kingwal wetland. This targeted cultivation, grazing, brick making who were grouped into stratus. We visited Individuals for interviews from each stratum (activity) whom were selected at random to ensure randomization of the selection of respondents for the interview (Kirubi *et al.*, 2000). A total of 20 individuals from each strata (activity) working at the wetland was selected for sampling. It was expected that this will form between 10-20% of the total individuals in each stratum as recommended (Kangwana, 1996).

Key informants as Chiefs, Assistant chiefs, Village Elders, area councilors, and KWS officials Nandi District were interviewed. Focused group discussions (Community conservation forums, women and youth groups focused on conservation).Field visits and observation were conducted on the study area to ascertain biodiversity loss. This method enabled us to obtain first hand data that was highly reliable.

Collection of meteorological data

Meteorological data for the study site used in this paper was obtained from hydrological year book at the Eldoret Meteorological Services Department.

3 Results and Discussions

Cultivation in the study area was observed to be the leading activity recording (38%) with most respondents owning 1/4acre of cultivated area (60%) and most of them using it for the least 6 to10years(40%). Extensive maize and vegetables cultivation is predominant among cultivators at the wetland with 15% and 70% respectively. It should be noted, however, that unreliability of rainfall (91%) was an important factor associated with the choice for wetland cultivate especially during dry period Table 1(a-f)}. Draining of water for easy cultivation was done with majority of the respondents digging trenches to drain excess water (85%). However, those who cultivated either used chemicals or fertilizers on their fields (80% and 60%) respectively Table 1(g-i)

Table 1 statement of Anthropogenic activities in Kingwal Wetland

a)

Activity Engaged at wetland	*Percentage*
Cultivation	38.3
Grazing	25.0
Cultivation and grazing	21.7
Brick Making	15.0

b)

Use of wetland for cultivation	*Percentage*
Yes	90.0
No	10.0

c)

Reliability of rainfall	*Percentage*
Reliable	05.0
Unreliable	91.7

Not sure	3.3

d)

Methods used in clearing land	*Percentage*
Burning	60.0
Slashing	10.0
Chemicals	00.0
Burning and Slashing	30.0

e)

Cultivated area(Acres)	*Percentage*
1	05.0
0.75	00.0
0.5	35.0
0.25	60.0

f)

Time stayed in wetland(years)	*Percentage*
1-5	03.1
6-10	12.9
11-15	78.0
Over 15	06.0

g)

Duration of cultivation on the wetland	*Percentage*
Permanently	15.0
Only in dry periods	85.0

h)

Methods of draining Excess water	*Percentage*
Digging trenches	85.0
pumping	03.0

i)

Crops grown in the wetland	*Percentage*
Maize	10.0
Tomatoes/Vegetables	75.0
Potatoes	0.5
Legumes	10.0

j)

Use of chemicals /fertilizers	*Percentage*
Yes	80.0
No	20.0

Grazers

Majority of the respondents who grazed on the wetland (75%)had large number of herds(70%)with most of them owning cattle and sheep(55%) Table 2(a-c)}.

Brick Making

Most of the Brick makers conducted their activities on the wetland representing 78%.Out of the respondents interviewed majority(70%) indicated their fear of the future status of Sitatunga animal declining at a fast rate, and that there is need to conserve the wetland(96%) if the reverse has to be observedTable3(a-c).

Generally, From the meteorological data obtained results showed that there was low mean monthly rainfall with majority months 8 out of the 12 months getting less than 100mm(Jan,Feb,Mar,Jun,sep,Oct,Nov and Dec) for the study period of 30 years(1981-2010).

Table 2 Analysis of Brick makers

a)

How often do you graze at the wetland	*Percentage*
Regularly	75.0
Not regularly	25.0

b)

Type of animal grazed	*Percentage*
Cattle	25.0
Cattle and Sheep	55.0

Sheep and Goats	05.0
All of the above	15.0

c)

Quantity of livestock owned	*Percentage*
Large	70.0
Small	30.0

Table 3 Human Activities

a)

Where do you carryout Brick making Activity	*Percentage*
Wetland	93.0
Outside wetland	07.0

Future of Sitatunga	*Percentage*
Fast declining	70.0
Slowly declining	20.0
No idea	10.0

b)

What should be done to the wetland	*Percentage*
Conserve our wetland	96.7
Continue with our daily activities	03.3

Human activities have affected, and will continue to affect, biodiversity, through land use changes and habitat destruction. This has given rise to widespread concern that changes in climate will exert additional pressure on species, communities and ecosystems (Gitay *et al*. 2002). Habitat destruction is currently ranked as the most important cause of species extinction worldwide (pimm et .al, 2000). Climate change may modify and enhance local anthropogenic disturbances. According to Jenkins (1992), rates of habitat modification are currently so high that virtually all natural terrestrial habitats and protected areas are destined to become ecological 'islands'in surrounding 'oceans' of habitat much altered.

Kingwal wetland is a massive wetland on the catchments of Yala River. The wetland is popular, as a habitat for rare Sitatunga. Cultivation in Kingwal wetland in time of dry season (food stress) is on increase and cause the biggest threat to the system (85%) Table 2. Extensive maize cultivation and vegetables poses a threat not only to the availability of alternative products from wetland but also to the ecological functions of wetlands and socio-economic wellbeing of the community who depends on them. The biggest threat to degradation of Kingwal is linked to dry season which encourages farmers to move to the wetland for cultivation as a result burning the wetland vegetation(60%){Appendix 1,Table1d}.Most of those who cultivate at the wetland Burn their lands. They also engage in draining excess water by digging trenches (85%) thus destroying the habitat and leading to loss of biodiversity. The use of fertilizer and chemicals (80%) cause water pollution and endanger the species within the wetland and especially the Sitatunga Animal. Another threat is planting of Eucalyptus trees in the wetland which lowers the water table. The growing urban market opportunities do also encourage wetland drainage for vegetation growing.

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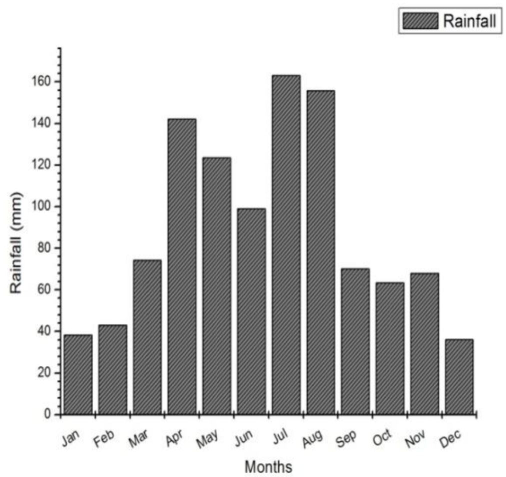

Figure 2 Mean monthly rainfall in Kingwal Area for the last 30 years (1981-2010)

Significantly Kingwal wetland is upheld highly in the community as an important pasture during dry season (85%). Traditionally this wetland has been used in the region to provide communal grazing for animals and customary initiation site for Nandi community. The local community has relied on this resource for a long time as a food security safety valve. The study noted that regular (75%) and increased grazing with large herds (70%) causes' threat to the already shy sitatunga as competition for the scarce pasture material and continuous disturbance affects the breeding site for the sitatunga animal (,Table2c). Encroachment of the wetland by brick makers threaten wetland area, plants and wildlife which are of social-economic importance to the riparian communities. It exploits and destroys wetland resources leading to the loss of original characteristics, modifying this important ecosystem and threatening the life style and livelihood of local communities (Iyango *et al.*, 2005). Brick making activity is largely practiced within the wetland (78%) and these poses threat to sitatunga as the abandoned pits may harm or cause death to the animal. From the study it was confirmed that the future of sitatunga is fast declining(70%) due to this factors contributed by anthropogenic activities and climate change, and that the only way to reverse this state is to find ways of conserving the wetland and avoiding destruction and habitat loss, hence sustainability of ecosystem and sitatunga environment. From the results the area receives low rainfall with majority months getting less than 100mm (Fig2), which relates to unreliability (91.7%) Table1c, to maintain growth in plants to maturity levels and low pasture for livestock this has always left people with little or no hopes at all for survival forcing them to seek alternative source at the wetland.

4 Conclusion

From the results of the study, the major anthropogenic activities which caused positive impact on the biodiversity in Kingwal wetland were Cultivation, Grazing and Brick making in order of importance. Cultivation during dry seasons was observed to have increased over the years, and continuous use causing the biggest threat to the system (85%). The impacts of climate change depicted by erratic changes in rainfall patterns have always resulted to continued spell of long dry months forcing farmers to look for alternative adaptative mechanism thus resorting to wetland cultivation. This has contributed to massive burning of wetland vegetations (60%).While, Grazers seek pastures for their livestock and brick makers sort livelihood from brick making to enhance socio-economic benefits. In order to sustain the ecological-importance Kingwal wetland as well as biodiversity conservation initiatives in the study area, the following are recommended:(i)Initiation of education and awareness programmes targeted at children and the youth, stressing the direct and indirect values of wildlife.

(ii) Initiation of forestation programme to attract wildlife to maintain catchment areas and discourage planting of Eucalyptus trees in wetland ecosystem.
(iii)Provision of adequate financial resources for agencies involved in conservation efforts in the wetland to enhance their efficiency and performance
(iv) Provision of alternative sources of income for the local people to reduce pressure on the already depleted biodiversity of the wetland

Acknowledgements

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Interactive effects of livestock and trees on nutrients and herbaceous layer production in a humid Kenyan savanna

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Abstract: Savannas are key ecosystems that provide vital services such as fodder for wild and domestic animals, recreation, biodiversity habitats, CO_2 sequestration and timber. Their characteristics and distribution make them relatively susceptible to disturbances such as land-use and climate change. This study was carried out to monitor seasonal changes in soil moisture, soil and plant nutrients, and grass primary production as well as establish the impacts of grazers and *Acacia* trees on ecosystem processes in a humid tropical savanna. Soil moisture, soil and plant N/C content and grass biomass were monitored in grazed, non-grazed, under canopy and open locations. Soil moisture was monitored through core method, N and C concentrations (%) were determined by means of elementary analysis while biomass was assessed through harvest method. The results indicated an increase in above ground biomass with progression of wet season with peaks of 1757.63±46 and 1906.75±115 g/(m^2•a) recorded in grazed and non-grazed plots respectively. Understorey sites recorded significantly ($p<0.001$) higher peak aboveground biomass compared to open sites. Significantly higher soil and shoot N content, 0.35±0.1 and 0.93±0.28 %, respectively were observed in the understorey sites, while %C content declined with progress of wet season. In this humid ecosystem, grazers were responsible for keeping grasses low during the dry season; however, they had minimum influence on primary production during the growing season. *Acacia* species strongly influenced organic matter accumulation, soil moisture and biomass production under their canopies. The observed trends created a unique production mosaic of ecosystem function and productivity in the humid savanna. This ecosystem can therefore be a significant source and sink of both N and C with processes that control their emissions being complex and influenced by a variety of interrelated factors such as quality and rates of organic matter turn over. Therefore, processes in humid savannas are not a simple function of rainfall patterns or herbivory, but regulated by interactive effects of grazing and nutrients with trees acting as modifiers.

Keywords: Grazing, Understorey, Primary production, Nutrients, Ruma national park

1. Introduction

Savanna ecosystem is characterized by the co-existence of grasses and trees (Isichei, 1995; Chidumayo, 2001; Lloyd *et al.*, 2008; Kalwij *et al.*, 2010), a stable structure that is largely determined by facilitation, competition and disturbances (Okin, *et al.*, 2008). The contrasting plant life form of trees, shrubs and grasses, cover approximately an eighth of the global land surface

(Sankaran *et al.,* 2004; Otieno *et al*., 2005), which translates to 25% of terrestrial biomes and thus second to tropical forests in their contribution to terrestrial primary production. They support a considerable proportion of the world's human population and a majority of their rangeland and livestock (Sankaran *et al.,* 2004), as well as a continuous layer of drought resistant herbaceous plant and scattered woody species (Fitzgerald, 1973) due to their unique climate.

In Kenya, savanna occupies over one third of the total land area, dominating regions that are characterized by alternating humid and dry seasons and a stable, though considered pre-climax vegetation (Hubbell, 2001). Most of the Kenyan savanna experience warm continental climate, with unreliable precipitation ranging between 150 - 500 mm per annum (Otieno *et al*., 2005), and seasonal fluctuations. However, savannas found in the western part of the country, bordering the tropical rain forest, receive relatively high rainfall amounts that can reach 1500 mm per annum (Otieno *et al.*, 2010). The soil of the savanna is porous, with rapid drainage of water. It has only a thin layer of humus, which provides vegetation with nutrients.

A large number of wild herbivores are found in African savannas with major effects on ecosystem structure and functioning by influencing plant growth and development (Leriche *et al.,* 2003; Kalwij *et al.,* 2010). Herbivory of both wild and domestic ungulates induces changes in soil and vegetation, which in turn may promote or deter further foraging (Skarpe, 1991; Cech *et al*., 2010). Herbivores can control the ecosystem function through modification of feedbacks between dominant plant species and nutrient cycles (Cech *et al.,* 2008; Coetsee *et al.,* 2010), as well as increase tissue loss rates of plant species that tolerate herbivory but have nutrient rich tissues (Augustine and McNaughton, 2006; Cech *et al.,* 2008). Previous studies in semi arid savannas (Augustine and McNaughton, 2004, 2006), indicated that herbivores spatial pattern of habitat use for feeding and excretion affects nutrient distribution. However, domestic herbivores are less mobile than many wild species, which may impede large-scale selectivity when kept at low density. This conclusion is supported by the observed migratory behavior of ungulate species in the Serengeti (Tanzania) and Yellowstone (South Africa) National Parks in response to spatiotemporal gradients of plant productivity and nutrient content (Augustine and McNaughton, 2006).

Due to high organic matter accumulation and reduced evaporation under trees, rapid nutrient movement is anticipated under trees compared to open locations outside tree canopies (Bernhard and Poupon, 1980; Smith, 1999). Thus, compared to neighboring grasslands, soils under tree crowns (canopies) are likely to have higher concentrations of available N (nitrogen) and other important nutrients, higher biodiversity, and faster water infiltration (Belsky *et al.,* 1993). Savanna trees provide a browsing habitat for herbivores and fuel wood for human harvesting (Wang *et al.,* 2009b). They also ameliorate environmental stress under their canopies (Hussain *et al.,* 2009), which may stimulate primary production in the herbaceous layer.

It has been increasingly clear that there exist predictable, yet largely unresolved variations in nutrient balance in humid tropical savannas (Lalljee and Facknath, 2000). Since nutrients and soil water are important limiting factors on primary production in this ecosystem (Isichei, 1995), a better understanding of ecosystem processes related to their availability may help in designing appropriate management policies that ensures ecosystem sustainability. Several studies have indicated that N nutrient is most often limited in the soil (Belsky *et al*., 1993; Wang *et al.*, 2009; Cech *et al.*, 2010), and thus necessitating clear understanding of its dynamics from grazer to plant, plant to soil and finally to the atmosphere. Recent studies have shown that N dynamics are initiated at the beginning of humid seasons when moisture availability stimulates bioactivity and release of nutrients from detritus as well as translocation of the organic carbon (C) from plant roots (Smith, 1999; Cech *et al.*, 2008; Cech *et al.*, 2010).

In most savannas, the major constraint on soil N availability is an increased leaching during rainfall periods (Cech *et al.*, 2008). However, other studies have shown that under increased temperature and carbon dioxide (CO_2) levels (Isichei, 1995), interactions between C and N dynamics have impacts on ecosystem function and C storage. Nitrous oxide (N_2O) in the atmosphere has been increasing at an average rate of 0.2 to 0.3 % per year (Watson *et al.*, 1990; Serca *et al.*, 1998), with major sources being land-use conversion and vegetation disturbances (Serca *et al.*, 1998; Otieno *et al.*, 2010). This is expected to impact negatively on global climate, resulting in water scarcity and even greater limitation to plant productivity across an increasing amount of land in the savanna. Therefore, an informed knowledge on the processes involved in input, losses and utilization of N through interacting components of this ecosystem will aid in sustainable management decisions.

In this paper, seasonal biomass and nutrient quantities are determined as driven by ungulates. A change in soil properties is also established through long term monitoring as well as the role of trees is defined. Further examination on the underlying mechanisms responsible for any observed changes were carried out by conducting experiments on the relationships among ecosystem components. We hypothesized that primary production in this ecosystem is controlled by soil moisture but accelerated by herbivory. Land use practices, such as increased grazing pressure have been associated with shifting savanna ecosystems from grass to woody plant domination (Archer, 1995), with other interacting factors that includes climate change (Otieno *et al.*, 2010). However, Aranibar *et al.* (2004) found that photosynthetic machinery in plants accounts for more than half of the N in the leaves. Therefore, knowledge of the N cycle in ecosystems is crucial for investigating the effects of global change on vegetation and C cycle since photosynthesis is strongly affected by N availability.

Due to their expansive nature, tropical savanna grasslands play an important role in the annual C balance (Hanan *et al.*, 1998; Ardö *et al.*, 2008), and hence providing a significantly larger photosynthetic surface compared to trees. At the moment, proper studies are scarce on this humid savanna (Muriuki *et al.*, 2003), but results presented by Otieno *et al.* (2010) seems to point out the mechanisms that concentrate nutrient flux at the soil-plant interface. However, the mechanism at soil-plant-herbivore interface has not been well documented and, therefore, the effects of manipulating the carrying capacity on nutrients cannot be predicted.

2. Material and Methods

Study site

Lambwe valley, Ruma National Park, (00° 35’27.72” S & 34° 18’81.64” E) is located in Suba District, Nyanza Province, Kenya (Fig. 1). The altitude of the area is 1400 meters above sea level. The Park is situated about 10 km east of Lake Victoria in Western Kenya, southwest of Homa Bay town and east of Gembe and Gwasi Hills. The park (formerly Lambwe Valley National Reserve) was established in 1966 but its isolation, and consequent lack of income, ensured a very slow pace of development. With its elevation into a National Park since 1983, game viewing tracks and general Park maintenance have been established.

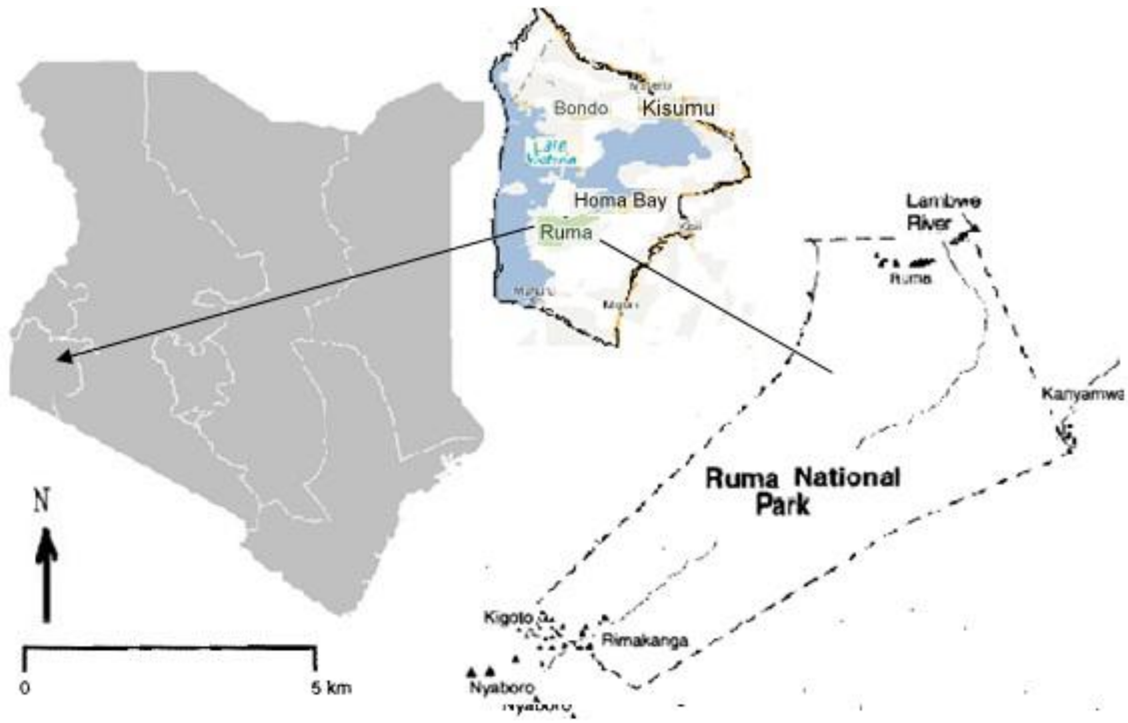

Figure 1 Map showing the study site at Ruma National Park, (00° 35’27.72” S & 34° 18’81.64” E).

The terrain is mainly rolling grassland, with tracts of open woodland and thickets dominated by species of *Acacia*, *Rhus* and *Balanites* (Table 1). Located just south of the equator and adjacent to Lake Victoria, the area experiences a warm and humid climate, and is classified as sub-humid to semi-arid (Muriuki *et al.*, 2005). The recorded metrological variables are presented in figure 2. Soils are largely “black cotton” clays corresponding to Vertisols according to WRB soil classification. The area around the park is settled with a mix of small-scale cultivation and grassy pastureland. Main grazing animal populations within the Park consist of roan antelope (*Hippotragus equinus*) and Jackson's hartebeest (*Alcelaphus buselaphus*), a larger and redder species than Coke's which is found in most Kenya parks, Oribi (*Ourebia ourebi*), one of the smallest of the antelope family and

Rothschild giraffes (*Giraffa camelopardalis rothschildi*). The park has a perimeter fence around it, which keeps the game animals within. Included within the park but separated by the perimeter fence is a section owned by the Kenya National Youth Service (NYS), which acts as a youth training camp. Our experimental plots were located within the NYS section of the Park, which was grazed mainly by domestic animals; the Zebu (*Bos Indicus*) cattle consisted of drought resistant Sahiwal and Boran breeds.

Table 1 List of plant species growing in the different locations categorized according to the physical feature or land use practice. Vegetation sampling was conducted during the month of March 2008.

Grazed	Fenced		Acacia understory
Acacia ancistroclada	*Acacia ancistroclada*	*Leucas calostachyus*	*Acacia ancistroclada*
Aspilia asperifolia	*Acacia gerarrdii*	*Nuxia congesta*	*Albizia coriaria*
Balanites aegyptica	*Acmella calirrhiza*	*Panicum maximum*	*Aspilia asperifolia*
Conyza floribunda	*Albizia coriaria*	*Pilliostigma thonningii*	*Balanites aegyptica*
Eragrostis atrovirens	*Aspilia asperifolia*	*Pseudathria hookeri*	*Berkeya spekeana*
Kyllinga bulbosa	*Balanites aegyptica*	*Psidium guajava*	*Cordia ovalia*
Panicum maximum	*Berkeya spekeana*	*Rhus natalensis*	*Leucas calostachyus*
Pseudathria hookeria	*Commiphora myrrha*	*Rhus vulgaris*	*Panicum maximum*
Psidium guajava	*Conyza floribunda*	*Solanum incanum*	*Rhus vulgaris*
Striga asiatica	*Cordia ovalis*	*Steganotaenia araliacea*	*Themeda triandra*
Themeda triandra	*Crotalaria pallida*	*Themeda triandra*	*Urena lobata*
	Dyschoriste radicans	*Tithonia diversifolia*	
	Hyparrhenia hirta	*Lantana camara*	
	Indigofera arrecta	*Lantana trifoliate*	

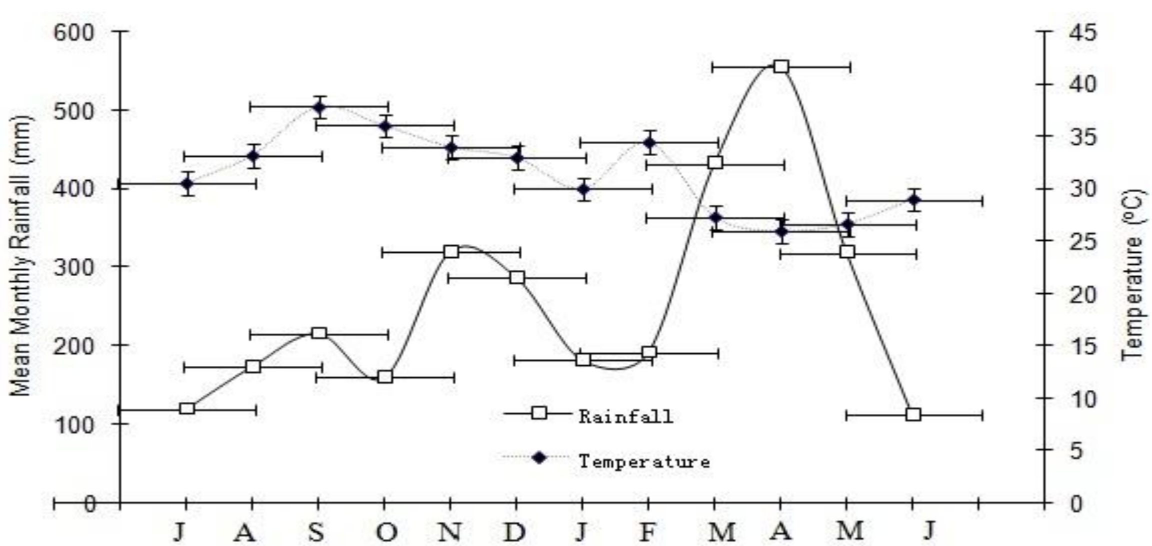

Figure 2 Rainfall and temperature during the growing season of 2007, 2008. Horizontal and vertical bars represent SE.

Experimental design

Experimentation at this site has been going on since 2006. We report here the results of an intensive study carried out between November 2007 and July 2008. Two plots measuring 50 × 50 m were established within *Acacia* woodlands. One plot was enclosed using a 2 m high fence (to exclude grazing), and the other plot was left open to grazing and was strategically located at the intensively grazed site. The animals passed over this area at least 2-3 times a week, with the intensity of grazing increasing during the dry season, when grass was limited elsewhere. They could spend approximately 10-20 minutes feeding on the same area and moving on to other locations since the grazing area was expansive. Within the plot, (grazed and fenced), we randomly established ten (10) 3 × 3 m measurement units, i.e., (5 units) under canopy and (5 units) in open grassland.

Measurements

Weather conditions were continuously recorded at a mini-meteorological station set up at the field site. Air temperature (T_{air}) and humidity (Fischer 431402 sensor, K. Fischer GmbH, Drebach, Germany) data were measured every 5 min, averaged and logged every half-an-hour by data logger (DL2e, Delta-T Devices Ltd. Cambridge UK). In addition, temperature (T_{air}) above grass height (Digital thermometer, Conrad, Hirschau, Germany) and soil temperature (T_{soil}) at 10 cm depth (Einstichthermometer, Conrad, Hirschau, Germany) data were recorded every 15 seconds.

Soil water content

Soil samples were collected with a 3 cm diameter core sampler at the middle of the collars down to 30 cm and the soil cores divided into three layers from 0-10, 10-20 and 20-30 cm from fenced and grazed site. This was done on a monthly basis where two replicates from each collar per sampling date and hence ten replicates in total from each location (open and under canopy) in both grazed and fenced plots. Each sample (layer) was immediately weighed to determine its fresh weight before oven drying at 105ºC for 48 hours and determining the dry weight. Gravimetric soil moisture content was determined as the relative change between fresh weight and the weight difference between the fresh and dry soils as follows:

$$SMC = \left[\frac{(Weig\ ht\ of\ wet\ soil) - (weig\ ht\ of\ dry\ soil)}{(weig\ ht\ of\ dry\ soil)}\right] \times 100\%$$

(1) Bulk density, Plant and Soil N

The second soil sampling was done at the middle of the collars located in both grazed and fenced plots, down to 30 cm and the soil cores divided into three parts from 0-10, 10-20 and 20-30 cm. In each plot, 10 samples were collected; 5 samples under canopy and 5 samples from open sites per sampling date. These set of samples were used for the determination of N content where soil and plant samples were dried and homogenized in a ball mill. The homogenized samples were re-dried in a desiccator to eliminate all the water. A portion of the dried samples, 4–5 and 15–100 mg of plant and soil samples, respectively were analyzed to determine their N and C concentrations (%) by means of elementary analysis (Markert, 1996). Total N content was determined from the total weight of the aboveground biomass and expressed as $g.m^{-2}$. Similarly, total root N content was calculated from the total weight of belowground biomass. A similar procedure was followed to determine the total N content (%) in soil. Bulk density was determined by core method where a fixed volume of soil samples from different depths were weighed after drying at 100ºC.

Biomass measurements

Collars measuring 38 × 38 cm were used to demarcate aboveground grass biomass for harvesting every month in each measurement unit. Each month, five replicate collars were sampled from open and under canopy locations in both grazed and fenced plots. The harvested biomass was sorted into green and dead material before oven drying at 80°C for 48 hours and weighing by use of an electronic weighing balance (Denver Instrument Model XL-3100D). Root biomass was sampled with an 8 cm diameter soil cores down to 30 cm, from the same plots after removal of the aboveground biomass. The sampled soil cores were separated into three different layers (0–10, 10–20 and 20–30 cm). Roots from each of the layers were carefully removed from the soil and washed under running tap water using micro-pore (<2 mm) soil sieves. The sieved samples were then oven-dried at 80 °C for 48 h before determining dry weights. Due to difficulty in separating dead and live biomass, the reported results include profile averages for combined dead and live biomass.

Data Analysis

A one way ANOVA was applied to compare differences between means in nutrients, biomass and water content with treatments (plots) as the fixed effects using statistical software SPSS (SPSS 15.0 for Windows, SPSS Inc., Chicago, USA). In case of significant effects, means were compared using least significant difference (LSD) (as described by Little and Hill, 1978) with significance level set at P≤0.05. Best fits for nutrients, biomass and moisture response curves for grazed and fenced locations were performed using Sigma Plot version 8.0.

3 Results and Discussions

Climate and Soil Properties

The region had a bimodal rainfall pattern with long rains from March to June and short rains in November and December. April was a comparatively wet month with an average monthly rainfall of >500mm while February was the driest month (Fig. 2). Mean monthly temperatures ranged between 38^{o}C and 23^{o}C with lowest temperatures recorded during the wet season. Soil moisture increased with progression of the wet season in all sites, with grazed sites recording higher values compared to fenced sites (Table 2, Fig. 3). Understorey had significantly higher soil moisture 23.83±2.0% compared to open sites 16.79±2.5%. In grazed plot, soil moisture increased with increase in depth during the wet season, however, there was no clearly defined trend in fenced plot (Fig. 3). During the long rain, an increase in soil moisture led to an initial increase in soil N content with highest soil N content 0.32±0.07 recorded between the months of April and May (Fig. 4). In understorey soils, significantly higher N content was exhibited than open locations when data was pooled together, but declined in June and July. However, there was a spiked increase in soil N at the beginning of wet season which later declined with progression of wet season. Soil N at fenced plots was significantly higher than grazed plots during the study period except in the month of February. In open grassland sites, there was a uniform increase in soil N throughout the study period.

Table 2 Summary of results of different parameters measured in the different locations/treatments. ± 1 standard deviation from the mean.

	Grazed	Nongrazed	Understorey (Acacia)	Open	No. of replicates	*P*
SWC (%)	*25.61±2.2*	*28.44±2.5*	*23.83±2.0*	*16.79±2.5*	*40*	*<0.001*
Bulk Density (g cm^{-3})	*1.19±0.08*	*1.08±0.05*	*1.54±0.01*	*0.73±0.02*	*6*	*<0.001*
Soil N (%)	*0.22±0.01*	*0.32±0.07*	*0.35±0.1*	*0.15±0.1*	*40*	*<0.001*
Soil pH.	*6.4±0.10*	*6.4±0.15*	*6.5±0.31*		*40*	*=0.014*
Plant N %	*0.44±0.01*	*0.55±0.11*	*0.93±0.28*	*0.41±0.01*	*48*	*<0.001*
Total N content g m^{-2} yr^{-1}	*757.15*	*661.49*	*769.36*	*210.82*	*Biomass* %N*	
Soil C (%)	*3.40±0.2*	*4.84±1.5*	*4.90±0.7*	*2.54±0.20*	*40*	*<0.002*
C: N ratio	*45: 1*	*35:1*	*-*	*-*	*=18*	
Peak aboveground biomass g/(m^2•a)	*1757.81±46*	*1906.75 ±115*	*1137.5 ±25*	*815.625±31*	*40*	*<0.001*
Peak belowground biomass g/(m^2•a)	*862.5±12*	*787.5±53*	*687.05±15*	*334.38±1*	*36*	*<0.001*
Dead biomass g/(m^2•a)	*-*	*-*	*195±39*	*181.25±02*	*<12*	*<0.001*

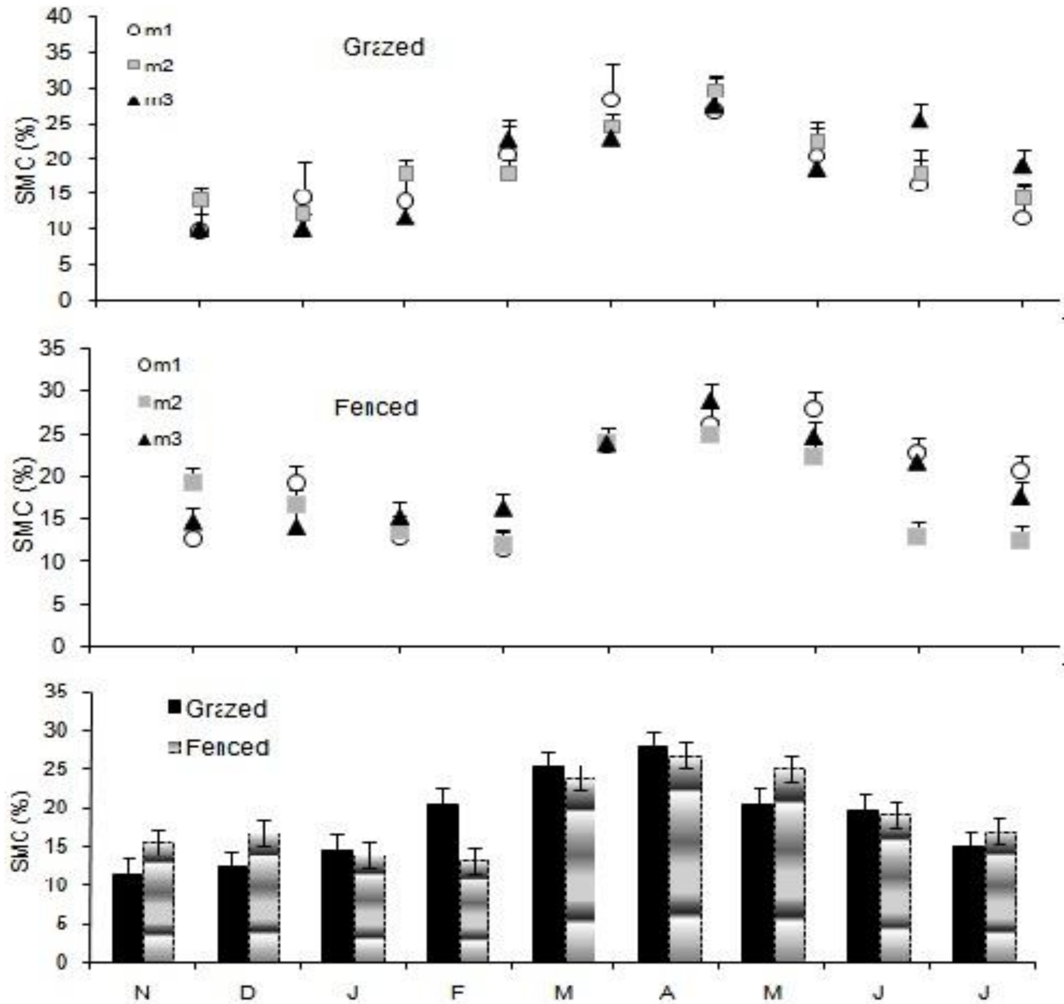

Figure 3 Seasonal Soil Water Content (%) between November 2007 and July 2008 in grazed and fenced sites; m1 (0-10cm depth), m2 (10-20cm depth) and m3 (20-30cm depth). Error bars show ±1 SE based on months variations.

There were seasonal differences in soil C content with lower values recorded during the dry season as well as site differences with grazed plots recording lower values (3.40±0.2%) than fenced plots (data not shown). Understorey sites had significantly higher soil C (4.90±0.7%) compared to open sites (2.54±0.20%) (Table 2). Bulk density was significantly higher at understorey sites (1.54±0.01 gcm^{-3}) compared to open sites (0.73±0.02 gcm^{-3}) (Table 2). Despite the noted differences in bulk density between surface and deeper soils in fenced plots, no significant differences were vivid between grazed and fenced plots..

Plant nutrients

Foliar N content was significantly ($p<0.001$) higher in the grazed plot than fenced plot throughout the growing season (Fig. 5) with values of (0.55±0.11%) and (0.44±0.0%), respectively. Foliar C increased in the fenced site with the progress of the wet season. Equilibrium was attained in the month of April, coinciding with the highest rainfall month. Foliar C/N ratios between plots had a unique trend with 54:1 and 36:1 occurring in the grazed and fenced plots, respectively (Table 2). Site differences may have been caused by different biomass developmental stages where most leaves were newly formed after tiller removal by herbivores and hence the high C/N ratio.

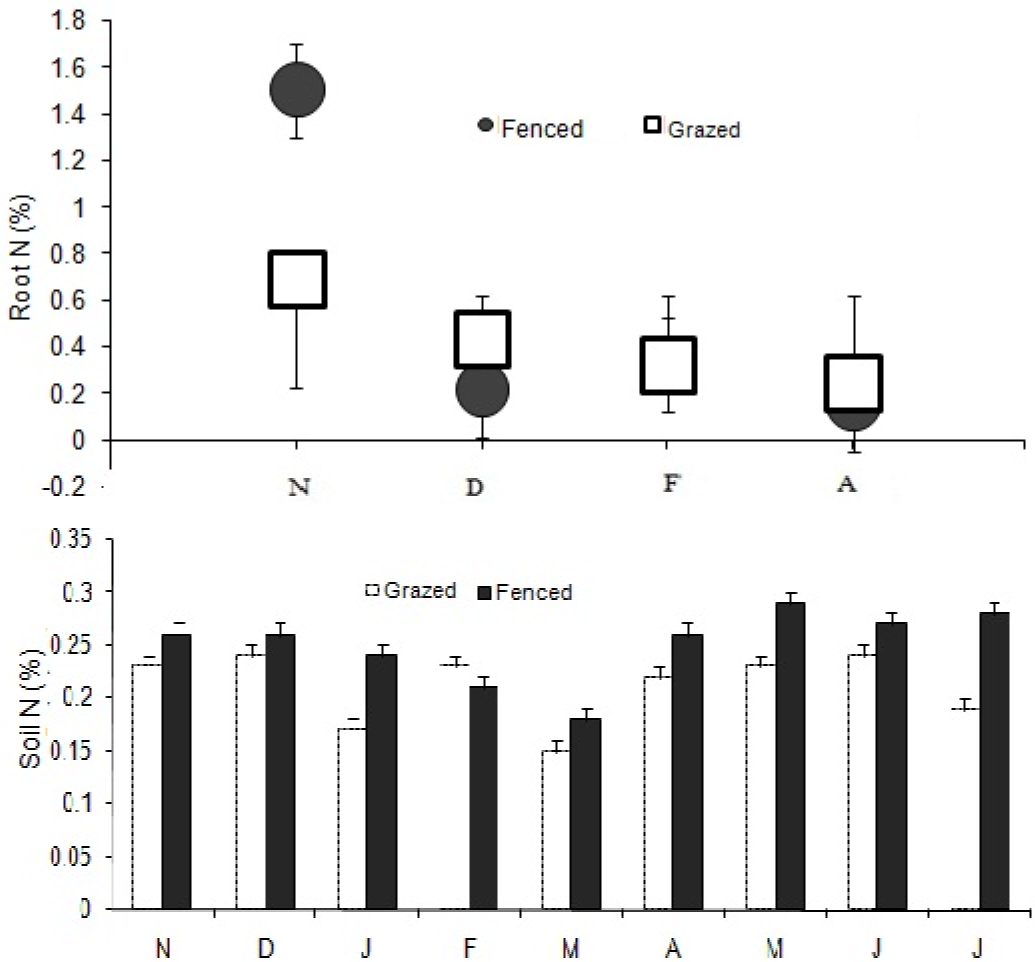

Figure 4 Soil Nitrogen content at understorey vs open sites and grazed vs fenced sites. Error bars show ±1 SE based on months variations.

Root N content in the non-grazed plot was higher than in the grazed plot during the dry season with values ranging between 0.2 to 1.5%, while there was a steady decline from November to April in the grazed plot (Fig. 4). When root C was assessed during the wet and dry seasons, fenced sites had higher content than the grazed sites. Variability of C and N content across sites and profile depths probably reflected the intensity of leaching of manure and urine input from herbivores and organic matter thus leading to lower soil ionic strength.

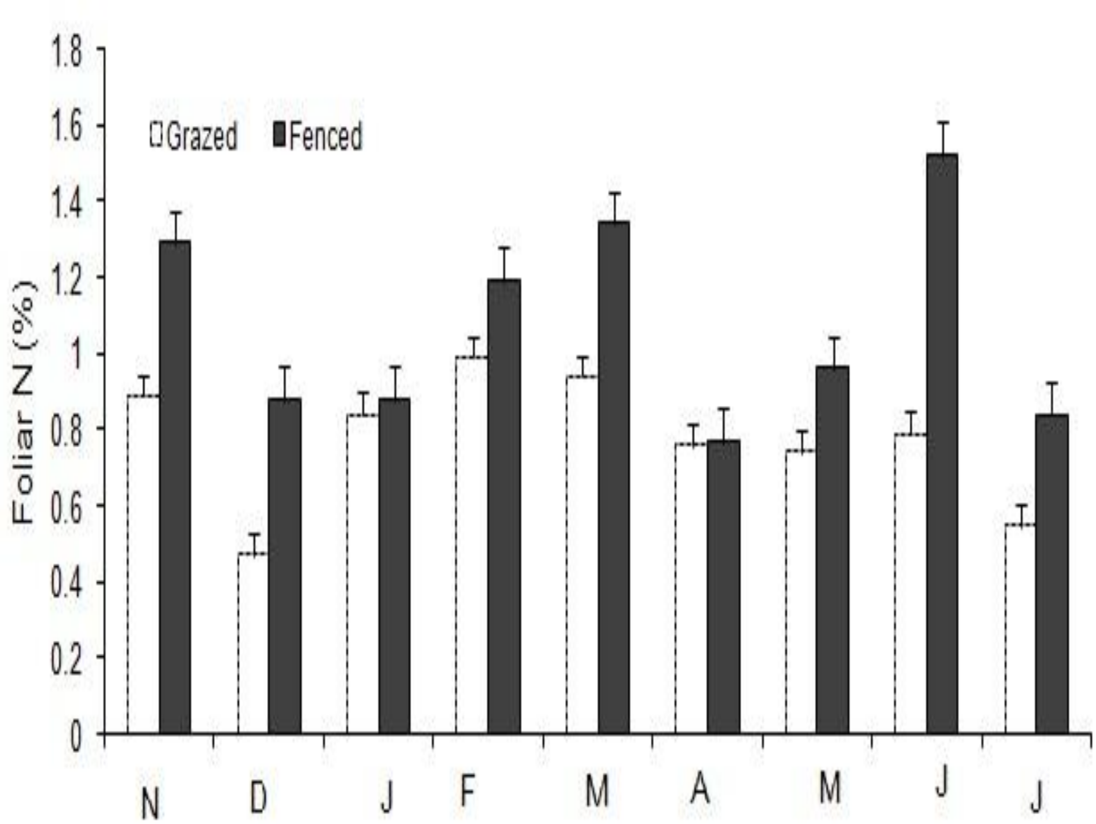

Figure 5 Foliar and root nitrogen for grass material. Error bars show +1 SE based on among months variations.

Biomass production

During the study period, peak aboveground biomass was 1757.63±46 g/(m^2•a) and 1906.75±115 g/(m^2•a) in grazed and non-grazed plots respectively (Table 2). Above ground biomass increased significantly during the wet season from March through May in grazed plots. Aboveground biomass was higher between April and July corresponding to the increase in soil moisture. During this period, the region experienced the long rains, with understorey and open sites recording 1137.5±25 g/(m^2•a) and 815.625±31 g/(m^2•a) respectively (Fig. 6). Biomass at understorey and open sites in grazed plots were similar during the wet season but higher values were recorded during the dry season. However, understorey sites maintained high above ground production during the wet season in fenced plot.

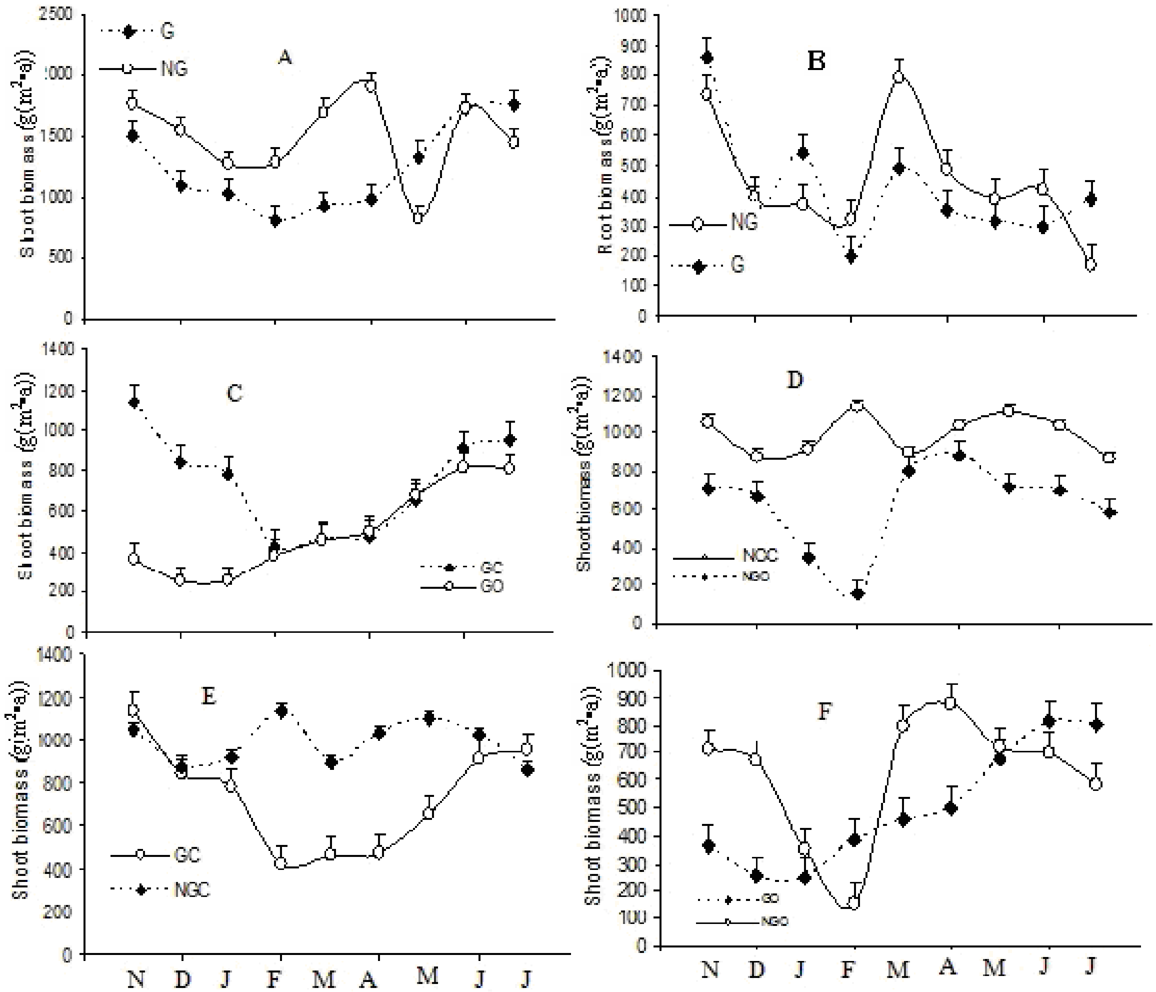

Figure 6 A: Total aboveground (shoot) biomass (*g/(m^2•a)*), in grazed (G) and fenced/non grazed (NG) plots. B: Total belowground (root) biomass in G and NG plots. C: Shoot biomass in grazed canopy (GC) and grazed open sites (GO). D: Shoot biomass in fenced canopy (NGC) and fenced open (NGO) sites. E: Shoot biomass in GC and NGC. F: Shoot biomass in GO and NGO sites. Error bars show +1 SE based on months variations

Highest root biomass values of 862.5±12 g/(m^2•a) and 787.5±53 g/(m^2•a) were recorded in the grazed and non-grazed plots respectively (Table 2). Root biomass was significantly higher in fenced plots during the wet season, where this biomass increased throughout the wet season (Fig. 6). More than 50% of belowground biomass was concentrated in the top 10 cm of the soil; no significant differences in sites were observed for belowground biomass during the dry season when data were pooled together. These phenomena were supported by a decrease in soil nutrients. Dead biomass at understorey sites in grazed plots was 195±39 g/(m^2•a) at the end of the growing season, which was higher than open sites 181.25±02 g/(m^2•a) (Table 2). Standing dead mass was greatly reduced in grazed plots especially in open sites due to continuous removal of tillers by grazers thus reducing accumulation of dead mass.

A higher primary production within the herbaceous layer is associated with increased accumulation of N in the plant biomass and leads to a higher proportions of organic soil N (Laclaua et a., 2002; Skarpe, 1991). This reduces immediate losses and ensures that N retained and hence improves the recycling process within the ecosystem. In this study, it was apparent that grazing led to an increase of the labile fraction in the upper soil through changes in the ability of grass to acquire limited resources through alteration of key morphological traits. These affected distribution and availability of soil nutrients across the profile especially where plants particulate nutrients. In open sites, grazing reduced plant nutrient demands through alleviating plant nutrient limitation and increasing particulate nutrients in plant tissues. However, decline in soil nutrients at the end of the growing season was linked with the high abundance of understorey species as well as the overstorey, which took up the soluble nitrogen under the canopy, hence reducing its availability in the soil. Therefore, despite fact that trees improved water and nutrient status with progression of wet season, they suppressed these effects by causing low irradiance and competition between trees and grasses for soil resources.

An increase in biomass in fenced plots correlated positively with soil moisture resulting in increases in immobilization of foliar N and standing dead biomass. This accumulation was accelerated through reduction in soil microbial turnover rates and soil N mineralization. Seasonal differences in foliar and root nutrients were conspicuous during the dry season in this ecosystem and hence may be related to the length of the dry season, occurrence of sporadic rains during the dry season, and the quality and quantity of vegetation material. Reduction in nutrient exports during the dry season by incorporation in root biomass increased soil organic C stocks in combination with immobilization due to slow microbial processing. Although we did not present root biomass by depth due to minute fractions in deep layers, the data showed that grasses had the ability to invest heavily in belowground tissues in readiness for the long dry spell by utilizing nutrients from animal dung and decomposed litter during the rainy season. However, changes in the soil organic C fraction seem to have been influenced by soil bulk density as affected by herbivore trampling, resulting in the observed nutrient distribution.

Despite the lack of well defined differences in soil moisture between depths in the presence or absence of herbovores, root biomass as well as soil nutrients decreased with increase in depth in all sites, with gazed plots recording the highest belowground biomass during the dry season. The observed higher soil nutrients during the dry season can be attributed to contribution from trees by litter fall, while wet season nutrients are attributed to grass litter in the absence of herbivores. Previously, (Isichei, 2005; Wang *et al.,* 2009) elaborated that natural and anthropogenic disturbances associated with climate fluctuations, grazing and browsing pressure contributed to determine conditions favorable to the existence of mixed tree-grass communities. In this humid savanna, presence of *Acacia* trees led to an increase in the quantity of soil nutrients below their canopies through nitrogen fixation and production of litter rich in nitrogen. It is worth noting that biological N fixation may not reflect an increase in nitrogen content over the long-term assessment in savanna soils due to depletion by non N-fixing species (Fulco *et al.,* 2001; Sankaran *et al.,* 2004). Therefore, grasses were more effective at exploiting soil resources in the upper layer as demonstrated by higher root nutrients in the fenced location. However, defoliation by grazers at understorey sites diminished the grasses' ability to compete against trees for soil resources, while trees dominated resource capture in deeper soils hence low nutrient levels were recorded in grazed plots.

It was difficult to unravel the mechanisms by which herbivores influenced foliar N because consumption and nutrient-mediated effects occurred simultaneously in this ecosystem. However, a relatively high root N concentration in grazed compared to fenced grass was attributed to enhanced nutrient uptake by defoliated grass driven by available moisture, which yielded faster litter decomposition and nutrient turnover in this humid ecosystem. Nutrient supply rate was enhanced with the presence of herbivore waste products and favorable moisture conditions. However, we did not measure excretion rates directly, but based our argument on observed intake, retention, and subsequent excretion by herbivores. It is worth noting that large variances due to methodological difficulties may conceal these variations particularly when seasonal variations are not uniformly marked.

High biomass at understorey sites during the wet season in fenced plot indicated the positive effects of trees. High soil moisture and nutrients were attributed to leaf-fall, while reduction in soil temperature to canopy closure. These effects halted of water loss due to evapotranspiration and when combined with the canopy attraction of fauna that added nutrients to the soil in their droppings, led to an enhanced environment for high biomass and soil nutrients. In both grazed and fenced plots, there were negative effects on soil moisture at understorey sites during the dry season. This occurred when low rainfall events was intercepted by the tree canopies, which subsequently evaporated from the canopy leaves before reaching the ground, although the effects of canopy interception would have been masked during larger rainfall events. Understorey samples were within the tree root zone, and this may have exaggerated the positive effects of the trees by consequently affecting the results through depletion of fixed nutrients and soil moisture. However, *Acacia* canopies promoted a variety of grass responses at small spatial scales, including the proliferation of roots into resource-rich patches, which modified the competitive ability of the grasses.

Seasonal increase in biomass especially the wet season in the presence of herbivores revealed that grasses compensated for grazing with faster nutrient uptake. This ensured faster relative growth rates and higher tissue nutrient concentrations. Similar conclusion had been observed in clipping experiments (Leriche *et al.*, 2003). Therefore, grazer-accelerated decomposition led to high nutrient turn over in the presence of moisture and this is essential for maintaining equilibrium humid savannas. Site differences observed in biomass during the dry season was attributed to grazers continuously grazing in some sites but abandoning them when the grass grew above critical heights during the wet season (Maina *et al.,* personal observation). When dead biomass was assessed at the end of growing season, higher values were recorded at understorey sites in such sites. However, in these sites, there was no removal of plant material and since we did not assess decomposition rates of dead biomass, we could not rule out a possibility of biomass carry-over from the previous season.

Based on the results, herbivores were essential in keeping grass biomass low in this specific humid savanna during the dry season but they did not have any effects during the wet season. Although the current study does not point out any overgrazing by domestic stock, humid ecosystem modelers, rangeland managers and owners need to pay careful attention on carrying capacity due to the clarity on the potential consequences of herbivory on nutrient turn over and primary production, especially during the prospected climate change, elevated nitrogen deposition and accelerating land-use changes. It is however difficult to evaluate the future behavior of this humid ecosystem due to our sample size. Therefore, more long-term studies are required with a combination of other factors such as fire, insects and N fixation by legumes on an expansive area in this unique less studied humid ecosystem.

4 Conclusions

This study highlighted the major effect that livestock grazing and tree canopy may pose on the distribution of soil and plant nutrients, and biomass production at the landscape level. Grazers were responsible for keeping grasses at low height during the dry season but they could not be effective in tracking primary production during the growing season. This is because the grasses compensated for grazing with faster nutrient uptake, faster relative growth rates, and higher tissue nutrient concentrations. The effects of trees on nutrients and biomass production were more pronounced during the wet season. A greater nutrient supply rate at understorey sites favored grass in competitive ability with others through altering soil properties below their canopies. Accumulation and decomposition of organic matter and subsequent release of mineral nutrients in the presence of herbivory and sufficient soil water moisture drove seasonal partitioning of soil nutrients. Although this research provides ample evidence on grazer-tree interaction, a holistic approach, which incorporates all driving parameters, is essential when assessing ecosystem processes. Such approach will facilitate in identifying how savanna structure varies across broad environmental gradients and help to infer the relative contributions of each parameter.

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Statistical Analysis of Climatic Variables and Prediction Outlook in Rwanda

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ABSTRACT: Under the anthropogenic impacts, the climate is changing and has brought about severe and possibly permanent alterations to our planets' geological, biological and ecological systems. Climate change is real and the technosphere is burdening the environment. This study covered 30 years (1980 to 2009) climate data (temperature, precipitation and humidity) to study the climate variability by using ORIGINPRO 8 software for statistical analysis. By presenting the status of climate variables (temperature, precipitation and humidity), this study presents the long term variation which shows decreased trends for precipitation and humidity while the temperature increases. However, the short –term variation showed the monthly variation of temperature to be higher in July to September (21℃ t o22℃). Finally, this study has showed that the precipitation trends in the coming years will gradually decline from nearby 80mm in 2010 to 70 mm in 2030 while the temperature will increase by 0.6 ^{0}C in these two coming decades. Finally, it is predicted that the atmospheric humidity will slightly decrease from 73.3% to 72%.

Key words: climate change, temperature, precipitation, humidity, Rwanda

1 Introduction

Climate is often defined as weather averaged over time or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state including a statistical description of the climate system {Intergovernmental Panel on Climate Change (IPCC), 2002}. There is a lot of evidence that our climate is changing and severe consequences would occur. It is well known that the average global surface temperature has warmed by 0.8°C in the past century and 0.6°C in the past three decades,in large part because of human activities (IPCC, 2001). A recent report produced by the U.S. National Academy of Sciences confirms that the last few decades of the 20th century were in fact the warmest in the past 400 years (National Research Council of the National Academies, 2006). The Intergovernmental Panel on Climate Change (IPCC) has projected that if greenhouse gas emissions, the leading cause of climate change, continue to rise, the mean global temperatures will increase from 1.4°C to 5.8°C by the end of the 21st century (IPCC, 2001).

Overall, Africa has warmed by 0.7°C over the 20th century and general circulation models project warming across Africa ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario) (Hulme et al 2001; IPCC, 2001). For comparison, warming through the 20th century was at the rate of about 0.05°C per decade. Precipitation patterns in East Africa are more variable. However, historical records indicate that there has been an increase in rainfall over the last century. Hulme et al (2001) suggests that under intermediate warming scenarios, parts of equatorial East Africa will likely experience 5% to 20% increased rainfall from December to February period and 5%~10% decreased rainfall from June to August by 2050. A statistical analysis has become an indispensable technique for the study of climate changes and short- term climate prediction (Li Maicun; Yao Dirong, 1995). This study is purposely carrying a statistical data analysis of climatic data (precipitation, temperature and humidity) to present its historical and status quo and tries to estimate future climate variability so as to allow decision makers to adapt accordingly

2 Materials and Methods

The study opted to work on available data 30 years {data January 1980 to December 2009 for climate data (temperature, rainfall and relative humidity). The climate data archives were accessed from the National Meteorology office at Kigali since 1980. Meteorological data were only recorded at Kigali Airport station. It is typical in impacts assessment to use a period of years of observed meteorological data to define a "current climate baseline". This set of years can be used to calibrate impact models and to quantify baseline climate impacts. A 30-year period is likely to contain wet, dry, warm, and cool periods and is therefore considered to be sufficiently long to define a region's climate. The 30-year "normal" period as defined by the World Meteorological Organization (WMO) is recommended by the Intergovernmental Panel on Climate Change (IPCC) for use as a baseline period (**Carter et al 1994**). This study analyzed different Annual variabilities and abnormalities/anomalies using ORIGIN PRO. 8.0 software.

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3 Results and discussions

Long- term variation of main climatic variables

The long-term variations of the main climatic variables such as temperature, humidity and precipitation have been studied. The main observation is that these aforementioned climatic variables change and hence it proved that climate is changing. The trends of the long term variation of the major climate variables are presented in Figure 1. Both precipitation and humidity are showing a decreasing tendency while temperature increases. The slope coefficients indicate that precipitation and humidity coefficients are negative (-0.415 and -0.067 respectively) while for the temperature, it is a positive value which equals to 0.03.

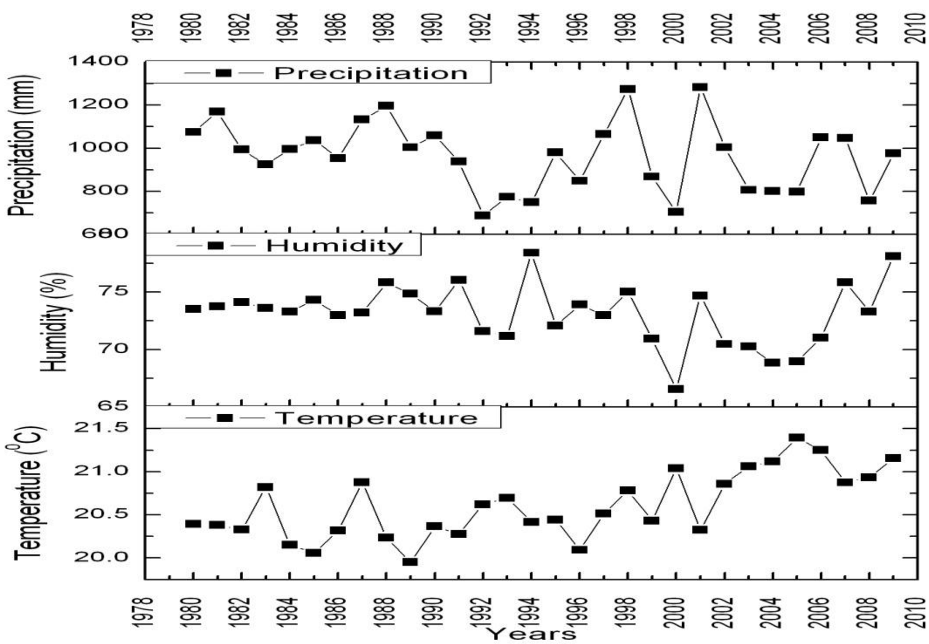

Figure 1 Annual mean variations of precipitation, temperature and humidity (1980~2009)

t is also clear that the temperature is rising notably from the year 2002. Also the year 2000 was less humid than the others. Again, precipitation has decreased as clearly remarkable in the period 1991 to 1994 and from 2003 to 2005.

Short- term variation of main climatic variables

This study has examined the trend in short term variations of the precipitation, temperature and humidity where monthly variations have been analyzed and Figure 2 gives clear trend in each climatic variable presented

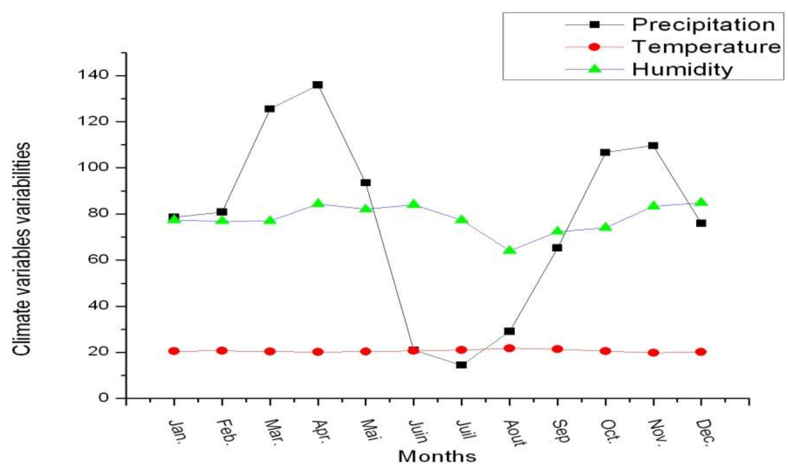

Figure 2 Mean monthly variation of climatic variables: Precipitation, temperature and humidity (period 1980~2009)

Figure 2 above shows that the temperature varies from 19.85℃ to 22℃. The hottest period is from July up to September where the mean temperature lies between 21℃ to 22℃. Humidity keeps changing from 67% to 78% and the hot the period, the less humidity becomes and of with little precipitation. The figure 2 shows that there are two rainy seasons during February to May and the other one in October to December. Also two sunny seasons are remarkable where the period of June to August is characterized with little and in most cases no precipitation.

Inter-annual variability and abnormalities of climatic variables

The abnormality (anomaly) is the state of something deviating from the normal or differing from the typical such as an aberration. Anomalies are obtained by subtracting the long-term means respectively for temperature, precipitation and humidity data from observed data. Anomaly is then the value above and below the long-term mean.

Standardized anomalies of total annual rainfalls, temperature and humidity have been analyzed. Therefore, pluviometric excesses and deficits, higher and lower temperatures and humidity have been considered for values of standardized anomalies, where the differences between observations and their averages are more than standard deviation (SD) or inferior to the negative value of standard deviation (-SD) (Figure 3).

Finally, Table 1 shows the descriptive statistics which have been considered when performing the aforementioned tasks.

Table 1 Descriptive statistics of precipitation, temperature and humidity in the study area (1980-2009)

	N	Minimum	Maximum	Mean	Std. Deviation
Precipitation(mm)	30	57.30	106.90	81.4673	13.19694
Temperature (^{0}C)	30	19.95	21.39	20.6050	0.38674
Humidity (%)	30	66.55	78.40	73.1040	2.62703
Valid N (listwise)	30				

The above table shows that the mean monthly values for precipitation, temperature and humidity all considered for 30 years from 1980 to 2009 are respectively 81.47 mm; 20.6℃ and 73.1% while the standard deviations are 13.2; 0.38 and 2.62 for the precipitation, temperature and humidity respectively.

Inter-annual variability and abnormalities of precipitation

The inter-annual variability and abnormalities of precipitation have been analyzed and presented in Figure 3 where excesses and deficits of precipitation correspond to the values above and below the standard deviation dotted lines. The analysis of rainfall variability for the period from 1980 to 2009 indicates that the period of 1992 up to 2008 was the driest since 1980. In fact, the study area was marked by pluviometric deficits during five years (1992, 1993, 2000, 2003, 2004, 2005 and 2008) out of which two were very remarkable (1992 and 2000). The pluviometric excesses were outstanding in the years 1981, 1988, 1998 and 2001.

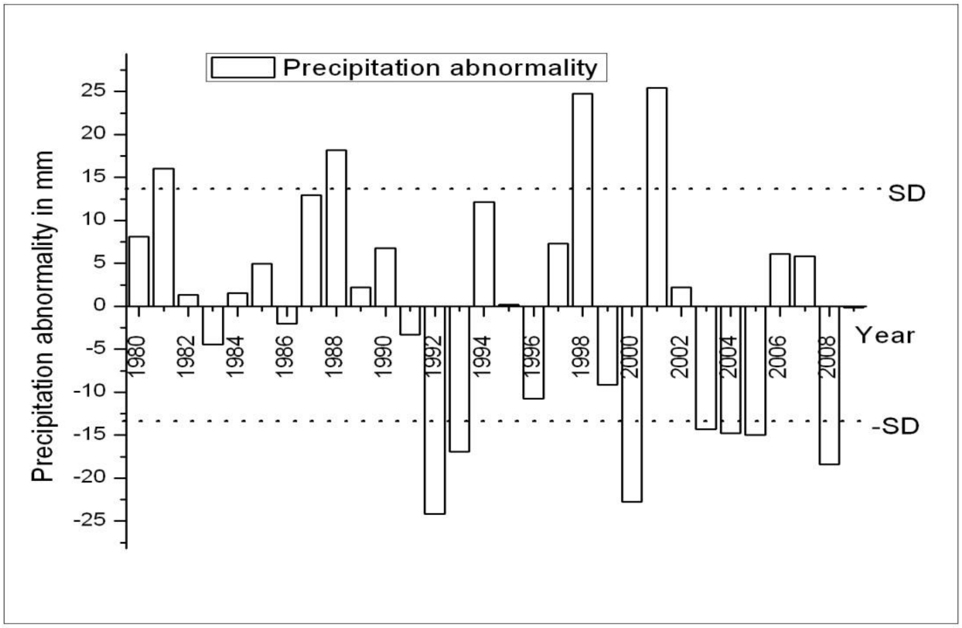

Figure 3 Trends in precipitation anomalies from 1980~2009

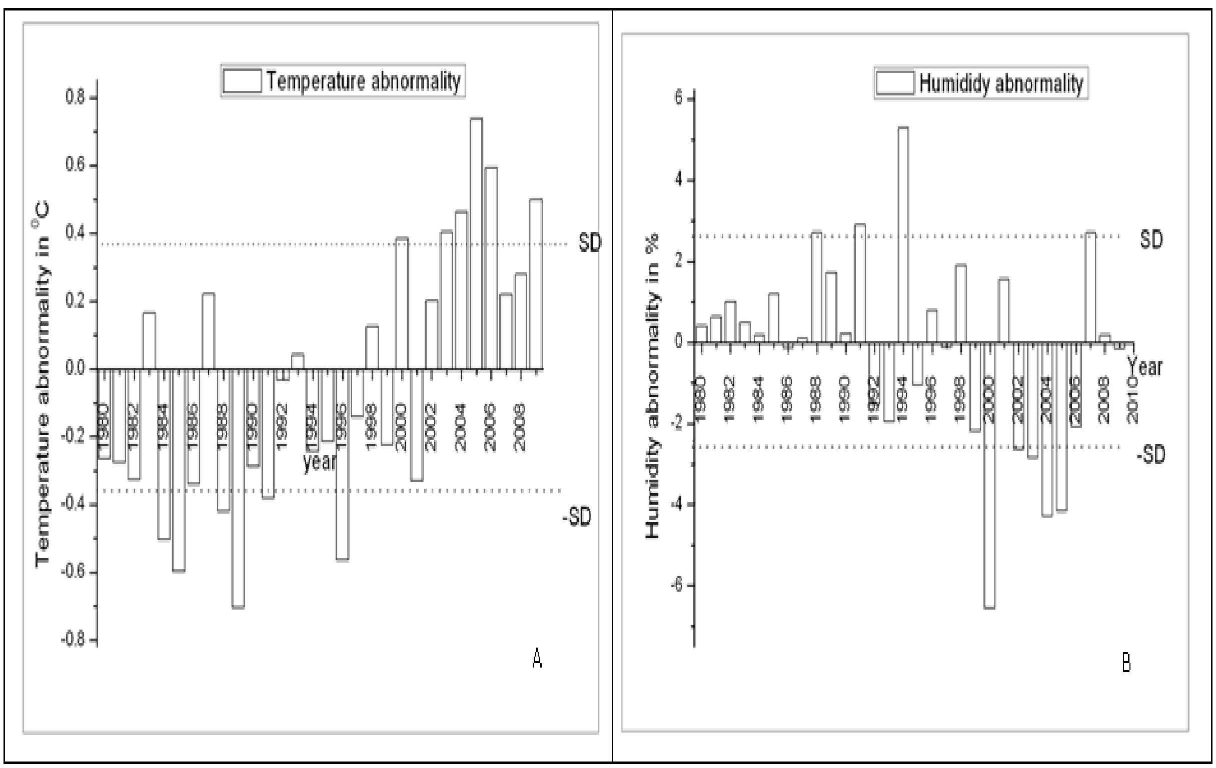

Figure 4 Trends in temperature and humidity anomalies in (A) and (B) respectively from 1980~2009

Based on Ministry of Infrastructure, Rwanda (MININFRA, 2004), the influence of El Nino/Southern Oscillation (ENSO) on seasonal rainfalls has played a big role as remarked in the following statements:

- ✓ El Nino years were characterized by a pluviometry which tends to be excessive. However, some years of El Nino registered pluviometric deficits. These years are also associated to the lateness of the start of rainy seasons and some years are characterized by significant frequency of short droughts (dry spells)".
- ✓ "During rainy seasons, the years, which immediately followed the El Nino phenomenon, registered deficitory rainfalls marked by a significant frequency of drought short periods".

Inter-annual variability and abnormalities of temperature and humidity

The variability and abnormalities of temperature and humidity in the period of 1980 to 2009 has been analyzed and presented in Figure 4.

Figure 4 (A) shows that the variability of air temperature was marked by the increase of temperature from 2000 and higher values were attained in 2000, 2003, 2004, 2005, and 2009 and the year 2005 being the hottest one. However, the lower temperatures were observed before the year 2000 where the lowest temperature was in year of 1989.

Figure 4 (B) shows that the higher the temperature the lower the values of humidity and hence lowest values of humidity were noticed from the year 2000.

Climate variables prediction from 2010-2030

Precipitation

a) As observed from Figure 5, the precipitation trends i are showing gradual declining trends from almost 80 mm in 2010 to 70 mm in 2030.

This projection was performed using the equation derived from the used software and available data, $y = -0.4156x + 910.44$ where it expected to change with time x, year

Temperature

Temperature is the physical property of matter that quantitatively expresses the common notions of hot and cold.

Figure 6 presents the temperature trends as expected to occur in two coming decades

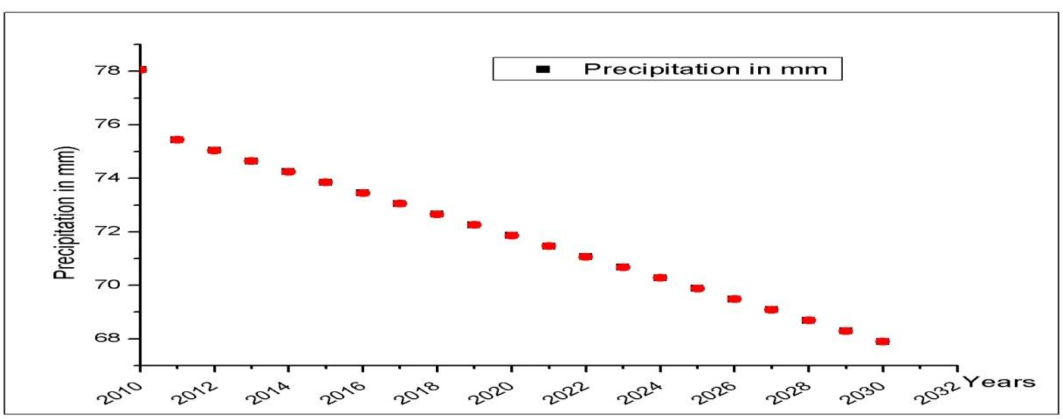

Figure 5 Mean monthly estimated precipitation projections from 2010 -2030

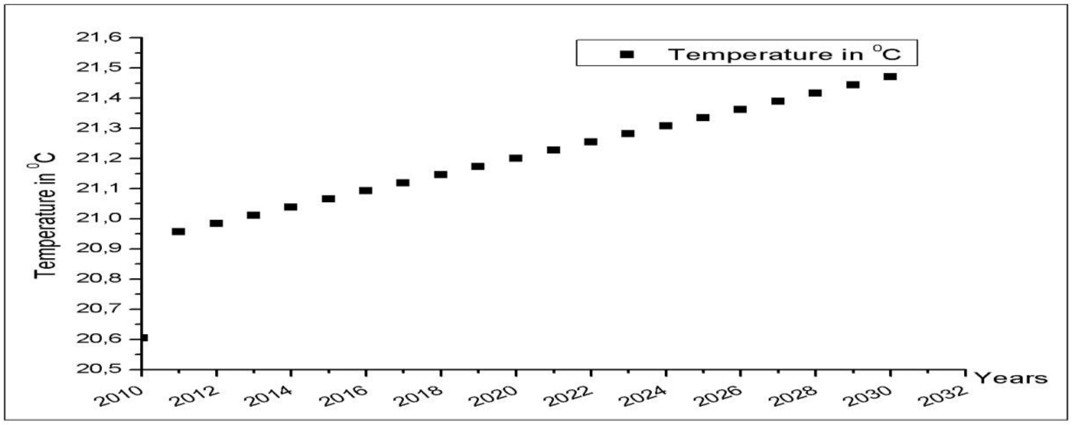

Figure 6 estimated projections in Temperatures from 2010 – 2030

Figure 6 shows how the temperature is gradually increasing. The graph shows that temperature will increase by 0.6^{0}C in these 2 coming decades. This is somehow similar to the prediction of Hulme et al (2001) and IPCC (2001), where according to them, the projected warming for Africa ranges from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario).

Atmospheric humidity

Atmospheric humidity is the amount of water vapor carried in the air.
7.

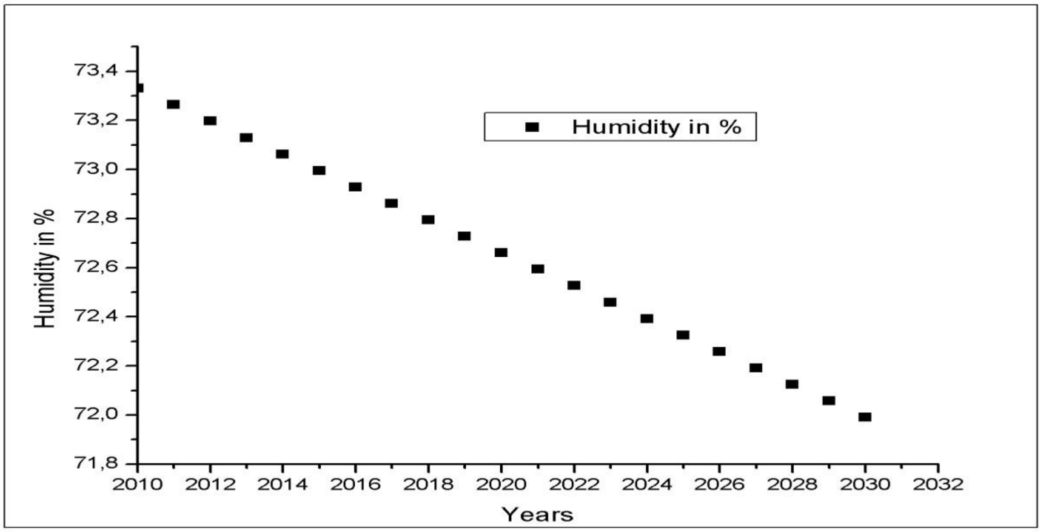

Figure 7 Estimated projections in Atmospheric humidity from 2010 - 2030

Figure 7 shows the decrease in atmospheric humidity from 73.3% to 72%. This may be associated to the increase in temperature in the coming days as discussed earlier.

4 Conclusion

Climate change is real and the technosphere is burdening the environment. A lot of evidences prove that climate is changing and severe consequences occur and its effects are being felt and human activities are a principle cause. This study presented the status of climate variables (temperature, precipitation and humidity) and their long term variation showed a decreased trends for precipitation and humidity while the temperature increases.

The short–term variation showed the monthly variation of temperature to be higher in July to September (21℃ to 22℃) while two sunny and two rainy seasons were identified.

The inter-annual variability and abnormalities have been studied to identify the deficit in precipitation as well as excess of pluviometric values and higher temperatures. It has been observed that the driest period was 1992 to 2000 since 1980 and several years were marked by a pluviometric deficit due to El-Nino. The temperature increased from the year 2000 and the higher the temperature the lower the humidity.

The study has shown that precipitation trends in the coming years are showing gradual declining trends from nearby 80 mm in 2010 to 70 mm in 2030 while the temperature will increase by 0.6 ^{0}C in these two coming decades. Finally, it is predicted that the atmospheric humidity will slightly decrease from 73.3% to 72%.

Based on the above, climate is changing and decisions makers in all domains should consider this scenario.

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he Study on the Countermeasure and Impacts of Heavy Materials in Soil

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Abstract: The research was undertaken at Salakham Marsh to assess the countermeasure and the impact of heavy materials in soil**.** Soil sample analysis was carried out by spectroscopic technique and pHmeter. Results indicated that As, Cd, Cu, Ni, Pb, and Zn were main heavy elements that contaminated the soil in salakham marsh with pH ranges between 4-6 mg kg^{-1} which makes the soil to be very acidic. Based on these results, different solutions can be demonstrated to avoid heavy metals in soil. The erosion control verification and watershed regulation may be good strategies that can be applied in order to prevent an increase of heavy elements in Salakham marsh.

Keywords: countermeasure, heavy materials, pollution, sediment

1 Introduction

Heavy metals are natural components of the earth's crust. They are dangerous because they tend to bioaccumulate. Soil degradation involves both the physical loss (erosion) and the reduction in quality of topsoil associated with nutrient decline and contamination (Mupenzi et al., 2009). It affects soil quality for agriculture and has implications for the urban environment, pollution and flooding (Mupenzi 2010). Eroded soil damages many infrastructures especially in developing countries. In recent time, any discovery of contamination has increased dramatically as environmental science investigations have become more common for the redevelopment of ex-plant/factory sites forth commune search for ISO 14000 (SEIICHI et al 2004), aiming save the economic value of soil properties. Soil contamination cons-law was promulgated on 22 May 2002 and entered into force February 15, 2003 (SEIICHI et al 2004). In their study revealed that there is no single analytical method that can detect all components of microbial EPS, and say that there is a method commonly used to quantify EPS in sediments, which is the phenol-sulfuric acid assay. The primary goal of the Soil Contamination Countermeasures Law as revealed by Seiichi et al (2004) is to protect peoples' health for determining soil conditions and by providing countermeasures to prevent danger caused by soil contamination.

Several studies have investigated this problem where they affirm that the costs of damage to agricultural soil in England and Wales have been estimated as £ 264 million a year and the costs of treating water contaminated with agricultural pollutants as £ 203 million a year. Soil is being degraded as a result of pressure coming from nearly all economic sectors which are dominated by industrialization sector (Environment Agency, 2002; Samecka-Cymenman and Kampers, 2001; Mupenzi el al., 2010). It is also said that Heavy metal pollution of soil enhances plant uptake causing accumulation in plant tissues and eventual phytotoxicity and change of plant community (Ernst 1996; Zayed et al.1998; Gimmler et al. 2002). Face to the gravity of this problem which taking high level in most parts of Vientiane, our main objective was to analyze the soil contamination level in order to propose the methodology for providing countermeasures and prevent danger to population living in Salakham Marsh (That Luang)

2 Materials and Methods

Study site

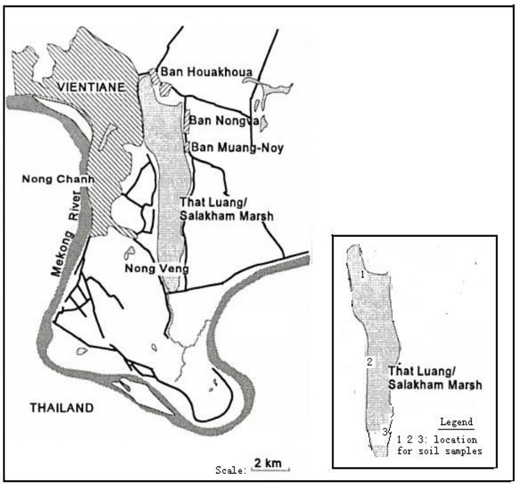

Figure 1 Mapping of the study area location

The Salakham marsh known under name of That Luang marsh is one of the largest wetlands located in peri-urban Vientiane with an area of 68 km^2. The main activity in this valley is agriculture where approximately half of its 2,000 hectares is under hoe cultivation. Also, Fish ponds are generally located along the margins of the marsh with an estimated of 15,000 people are involved with fishing-related activities on both commercial and subsistence levels (Coates, 2002). Other activities are affecting the wetland's natural functions among them are: the construction a drainage canal through the swamp by the Vientiane municipality and the construction of a pumping station to remove water for paddy irrigation. The studies have shown that water quality have also indicated that seepage of saline groundwater into the marsh may be occurring which would have a dramatic impact on the marsh ecosystem.

Soil samples and pot experiment

Study was conducted on the soil samples, which were collected from the

Cd, Cr, Zn-loaded (270 kg/ha metals: CdSO4, K2CrO4, ZnSO4) plots in May 2010, we took soil samples by dryer on three locations in LUANG MARSH.:

The sampling techniques were broadly and free random chosen, implying almost homogeneous soils. To have representative soil samples from each sampled block, three small randomly dug holes were predicted using a Dutch (Eldman) auger. Sampling was replicated in some sites to allow for statistical analysis to determine repeatability of data. Sampling was carried at three different depths with different sizes according to the regulation: top or surface soil (0-20cm); middle soil (20-40cm) and sub-soil (40-60cm) (Mupenzi et al. 2010).on other hand , on pot experiment we tested Six plants (antirrhinum, erysimum, orache, radish,Sorrel and wallflower) which were sown and grown in a greenhouse and harvested between 45^{th}-60^{th} days after emergence, whereas growth rate and element content was determined. Note that this analysis was made after being air-dried and sieved it to 2 mm, the homogenized soils were watered to <70% of saturation water holding capacity. The samples were analyzed for soil pH, available soil nutrients organic carbon (C), Calcium (Ca), cupper(Cu), hydrogen (H), (Iron (Fe),total Magnesium (Mg), manganese (Mn), Nitrogen (N), organic matter, available phosphorus (P), Potassium (K), Sodium (Na) and zinc (Zn) were also analyzed

Estimation and testing (Statistical Analysis)

Mean values and Standard Deviation of the element contents were calculated, and analysis of variance (ANOVA) and Student's t-test (Box 1953; Murkowski and Eduard, 1990) were performed as follows:

$$x = \mu + \delta + e$$

Where

X= measured value; μ =true values,

δ =systematic error bias and e = random error precision

The effects were estimated using direct formula by using the least squares approach (the outcome is the same). The first test of interest is whether there is a difference in the levels of the factor. It was compared:

$H0$: $\boldsymbol{\alpha}\ i = 0$, ~~∀i~~

Ha: at least one $\boldsymbol{\alpha} i$ is non zero

3 Results and discussion

Analysis of Elements and pH in Soil Samples

Soil sampling and analysis was then done on three selected zone areas. Major chemical elements identified in table 1 were analyzed using standard methods. Their physical, chemical and clay mineralogical properties are distinctive from those of soils, the soil in all three areas founded to be acidic

1 Analysis of major elements and their concentration in soil samples

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samples	Type of major elements and their concentration (mg/kg)													pH
	N	P	K	Ca^{2+}	H^{+}	Na	Mg^{2+}	S	C	Fe	Cu	Mn	Zn	
1	1.24	56.2	0.23	1.56	26.4	0.09	0.52	20.2	18.2	2198	367	80	61	3.7
2	1.46	38.1	0.16	1.7	25.1	0.21	0.56	18.9	18.6	2871	360	110	80	3.6
3	1.33	10.1	0.19	1.57	20.2	0.12	0.45	19.3	18.9	2634	336	81	80	3.7
average	1.34	34.8	0.19	1.61	23.9	0.14	0.51	19.5	18.6	2567.7	354.3	90.3	73.7	3.6

Table 2 Analysis of relative values of the microbial respiration rate and the Fraction of labile humus

Soil treatment	Microbial respiration rate	Fraction of labile humus
+Cr	0.6***	1.41*
Cd	1.04**	1.21*
Zn	1.02**	1.39*

Table 3 Assessment of Cr , Cd and Zn concentrations (mg/kg^{-1} dry weight) in plant shoots

Plant species	Cr,Cd and Zn inmg/kg-1 (DW)					
	Control	Cr	Control	Cd	Control	+Zn
antirrhinum		0.58	0.22	0.62*	46	52
erysimum	0.73	0.82	0.22	3.11**	33	36
orache	0.47	0.72	0.48	1.26***	137	168*
radish	1.04	1.12	0.41	3.56***	85	129*
sorrel	0.71	1.16	0.38	2.71***		
wallflower	0.36	1.27*	0.23	1.43***	60	67

In this study (table 1), the following elements were obtained after analysis of samples taken from three samples such as: Fe, Cu, Mn, and Zn that presented a high concentration level. Other elements which were found after analysis are : H^+ and C with minimum concentration and the elements Ca and Na which presented a low concentration level.

The analysis of chemical characteristics of the soil which put in evidence the soil pH in these three locations revealed that the soils in most of the Luang Marsh areas are acid soil. This was supported by a studies from Mupenzi et al. (2010) and Mupenzi (2010) who showed that soil pH of 5.0 to 5.8 represents acidic conditions and is considered as optimal for some plant leaves such as tea. They attributed the acidic to many factors: First, the rock in which the soil came from; this hypothesis confirms the acidic of soil in most of Luang Marsh that belongs to the sedimentary rock. Secondly, the use of fertilizers with NO_3 in this marsh through agricultural activities that seemed higher and an increase of $Al^{3+}$and H^+ ions in soil which implied effects on the soil salinity. High salt levels in soils reduce the ability of plants to grow or even to survive and this was observed in last year's where the production was not satisfactory. The result has been a rise in groundwater levels, causing greater discharges to the surface. Wetland salinity occurs where irrigation practices have caused a rise in water table, bringing saline groundwater within reach of plant roots

As indicated in Table 2 and 3 the plant species grown in contaminated soil in some cases were higher than those of control plants; after the second flight analysis different methods of detection, it was noted the existence of a gap between the proportions of the "available" forms of metal and other heavy elements: the lowest values were found for the case of Cr, while values were the highest in Cd. It revealed only the heavy metal pollution had no significant effect in raising seedlings and plants. Actual concentrations and the influence of metals is a consequence of mobility, bioavailability and toxicity of both direct due on the Utilization of chemical fertilizers which increased in this valley. The results give more precision comparatively to other studies that have used measurement of colloidal carbohydrate fractions as a useful indicator of microbial EPS (extracellular polymeric substances) (Decho 1990) or / and a direct measure of the EPS itself (Yallop et al. 1994), and most of the techniques used to characterize the components of the EPS from laboratory cultures are not easily applicable to samples that come from natural sediments especially in marshland. When the acid is estimated phenol sulfuric assay most often used as a general method. As shown in table 2, the rate of basal respiration was inhibited by Cr and was analyzed by Cd and Zn ; it is shown that the effect of heavy metal pollution analysis influence the metabolism of soil microbes in all cases, and measurement show that plant may be responses to this system as analyzed have been slight. This confirms the Microbial basal respiration rate that was stimulated by treatment of Cd and inhibited by Zn and Cr

Conclusion

The results of soil sample analysis show that the pH of all samples collected from three locations is less than 6 which implies that the soil in Salakham Marsh is acidic. The concentrations of Cd, Cu, Ni, Pb, and Zn were main heavy elements contaminating soil in Salakham Marsh and their effects influenced the metabolism of soil microbes and the reactions of plants were less. The results confirm the Microbial basal respiration rate that was stimulated by treatment of Cd and inhibited by Zn and Cr.

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For preservation of soil and underground water for sustainable environment; the research on soil remediation associated to countermeasures may be the best solution.

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Marketing-Mix and Customer Satisfaction in MTN Rwanda-cell: Kicukiro District, Rwanda

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Abstract: This study aimed at finding out the contribution of marketing-mix on customer satisfaction. An analysis of data collected by means of self-administered questionnaires to 164 respondents revealed that there was an inverse relationship between marketing-mix and customer satisfaction (r = -0.082). Though most of the MTN marketing plan has progressively increased the satisfaction of its subscribers, many other measures were to be taken. This study suggests that reducing price per second would be one of the keys to attract and maintain customers. The marketing initiative to put in the market cheaper and affordable handsets not only Nokia, would ensure easy access to MTN products/services. Increasing the willingness to understand customers would continue to positively impact on customer satisfaction of MTN Rwanda-cell. In order to remain the market leader in the telecommunication industry in Rwanda, MTN Rwanda-cell has to thoroughly revise its marketing policy minding that the market is overflowing competitors of higher caliber like TIGO.

Keywords: Marketing, Marketing-mix, Customer, Customer Satisfaction

1 Introduction

Today customers are very demanding than ever, and it is vital for managers to understand how apply effectively the marketing strategies for assuring a long financial sustainability in the fast moving competitive market. It becomes the first responsibility of the marketing manager to critically know how combine the diversified components of the marketing, that most of the time results in the application of the marketing-mix. In any company, there is no way that they can deal with the customer satisfaction, without understand the element of marketing-mix and to which extend they do affect the customer satisfaction. The way Marketing-mix is understood and applied contributes in increasing company's performance through the satisfied customer. Profit can be enhanced due to the provisional of customer driven services through the observation of the marketing-mix packages. According to Kotler (2006), Finance, Operations, Accounting and other business functions will not really matter if there is not sufficient demand for products and services so the company can make a profit. Marketing is a process for understanding markets, for quantifying the present and future value required by the different groups of customers within these markets, for communicating this to all other functions with responsibility for delivering this value and for measuring the value actually delivered (Malcolm MC Donald, 1999). According to Kotler and Armstrong (2001), marketing is the process by which individual and groups obtain what they need and want through creating, offering and freely exchanging product and services of value of others. Marketing is getting the right goods and services to the right people, at the right place, at the right time, with the right price and promotion. According to Roger and Karin (1989) marketing system plays a unique role in transforming the benefits of mass production in terms of physical distribution. The most common problem in the economic life today is distribution. Marketing in another hand is concerned with something that can attract the customer to enjoy product or service conformed to his or her need. To achieve such objectives therefore, marketing manager has to combine according to a delicate measured quantity the four sorts of elements that are composing the marketing-mix.

The marketing-mix refers to a total system of interaction on business activities designed to Product/services, Price, Place and Promotion which many companies in Rwanda not consider pretending that it creates diminution of the profitability. According to Kotler and Dubois (1992) customer satisfaction can be defined as person's feelings or disappointment resulting from comparing a service or product's perceived outcome in relation to his or her expectation. For Bo Bergman Bengt Klfsjo (2000) most companies range around the global understanding that customer satisfaction is essential in their success. Despite the concern of customer satisfaction by any business, few companies know how to link the customer's needs with the organization strategies in order to get a lasting customer satisfaction and those which ignore it will result in higher client turnover.

This paper on the marketing-mix and customer satisfaction emphasized on a Rwandan Telecommunication company that is MTN that came after few decades the Rwandan telecommunication market counting only one Telecommunication Company that was Rwandatel. Telecommunication service in Rwanda started in 1993. This is when Rwandatel, a national telecommunication company started its operations in Rwanda fully owned by the Government of Rwanda, by the time, it was the only telecommunication company providing fixed lines. In 1998, MTN Rwanda-cell a mobile telecommunication company was licensed and later in 2003, the company was given a license to provide fixed line in addition to mobile telecommunication services. The main problem was the constant migration of the customers to and from MTN Rwanda-cell to TIGO or to another competing company. This could be the consequence of customers' dissatisfaction in respect to the MTN services. Therefore a strong management of marketing-mix should be well indicated to overcome such issue faced by MTN Rwanda-cell in Kicukiro District, Rwanda. A lack of focus on marketing initiatives by any enterprise would result in poor performance and negatively affect revenue considerably. It was important therefore to analyze the contribution of marketing- mix to the customer satisfaction in order to provide useful recommendations to Telecommunication Company especially how MTN Rwanda-cell will strategically grow its markets and continue to outcompete in the industry.

2 Method

Descriptive and correlational research designs were used in this study. Descriptive method was used to describe the present characteristics of MTN Rwanda-cell clients as the study population while correlational design was used to determine if the variables of marketing-mix were associated with each other, and to determine the contribution of marketing-mix to the MTN customer satisfaction, in Kicukiro District, Rwanda.

Population and sampling techniques
Population (N)

Kenneth (1978) termed population (N) as a universe and defined it as a sum total of all units of analysis. Sommer et al (1992) defined a population as the total number items in a specified field of inquire and he add that population is asset of cases about which one wishes to draw some conclusions. As far as this study was concerned, it was difficult to know MTN customers in Kicukiro District because they buy airtimes in different areas. Thus this work considered an unknown population size.

Sample size (n)

This study used purposive and systematic sampling techniques to get a sample size (n=164) through which information concerning the MTN customer perception in respect to the offered services in Kicukiro District, Rwanda was gathered. The determination of the sample size for unknown population size was done following the formula

$$ni = \left(VC * \frac{T}{RC}\right)2$$

Where: ni = sample size for unknown population

T=Confidential interval (usually 1.282 or 1.645 for 2 sided test)

CV=Coefficient of variation (usually between 0.5 and 1)

RP=Relative precision (0.1 or 0.2)

Demonstration; ni= $\left(\frac{1.282*1}{0.1}\right)^2 = (12.82)^2 = 164.3 = 164$

Research Instruments

A questionnaire was used in this study. According to Mannheim and Richard (1995), a questionnaire is defined as a survey instrument intended to use mailed self administered surveys, He further content that a questionnaire is a set of related questions designed to collect information from respondents It is an information gathering technique that gathers information attitudes, beliefs, behaviors and characteristics from selected respondents', organizations who may be affected by a given phenomenon. The questionnaires were distributed in sampled different respondents of MTN customers in especially Kicukiro District to provide the necessary questioned information related to marketing-mix and customer satisfaction. The questionnaire of this research was constructed around the respondents' profile, the perception of customers on marketing practices in MTN Rwanda-cell, and the perception of customers on satisfaction of MTN services.

Validity of Instruments

To ensure that the instrument measured what it was supposed to measure in this research, the instrument was checked to assure validity. For further improvements, the questionnaires were presented to the experts as well as to the research advisors. The opinion of the expertise from the INILAK was solicited. Two senior lecturers in the department of management, one lecturer in the department of languages, and one lecturer (Statistician) in the department of mathematics validated the questionnaires. Because of their expertise and experiences, they were in a position to, without bias, advice on the contents and moderate the correctness and relevance of the instruments for this study. Before any adjustment to the questionnaires, any observation was discussed with the advisors and team members.

Reliability of the Instruments

A pilot study was conducted in Gasabo District. The researchers target in conducting pilot study was ascertaining the reliability of the instruments before distributing them to the respondents. This aimed at ensuring that the instrument would give the same results when given the second time to the relatively different sample.

Reliability Statistics

Cronbach's Alpha	N of Items
.736	35

The reliability was tested using Cronbach's Alpha coefficient and it was required that the higher the score the more reliable the generated scale would be. The research was expecting to get a reliability coefficient greater or equal to 0.75. The questionnaire was administered to 16 respondents in a pilot study to test the reliability of the scale and the result for Cronbach's Alpha was 0.736

Data Gathering and Collection Procedure

For the purpose of this research, and as principal means of data collection, the study employed the questionnaires. Based on the outcomes of the pilot study, and after performing the required adjustments to the questionnaires, the instrument was used for data collection. Before administering the research instrument to the respondents, ethical issues were taken into consideration. Researchers were given letter, by the Dean, of faculty of economic sciences and management to the Managements of MTN Rwanda, requesting permission to carry out research. They followed right protocols before approaching the respondents like looking for formal authorizations from relevant MTN before collecting any information, or conducting the research. In order to reach respondents, the researcher had two possibilities. For the first possibility, researchers distributed questionnaires to the respondents at their households or their operating areas. For the second possibility, the researcher self-administered questionnaires and respondents filled them being at the Kicukiro District.

Statistical Treatment of Data

Data was gathered, coded, and recorded into Statistical Package for Social Sciences (SPSS) program. Encoded data were then checked to ensure there were no encoding errors-missing data and outliers.

Method of Data analysis

The Statistical Package for Social Sciences (SPSS 18) was employed to organize and tabulate the data collected. The following statistical procedures were used to analyze and interpret the data:

a) Cronbach's Alpha coefficient was used to test the reliability of the questionnaires;
b) Descriptive statistics were used to describe the background of the respondents. In this research the following statistical tools from SPSS served to analyze data:

1. Frequencies
2. Percentages
3. Pearson's Product moment coefficient (r): It is the average product of the standardized scores of two variables. It is a very common measure of relationship between two variables. In this research the stated correlation, as respective responses to the research questions, was tested for the purpose of acceptance or rejection. A rejection of the correlation implied there was a significant relationship which meant the acceptance of the alternative answer. The test was at the 0.05 significance level.

3 Results and Discussions

Questionnaires targeted 164 respondents whose only 159 (196.96%) responded to the self administered questionnaires. The researchers gathered data from respondents; the findings were analyzed by means of SPSS and interpreted in four parties. Those parties included the respondent profile, the Marketing-mix, the level of customer satisfaction and their perceptions on the same satisfaction.

Table 1 Distribution of the respondents by Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	10-20Years	21	13.2	13.2	13.2
	21-30Years	54	34.0	34.0	47.2
	31-40Years	51	32.1	32.1	79.2
	41-50Years	25	15.7	15.7	95.0
	51years and above	8	5.0	5.0	100.0
	Total	159	100.0	100.0	

II.

III. Table 2 Distribution of the respondents by Gender

Responses	Frequency	Percent	Valid Percent	Cumulative Percent
Male	80	50.3	50.3	50.3
Female	79	49.7	49.7	100.0
Total	159	100.0	100.0	

In respect to the respondents profile, table 1 shows that twenty one (21) people (13.2% of the respondent) were aged in the range of 10-20 years, fifty four (54) i.e 34.0% in the range between 21-30 years, fifty one (51) people i.e 32.1% of the respondents were between 31-40 years, twenty five (25) people i.e 15.7% of the respondent were in the range of 41-50 years , while eight (8) people i.e 5.0% of the respondent in the range of 51 years and above. The greater range was between 21-40 years. The raison was said to be firstly the youngness. Young people participate in different activities which require them to use Product and Service such offered by MTN, secondly the fact that people of that range are known to be active. From table 2, the distribution analysis of the respondents by gender shows that 50.3% of the respondents were male and 49.7% were female. That gave an idea that number of males and number of females were almost the same for consuming product and services accessible from MTN Rwanda-cell. From table 3, the survey conducted in MTN Rwanda-cell's Customers indicated that 36.5% of the respondents were married. Researchers were interested in knowing why married people had higher level than others. The answer was that married people were fully grown up and participate in different activities; therefore they need to use telecommunication from many companies as MTN.

Table 3 Distribution of the respondents by Marital Status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Single	42	26.4	26.4	26.4
	Married	58	36.5	36.5	62.9
	Divorced	42	26.4	26.4	89.3
	Widow	17	10.7	10.7	100.0
	Total	159	100.0	100.0	

IV.

V. Table 4 Distribution of the respondents by Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Primary Level	20	12.6	12.6	12.6
	Secondary	87	54.7	54.7	67.3
	University	52	32.7	32.7	100.0
	Total	159	100.0	100.0	

VI. Table 5 Distribution of the respondents by Occupation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Student	38	23.9	23.9	23.9
	Teacher	46	28.9	28.9	52.8
	Lecturer	27	17.0	17.0	69.8
	Business	25	15.7	15.7	85.5
	Agriculture	23	14.5	14.5	100.0
	Total	159	100.0	100.0	

Table 4 indicates that the overall distribution analysis of the respondents by education level representing 87.4% was of secondary and university levels. This demonstrates that almost the majority of MTN customers were educated at higher level which always has implication more than does primary level which represented 12.6%. Table 5 indicates that out of 159 respondents, businessman/businesswomen class represented 34.6%. The researchers found out that the clients who did businesses they needed MTN products which helped them to do their business. The students using MTN Network according to selected sample size represented 18.2% and those who are doing agriculture had lower percentage representing 13.8%.

Concerning the analysis of Marketing-mix in MTN Rwanda-cell, the focus was oriented on variables such as Price, Place, Product and Promotion. In respect to the question of knowing the number of household members, table 6 indicates that seventy seven (77) people i.e 48.4% of the respondents possessed from 1-4 people, seventy five (75) people i.e 47.2% declared having from 5-9 people, seven (7) people i.e 4.4% of the respondents affirmed having 10 people and above. Researcher asked this question in order to know the MTN subscribers in each respondent's house. The greater number of households possessing big number of members was into the two first ranges. This is due to the fact that holding a mobile phone was said to be costly.

VII.

VIII.

IX. Table 6 Members in household

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-4 people	77	48.4	48.4	48.4
	5-9 people	75	47.2	47.2	95.6
	10 people and above	7	4.4	4.4	100.0
	Total	159	100.0	100.0	

X. Table 7 Subscribers of MTN in House

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	One person	24	15.1	15.1	15.1
	Two people	60	37.7	37.7	52.8
	Three people	43	27.0	27.0	79.9
	Four people	29	18.2	18.2	98.1
	Five and above	3	1.9	1.9	100.0
	Total	159	100.0	100.0	

XI. Table 8 Kind of MTN Products

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Samsung	27	17.0	17.0	17.0
	Nokia	61	38.4	38.4	55.3
	Motorola	47	29.6	29.6	84.9
	Blackberry	20	12.6	12.6	97.5
	Others	4	2.5	2.5	100.0
	Total	159	100.0	100.0	

XII.

XIII. Table 9 Access on implementation of new product

		Frequency	Percent	Valid Percent	Cumulative Percent
valid	Yes	52	32.7	32.7	32.7
	No	107	67.3	67.3	100.0
	Total	159	100.0	100.0	

Table 7, illustrates that in family between two people and three people presenting 64.7% were MTN subscriber only. Researchers asked this question in order to know the situation of MTN clients in each respondent family. In a family of four members, the MTN subscribers represented 18.2%. From the same information it was shown that when the number of family members was greater than five people, the probability of being MTN subscriber was little. Table 8 indicates that for the different products offered by MTN, Nokia and Motorola were the products which were used in higher quantities. These products represented 68% of the total products. The researchers were interested in knowing the reason these products were consumed more than others and the given raison was the value or cost of these products. In addition to that reason, the researchers have been told that these products were lovely. Respondents told the researchers that they have longer life than others and that when they were damaged they were easy to be repaired. In regard to the implementation of new product, table 9 shows that fifty two (52) people i.e 32.7% of the respondents declared participating while one hundred and seven (107) people i.e 67.3% of the respondents opted for not participating in implementing the new products. This showed that there was no access to clients in implementation of a new product. This means that MTN use push method to put their products on market because clients have not any suggestion on the new product.

XIV.

XV.

XVI. Table 10 Price of MTN Product

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Expensive	21	13.2	13.2	13.2
	Expensive	63	39.6	39.6	52.8
	Cheap	43	27.0	27.0	79.9
	Very cheap	32	20.1	20.1	100.0
	Total	159	100.0	100.0	

XVII. Table 11 Opinion to MTN current Price

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Expensive	31	19.5	19.5	19.5
	Expensive	65	40.9	40.9	60.4
	Cheap	31	19.5	19.5	79.9
	Very cheap	32	20.1	20.1	100.0
	Total	159	100.0	100.0	

XVIII.

XIX. Table 12 MTN Pricing compared by other operator

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very high	46	28.9	28.9	28.9
	High	55	34.6	34.6	63.5
	Moderate	37	23.3	23.3	86.8
	Low	13	8.2	8.2	95.0
	Very low	8	5.0	5.0	100.0
	Total	159	100.0	100.0	

XX.

XXI. Table 13 MTN Distribution Channel

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Excellent	26	16.4	16.4	16.4
	Good	45	28.3	28.3	44.7

	Moderate	40	25.2	25.2	69.8
	Fair	24	15.1	15.1	84.9
	Poor	24	15.1	15.1	100.0
	Total	159	100.0	100.0	

XXII.

XXIII. Table 14 Promotion or Diminution from MTN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	62	39.0	39.0	39.0
	No	97	61.0	61.0	100.0
	Total	159	100.0	100.0	

XXIV. Table 15 Accessing Airtime from MTN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Difficult	44	27.7	27.7	27.7
	Easy	115	72.3	72.3	100.0
	Total	159	100.0	100.0	

XXV. Table 16 Product offered by MTN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Reliable	15	9.4	9.4	9.4
	Usable	50	31.4	31.4	40.9
	Adaptable	60	37.7	37.7	78.6
	Appropriate	27	17.0	17.0	95.6
	Aesthetic	7	4.4	4.4	100.0
	Total	159	100.0	100.0	

Concerning the price, Table 10 shows that sixty three (63) people i.e 39.6% of respondents declared the price of MTN as expensive, twenty one (21) people i.e 13.2% as very expensive, forty three (43) i.e 27.0% as cheap, while thirty three (33) people i.e 20.1% found it very expensive. It is seen that a greater number declared the price being expensive. This created a constant migration from one to another telecommunication company, because a half of MTN clients complained on price. Concerning the opinion about price, Table 11 shows that sixty three (65) people i.e 40.9% of respondents declared the price of MTN as expensive, thirty one (31) people i.e 19.5% as very expensive, thirty one (31) people i.e 19.5% as cheap, while thirty two (32) people i.e 20.1% found it very expensive. According to the researchers, majority of the respondents regard price as very expensive. However, fewer of the respondents found MTN Price as not much expensive comparatively to the price of some of the competitors.

Table 12 specifies that forty six (46) people i.e 28.9% of the respondents found the price as very high, fifty five (55) people i.e 34.6% found it high, thirty seven (37) i.e 23.3% as moderate, thirteen (13) i.e 8.2% as low while eight (8) people i.e 5.0% rated it as very low. The rate of high was chosen by the greater number of the respondents 63.5%.

From table 13, one hundred and one (111) people i.e 68.9% of the total respondents found MTN Distribution channel being good. They declared getting product knowledge easily. They said that MTN Distribution channel, MTN products and Services were knowledgeable to all. This was a result of training and strong marketing campaigns that has enabled MTN Rwanda-cell to meet its customer's targets.

As indicated by Table 14, even if sixty two (62) people affirmed getting the promotion from MTN, the research shows that the big number was those who were not getting access to diminution from them. The respondents not getting promotion from MTN represent 61.0%. From researchers' point of view this could generate conflict between customers where some clients took that issue as a bias. Table 15 indicates that forty four (44) people i.e 27.7% found the access as difficult while one hundred and fifteen (115) people i.e 72.3% found accessing airtime as easy. The given reason for those that found it difficult was that some of them live in village where to obtain airtime might require them to go far from their home. That is a problem said to be caused by the development of the country. In respect to the quality of product, table 16 shows fifteen (15) people i.e 9.4% found MTN product reliable, fifty (50) i.e 31.4% found them usable, sixty (60) people i.e 37.7% found them adaptable, twenty seven (27)) found them aesthetic.

Regarding customer satisfaction, the researchers focused on the willingness to listen customers, the customer care, the responses to requests, and the friendship between customers and MTN Rwanda-cell.

XXVI.

XXVII. Table 17 Willingness to listen customers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Excellent	13	8.2	8.2	8.2
	Good	43	27.0	27.0	35.2
	Moderate	69	43.4	43.4	78.6
	Fair	28	17.6	17.6	96.2
	Poor	6	3.8	3.8	100.0
	Total	159	100.0	100.0	

XXVIII.

XXIX. Table 18 Customer care

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very good	20	12.6	12.6	12.6
	Good	53	33.3	33.3	45.9
	Fair	60	37.7	37.7	83.6
	Poor	26	16.4	16.4	100.0
	Total	159	100.0	100.0	

XXX. Table 19 The way of MTN to respond request first class

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	76	47.8	47.8	47.8
	No	83	52.2	52.2	100.0
	Total	159	100.0	100.0	

XXXI.
XXXII. Table 20 Friendship between customers and MTN Employees

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	66	41.5	41.5	41.5
	No	93	58.5	58.5	100.0
	Total	159	100.0	100.0	

From Table 17 the willingness to listen customers was rated moderate with a percentage of 43.4% of the respondents, 27.0 % of the respondents rated it as good, 8.2% rated it as excellent while the remaining 21.4% rated it as fair and poor. The aim of this question was to recognize at which level MTN accept to understand their customers. The greater number was for moderate which translates some gap in responding to the customer wants.

In regard to the customer care, table 18 shows that customer care of MTN was not good. When researchers combined fair and poor it shows that care to the customer was low representing 54.1% of the respondents. From this point of view there were loopholes in the customer care of MTN Rwanda-cell, which needed to be addressed in order to provide good services to their customers.

Table 19 points out that the way of MTN to respond request of customers was not first class. Researchers wanted knowing at which activities they did not respond to the requests, and they were told that sometimes for example when a telephone was stolen it took long time to do an investigation. Some clients told that MTN did not make an effort in responding to their requests in order to incite buying new one.

As it is summarized Table 20 indicates that there was no any relationship between customers and MTN employees. Some of the customers said that there was no activity organized by MTN to customer which could create friendship between them. There was one who told the researchers that the relationship between them leaned only to the service received from MTN. In respect to the relationship between marketing-mix and MTN customer satisfaction as indicated on Table 21, the researchers calculated the coefficient of Pearson correlation. The correlation helped to measure if there was relationship between the two variables. Normally the correlation meaning when its significance is greater or equal to 0.05 or 5%. The following table summarized the calculations of correlation that ranged between [-1 to 1].

With the below table 21 it is shown that the relationship between marketing-mix and customer satisfaction was negative. Pearson correlation of -0.082 translates an inverse relationship between marketing-mix and customer satisfaction. Some of the components of marketing-mix like price, once they were increased, customer satisfaction decreased. This was also explained by the level of significance that was between 0.25 and 0.50. It was in the range of positive with moderate significance. MTN has to follow up its marketing-mix with intense attention. ensure easy access to MTN products/services. Increasing the willingness to understand customers would continue to positively impact on customer satisfaction of MTN Rwanda-cell. In short though MTN Rwanda-cell remains the market leader in the telecommunication industry in Rwanda

Table 21 Correlation between Marketing Mix and MTN Customer Satisfaction

		Activities of Marketing Mix	Customer Satisfaction
Activities of Marketing Mix	Pearson Correlation	1	-.082
	Sig. (2-tailed)		.305
	N	159	159
Customer Satisfaction	Pearson Correlation	-.082	1
	Sig. (2-tailed)	.305	
	N	159	159

*Significance level at 0.05

Legend:
[-1.00-0.00[: significance level is negative
[0.00-0.05[: positive but insignificant
[0.05-0.25[: positive but low significance
[0.25-0.50[: positive with moderate significance
[0.50-0.75[: positive with high significance
[0.75-1.00]: positive with very high significance

4. Conclusions

This study aimed at finding out the contribution of marketing-mix on customer satisfaction. Out of 164 respondents from MTN Rwanda-cell in Kicukro district, only 159 replied the self administered questionnaires. Based on the findings the researchers concluded that there was an inverse relationship between marketing-mix and customer satisfaction in MTN Rwanda-cell as a telecommunication company in Rwanda. Though most of the MTN marketing plan such as reduction of price, customization of MTN product/services, improved ways of responding to the customers' request, has progressively increased the satisfaction of its subscribers, many other measures are to be taken. Reducing price per second would be one of the keys to attract and maintain customers. The marketing initiative to put in the market cheaper and affordable handsets not only Nokia, would, it has to thoroughly revise its marketing policy minding that the market is overflowing competitors of higher caliber like TIGO.

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Radical Terraces in Rwanda

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Abstract: This study was undertaken in Rwanda to assess the system of radical terraces. The erosion was the main cause for soil degradation. The results showed that several strategies and techniques were taken in order to protect the environment against effects of different natural disasters. Among them for example are the digs and hedge anti-erosion and radical terraces. It was revealed that the Radical terraces have a positive impact to increase farm productivity. The lack of materials, lack of financial supports, hard soil and straight slope were among main problems identified in region that were barriers for significant positive achievements. It was used method of whole for measuring of erosion though water flow from mountainsides. The results indicated that its speed was reduced from 1 hour in April 2007 to 7 hours 12 minutes in April 2008. The radical terrace technique is a good solution for environment protection.

Keywords: Environment, Erosion, Radical Terraces

1 Introduction

Soil erosion is a complex phenomenon involving the detachment and transport of soil particles, storage and runoff of rainwater, and infiltration (Lindstrom, 986). It has been shown that the surface effect is considered from the viewpoint of local topographic gradient on soil loss (Wischmeier and Smith, 1978). The study in Ontario indicated that there are several forms of erosion that cause the loss of large quantities of top soil and subsoil each year (Omafra and Wall, 1987). In Rwanda, rivers became brown-red during the rain seasons because of eroded soils by rainfall from mountainsides; and many nutrients are also washed away implying the decrease of soil fertility. Since most of Rwandese population lives in the rural area and 83.4% depends on agricultural production (Kaberuka, 2002), agriculture is still done artificially where the farmers use rudimentary instruments. The topography of country dominated by high mountains (Joe and Mary, 2003) is a ***big problem for environmental protection.*** The relief of Rwanda is one of the causes of soil erosion, which is a big barrier to the improvement of farm produce.

The study in 2008 showed that over 1 tone of soil per hectare was swept away by erosion of rivers and lakes every month. Erosion has been responsible of soil degradation with the soil nutrients losses estimated at 945200 T of organic materials, 41210 T of nitrogen, 200T of phosphorus and 3055 T of potash annually. An estimation of 39.1% of land in the country has been affected by erosion (PMI Country Profile, 2009). It was indicated that between 1930 and 1950, the land of Rwanda was sufficient for cultivation because the population was estimated to about 1 million, and the soil erosion was not a serious problem due to the vegetation cover. The population grew to 10.5 million (PMI Country Profile, 2009) and the needs of soil cultivation increased hence led to complete destruction of vegetation cover. From 1980, erosion has been affecting agricultural activities (MINIPLAN, 1991; Encyclopedia of the Nations, 2008; MINITERE, 2003). In order to mediate these problems, different strategies have been taken with the aim of increasing farm productivity. For instance, the population has been mobilized and enlightened about the system of radical terraces in the whole country especially for those who live on highlands. The radical terraces were introduced in Rwanda in 1972 at Kisaro on ex Buyoga District in ex Byumba Province by a religious person named Syrille Wieme in 1979. This method was recognized by the Government of Rwanda and was officially encouraged; it was counted around 900ha of radical terraces in 1990 and was noted that the achievement of radical terraces required many processes. Since Rwanda is a hilly and rainy country, measures have been taken to control erosion with an estimation of 23% of land having no risk of erosion, but 39% are highly risky of erosion. It was showed that the erosion is the cause of the loss of 1.4 millions tones of fertile soils through water flow along the rivers. The study in CAMERO JIEJO (North western Iberian system, Spain) showed that, since 1950_s the Spanish Mediterranean Mountains have become a marginal territory and erosions were a big problem, the farmers constructed the terraces consisting of the small plot with stone walls and used them for intensive cultivation. The walls retained the soil and the damage caused by collapsing walls due to heavy rainfalls was quickly repaired by farmers in order to prevent further intense erosion (FAO, 1984; Theodore-Lasanta et al., 2001). Radical Terraces was among the strategies taken to protect land in order to increase farm productivity through mobilization of the population living in highlands.

2 Materials and Methodology

During this study taken at Kaniga Sector in Gicumbi district, a survey method was applied on five units called cells. 9 farmers per unit with a total of 45 people were interviewed. A questionnaire was used to get information about different activities regarding the system of radical terraces. This questionnaire was sent to different farmers sampled during 30 day period from 1^{st} to 30^{th} June 2008. After getting information from farmers, we interviewed some local governors for confirmation and finally we proceeded by searching different documents concerning this case. The method used for erosion measurement was proceeded with water flow measurement when it was raining. Water was captured through digging of 1 m^3 on three different locations for determinate the speed of water flow from the mountain. The three 1m^3 holes were located in three different zones, two holes were located at the foot of the mountain where the activities of terracing of radical terraces had a high intensity and another was placed where the evolution of Radical terraces was limited

Study area:

Relief: Its relief is characterized by a high altitude of 2500m. The region experiences heavy rainfall with an annual average between 1400-1500mm; the annual average temperature varies between 15-20^{o}C with four seasons: rainy season from mid-September to December and March to May, a dry season from January to February and June to September.

Soil and Vegetation: Most of its soil is acidic with $_{P}$H varying between 4 and 5.5 and characterized by much organic matter, potted on mountainsides. In Mulindi valley, which had been covered by Papyrus in the past, bracken and others weed; the surface is filled up because of the growing rate of population. Previously, it has been shown that between 1983 and 1993, Rwanda lost 4.8% of its forest and woodland areas (Mupenzi, 2010; Mupenzi et al., 2009).

Hydrology: A big part of Kaniga sector is supplied by ground water from Mulindi valley, which crosses Mulindi River; with many small stream rivers identified in this regions.

Agriculture and Livestock farming: 90% of the population practice a subsistence agriculture dominated by living cultivation land (beans, maize sorghum potatoes, wheat, cassava, banana and soya bean), it has also an agricultural industrial area dominated by tea and coffee. The livestock farming does not have a good infrastructure, but some farmers possessed domestic animals like cows, goat, pigs, chicken and rabbit.

Environment and forest: This involves the action to protect, preserve and improve the quality of environment. The Government's major responsibility is to mobilize and teach the population on the effects of land degradation on the country's economy. The biggest problems are deforestation and soil erosion, which have a negative impact on human health. The presence of Mulindi tea factory in Kaniga sector appears to be the main cause of environmental degradation because of the use of different pesticides on tea plantation, and then the factory uses a high quantity of wood fuel; around 100 ha of forest were cut in 2008. It is noted that pollution is also caused by domestic and industrial wastes, agro-pastoral activities and luck of modern sanitation facilities.

Erosion: The rainfall and topography are the major causal factors of soil rosion. Among others causal factors are; human activities such as deforestation, fire bush, pasture, extensive agriculture, and high demography. All those factors contributed to soil and environment degradation by loss of a large amount of nutrients element, water pollution and augmentation of flood on lowlands (SESA, 1986). It is indicated that between 1987-1990, the loss of soil fertility was a big problem that caused the decrease in farm productivity of maize and sorghum. Table 1 shows that a total of 516T/ha were lost through soil erosion; the production of maize was decrease from 1.2T/ha in 1987 to 0.09T/ha in 1990 and the production of sorghum reduced from 1.3T/ha in 1987 to 0.06 T/ha in 1990 (ISAR 1991). This situation is not only the specialty of Rwanda, the study held in India showed that 6 million tones of fertilizers were lost every year because of soil erosion (FAO, 1984)

Table 1 Soil Lost and Reduction of Production of Maize and Sorghum

year	soil lost (t/ha)	production of maize	production of sorghum
1987	10	1.2	1.3
1988	100	0.4	0.4
1989	124	0.3	0.5
1990	282	0.09	0.06
Total	516		

3 Results and Discussion

Table 2 *Importance of Radical Terraces*

importance	Frequency	%
Fight against erosion	20	44.4
retained water	1	22
getting forage	4	8.8
increase of farm productivity	10	22
reduction of poverty	7	15.6
increase of cultivation soil	3	6.6
total	45	100

The study showed that the biggest importance of radical terraces is to fight against erosion as it was an opinion of 44.4% of farmers. This hypothesis was confirmed by the decrease of floods in Mulindi valley; it was indicated that the soil is no longer washed away by rainfall after installation of radical terraces. It was also reveled through Table 2 that the importance of radical terraces is to increase the farm productivity as it was an opinion of 22% of farmers, and 15.6% of farmers esteemed that the importance of radical terraces is to reduce the poverty. Other importance of radical terraces are to get a forage by conifer which is planted between two radical terraces for retain of soil, increase of cultivation soil that represent an opinion of 8.8% and 6.6% of farmers respectively. However, the other importance of radical terraces is to retain water, which was an opinion from few members of farmers.

Radical Terraces in increasing the farm productivity

Table3 Production of potatoes gotten before and after terracing radical terraces

Before terracing of radical terraces

production (t/ha)	frequency	%
>25	0	0
25-20	3	6.6
20-15	5	11
15-10	8	16
<10	29	64.4
total	45	100

After terracing of Radical terraces

production (t/ha)	frequency	%
>25	2	4.4
25-20	8	18
20-15	20	44.4
15-10	12	27
<10	3	6.6
total	45	100

The potatoes were tested in order to compare the importance of radical terraces on farm productivity before and after terracing of radical terraces. It was showed through Table 3 that before the terracing of radical terraces any farmer was able to get the production > 25tones per hectare; 6.6% were the farmers who got between 25-20tones of potatoes per hectare and a big part of farmers produced less that 10tones of potatoes per hectare. However, it was showed that around 4.4% of farmers produced plus 25tones per hectare after terracing the radical terraces in their plots; 18% of farmers produced between 25-20tones per hectare and 44.4 of farmers were able to produce between 20-15tones per hectare; 27% of farmers got 15-10tones by hectare, but only 6.6% of farmers harvested less than 10tones of potatoes per hectare.

In general, it was revealed that 66.8% of farmers produced more than 15tones of potatoes per hectare after the terracing of radical terraces.

Difficulties in terracing of radical terraces

Even if the radical terraces contributed positively on environment protection, but many problems were big barriers for their achievement as indicated on Table 4 below:

Table 4 Difficulties which blocked the progress of terracing of the radical terraces

difficulties	frequency	%
heavy soil	15	33
raid slope	6	13.2
lack of means	15	33
negligence	2	4.4
lack of methods	3	6.6
lack of supervisor	2	4.4
lack of ownership	2	4.4
total	45	100

It showed that 66% of farmers were facing the problem of heavy soil and lack of means in their activities, 13.2% of farmers were confronted by the problem of raid slope; 6.6% of farmers faced the problem of lack of methods. Other problems which blocked the farmers in their activities to terrace the radical terraces were negligence and luck of supervision. It was revealed through Table 4 that many farmers failed to achieve the terracing of radical terraces because of they worked separately, yet this activity needs to put the force together; it was better if the farmers have been putting their forces together and worked in groups or associations for good achievement

Radical Terraces in Poverty Reduction

Table 5 Contribution of radical terraces on reduction of poverty

ways	frequency	%
giving job	4	9
augmentation of production	38	84
Program cow "Girinka"	3	7
Total	45	100

The reduction of poverty was one of the main objectives fixed by the Government of Rwanda in 2020 vision program. Many ways were tried and it was showed that the use of radical terraces had a positive impact on poverty reduction. The results in Table 5 showed that 84% of farmers confirmed this hypothesis where the radical terraces contributed to increase the farm productivity; the radical terraces help the population to get jobs or occupation as an opinion of 9% of farmers; the persons who achieved their radical terraces completely benefited by receiving a cow from National program called “Girinka” or a cow per family, this was the opinion of 7% of farmers.

4 Conclusions

The radical terraces have a positive impact on environment where it contributed to limiting water flow, which was the main cause of soil degradation. The results of the study showed that the radical terraces contributed to increase in the farm productivity, fight against erosion and also contributed to poverty reduction. Many difficulties such as heavy soil, raid slope, luck of means and lack of qualified supervisors were a big barrier to achieving aims of radical terraces. In order to protect the environment and to increase the farm productivity, it was recommended:

- A appropriate mobilization of population about the importance of radical terraces must be a good method for convincing the farmers
- Soil study and analysis are necessary to determine the type of soil before taking a decision on terraces in order to help the farmers in their activities
-The creation of associations or cooperatives must be good solution to achieve the radical terraces, and intensify the training of engineers and other technicians about radical terraces for capacity building.

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A Comparative Study on Oil Performance Prediction Methods: The Case of Shuanghe Oilfield, China

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Abstract: While being the dominant source of energy, oil has also brought affluence and power to different societies. Energy produced from oil is fundamental to all parts of society. In the foreseeable future, the majority of energy will still come from oil production. Consequently, reliable methods for forecasting that production are crucial. Petroleum engineers have searched for simple but reliable way to predict oil production for a long time. Many methods have been developed in the latest decades and one common practice is decline curve analysis. Prediction of future production of petroleum wells is important for cost-effective operations of the petroleum industry. This work presents a comparative analysis of methods used to predict the performance of Shuanghe oilfield, China. Using decline curve analysis including three different methods: Arps empirical methods, LL-model and simplified model and the new simplified model, LL-Model, to crosscheck Arps exponential decline model prediction results. The results showed by the comparative analysis of predictions calculated proved LL-model to be the best predictor for Shuanghe oilfield since it takes into account more parameters than the old models used in this work. However, the subsurface information or parameters of the reservoir used in LL-model may not be available every time, therefore Arps models may apply as defined. In Shuanghe oilfield calculated average geological reserves N was estimated at 9449.41 $\times 10^4$ tons, the average recoverable reserves N_R were estimated to 4274.61$\times 10^4$ tons while the water cut was 97% and the water cut predicted by LL-model was 96.7%; not far from water flooding curves value. The exponential decline model showed recoverable reserves $\mathbf{N_R}$ estimated around 4685.88$\times 10^4$ tons of oil while the decline phase of total development was estimated around 34 years which means that if the actual production conditions remain unchanged, Shuanghe oilfield would continue producing for another 25 years from 2008.

Key words: Shuanghe oilfield, Oil production prediction, decline curve

1 Introduction

Decline curve analysis is a graphical procedure used to analyse declining production rates and forecast future performance of oil and gas wells (Fetkovich, 1980; Da Prat et al, 1981). A curve fit of past production performance is done using certain standard curves. This curve fit is then extrapolated to predict potential future performance. Decline curve analysis is a basic tool for estimating recoverable reserves. However, conventional or basic decline curve analysis can be used only when the production history is long enough that a trend can be identified (Agarwal, et al., 1999; Agbi and Ng, 1987; Arps, 1945)

However, decline curve analysis is fundamentally an empirical process based on historical observations of well performance. Because of its empirical nature, decline curve analysis is applied, as deemed appropriate for any particular situation, on single or multi-fluid streams. It is implicitly assumed that, when using decline curve analysis, the factors causing the historical decline continue unchanged during the forecast period. These factors include both reservoir conditions and operating conditions. Some of the reservoir factors that affect the decline rate include: pressure depletion, number of producing wells, drive mechanism, reservoir characteristics, saturation changes and relative permeability (Chenet al., 2009; Hu et al., 2007; Fetkovich et al., 1987;). Operating conditions that influence the decline rate are: separator pressure, tubing size, choke setting, workovers, compression, operating hours, and artificial lift. As long as these conditions do not change, the trend in decline can be analysed and extrapolated to forecast future well performance. If these conditions are altered, for example through a well workover, then the decline rate determined pre-workover will not be applicable to the post-workover period (Agarwal, et al., 1999; Agbi and Ng, 1987, Feteke, 2010). Good engineering practice demands that, whenever possible, decline curve analysis should be reconciled with other indicators of reserves, such as volumetric calculations, material balance, and recovery factors. Most of the existing decline curve analysis techniques are based on the Arps empirical equations: exponential, hyperbolic, and harmonic. However, the main concern rise on one hand in the judgment of which equation among the three the reservoir will follow. On the other hand, these types of declines have their limitations. In some cases, production decline data does not follow any models and just crosses over these decline curves. So, estimating the natural decline rate has been a challenge for many years (Höök et al., 2009 Chen, 2003). Many experts have attempted to interpret the empirical Arps equations or to provide some theoretical based on specific cases. It seems that few of new models have consolidated theory behind. As Raghavan (1993) pointed out, "Until the 1970s, decline curve analysis was considered to be a convenient empirical procedure for analyzing performance; no particular significance was to be attributed to the values of D_i and b. To an extent, this is still true even today." This may be the case still, even though another 10 years have passed. Xie *et al* (2010) focused on advanced decline analysis using integration and analysis of sub-surface information and well performance data, and combined static (geological) and dynamic flow models to predict reservoir performance. There is more here than just replacing the modeling process with a function. In this work we cross-checked the results produced using LL-model of Xie *et al*, (2010) and the simplified model of Khaled (2006), for which the decline rate D and the exponent b (noted as n by some authors), are generated from production history data by double regression method in Shuanghe oilfield. Actually, we predicted the production performance using D_i and b calculated using LL-model in the Arps equations because those parameters (D_i and b) were already calculated considering sub-surface information. After this prediction we proceeded to the other prediction technique which, as proposed by Khaled (2006), combines both exponential and hyperbolic in one equation to predict production performance.

2 Methodology

It is always very difficult to decide which decline curve model (among the three; exponential, hyperbolic, harmonic) to be used to predict reservoir performance. This brings errors related either to the use of incompatible model or the natural weakness of the used model. Furthermore, previously used decline curve analysis techniques did not take into account the sub-surface information. To compensate

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for this problem, a solution has been implemented that limits the minimum decline rate value. On one hand, Khaled (2006) and Chen et al. (1996) developed a simple technique for evaluating production data by decline curve and combined both exponential and hyperbolic to generate a new model which use exponential decline to extrapolate hyperbolic decline. On the other hand, Xie (2010) developed a new model *"LL-model"* which involves sub-surface information to calculate the decline rate. The results of prediction calculated using both methods will be compared to decide which predicts more accurately the performance of Shuanghe oil reservoir.

i. Description of the simplified model

The model introduced a simple method to obtain the point where the decline is expected to hold and follow an exponential decline. One can easily calculate reserves for the separate hyperbolic and exponential decline segments, and add them together to estimate the total remaining reserves. The proposed model was simple compared to the models available in the literature, and provided almost similar results while saving significant time and efforts. In other words, this model is very handy and easy to use, especially for routine industry tasks. All decline curve theory starts from the definition of the instantaneous or current decline rate (*D*). Taking the derivative of exponential equation with respect to time, results in equations below.

$$\frac{dq}{dt} = \frac{d\left[q_i(1+bD_it)^{\frac{-1}{b}}\right]}{dt} = q\left[\frac{-D_i}{(1+bD_it)}\right]$$
(1)

$$\frac{-qdq}{dt} = \frac{1}{D_i+bt} \qquad \textbf{(1)}$$

From the definition of the hyperbolic decline curve, the value of decline rate *D* at time *t* can be determined from the following equations [17, 19-20, and 16] : Rowland and Chung,1985; Shirman, 1999 ; Nind, 1981; Thompson, et al., 1987; Ibrahim et al., 2002)

$$D = \frac{1}{-q}\frac{dt}{dq} = \frac{1}{\left(\frac{1}{D_i+bt}\right)} \qquad \textbf{(3)}$$

$$\frac{1}{D} = \frac{1}{D_i+bt} = \frac{1+btD_i}{D_i} \qquad \textbf{(4)}$$

$$D = \frac{D_i}{(1+bD_it)} \qquad \textbf{(5)}$$

By differentiating the equation 5 to determine the time t_o, at which one must change the forecast from hyperbolic to exponential decline we have:

$$\frac{dD}{dt} = \frac{d\left(\frac{D_i}{1+bD_it}\right)}{dt} \qquad \textbf{(6)}$$

$$\frac{dD}{dt} = \frac{-bD_i{}^2}{(1+bD_it)^2} \qquad \textbf{(7)}$$

With $\frac{dD}{dt}$, the rate of change of decline rate with time; which is constant and noted as *C*. That constant C should be close to zero where the decline rate of exponential decline is constant for all time, to match the transition point to transfer from hyperbolic to exponential decline. If the transition point occurs at t_o then from equation 7 t_o can be expressed as:

$$t_o = \frac{\left(\frac{-bD_i^2}{C}\right)^{0.5} - 1}{bD_i} \qquad (8)$$

From this time value t_o, we can determine the corresponding exponential decline rate D, which will be constant over the next time period to the economic limit by substituting t_o in equation 5: Therefore, the initial exponential production rate may be obtained by substituting t_o in equation 9. A production rate in the exponential decline segment can be expressed by expanding equation 8 as shows equation 10. Thus, the combined hyperbolic and exponential production decline equation can be expressed as follows:

Hyperbolic decline segment

$$q = q_i(1 + bD_it_i)^{\left(\frac{-1}{b}\right)} \qquad (9)$$

For $0 \le t \le t_0$

Exponential decline segment

$$q = q_i(1 + bD_it_i)^{\left(\frac{-1}{b}\right)} exp\left(\frac{-D_i(t-t_i)}{1+bD_it_i}\right)$$
(10)

For $t \geq t_0$

Description of LL-Model

The Arps decline curve analysis approach was proposed nearly 60 years ago. However, a great number of studies on production decline analysis are still based on this empirical method. Many published papers have tried to interpret the Arps decline equation theoretically (Hu et al., 2007; xie et al., 2010). The empirical Arps decline equation is used to represent the relationship between production rate and time for oil/gas wells during the pseudo-steady state period and is shown in hyperbolic equation:

Where *q* is the oil production rate at time *t* and q_i is the initial oil production rate; *b* and D_i are two constants. Hyperbolic equation can become two special cases when *b* equals to 0 or 1: b=0 represents an exponential decline in oil/gas production; b=1 suggests a harmonic decline in oil/gas production. Any other value of *b* between 0 and 1 indicates a hyperbolic decline in oil/gas production. The type curves based on the Arps equations are used for production decline analysis good for the pseudo-steady state phase. The curves (D_i vs water cut) are shaped like a set of saddles in different liquid production rates. The saddle shape enables D_i to decline quickly during high water cut periods. On the contrary, the decline rate is relatively slow in the field after water cut higher than 90 percent.

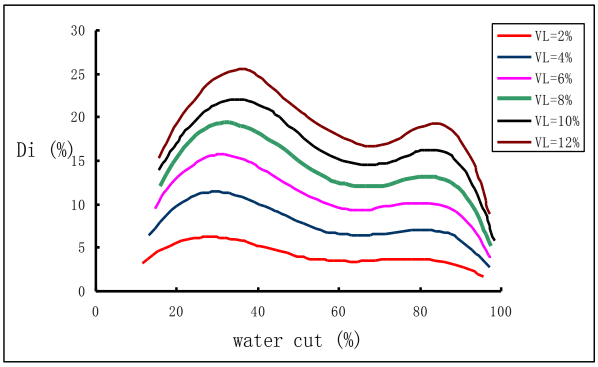


Figure 8. Typical decline rate curves (decline rate vs water cut) in different VL in Shuanghe oilfield (Xie , 2010)

Xie (2010) developed an analytical model called LL-model to predict decline rate with time for high water cut periods. This model is expressed as follows:

$$\boldsymbol{D_i = D_o + at^b e^{-ct}} \quad (11)$$

Where D_i is the decline rate at time *t* and D_0 is the initial decline rate by the year when the production starts to decline. The values of the three constants *a*, *b* and *c* are associated with the formation factors: Kh (product of formation permeability and net pay), porosity (φ) and remaining oil saturation (Soi), respectively (Table 1). Equation 11 was solved in terms of decline rate and time. Using the reservoir properties in Shuanghe oilfield, equation 11 could become the following equation:

$$\boldsymbol{D_i = 4.5 - 4.375t^{0.1837}e^{-0.1163t}}$$
(12)

Table 2 The relationship between three constants (a,b and c) and formation factors (Kh, Φand Soi)

Type	Kh(mD.m)	A	B	Φ (%)	C	Soi (%)
I	>10	-4.529～-4.22	0.1376～0.2298	>21	0.1089 ～ 0.1237	>35
II	6-10	-4.245～-3.81	0.1777～0.3238	19-21	0.1277 ～ 0.1518	30-35
III	1-6	-3.893～-3.17	0.2505～0.5387	10-19	0.1623 ～ 0.2123	28-30

The program written and ran in Matlab-m language can calculate the natural decline rate in any time. We use ND_i instead of Di to fit the curve in order to display when water cut is close to the limited water cut. ND_i is the sum of every D_i when the program was run. This program may predict future decline rates. More, the analytical model was benchmarked with some conventional models. Equation 12, demonstrates the non-linear relationships between the natural decline rates and the production time. If time *t* is replaced by water cut in equation 12, the curves could become the forms shown in Fig.3, which shows that the LL-model predicts decline rate during high water cut periods in the oilfield. The curve in Fig.3 indicates that the decline rate would become moderate when water cut is higher than 96.2 percent until the economic limit in the Shuanghe oilfield. A series of similar curves can be derived from different *a*, *b* and *c* within the range like shown in table 1. Fig.3 shows three types of decline curves which are practically used in Shuanghe oilfield. The best one is type I with high Kh (Kh>10), high porosity (φ>21%) and high remaining oil saturation (Soi >35%); the worst one is type III with low Kh (1<Kh<6), low porosity (φ<19%) and low remaining oil saturation (Soi<30%); Type II is the middle case between type I and type III. The exact relationships between *a* and *Kh*, *b* and *φ*, *c* and Soi need to be investigated further. But one thing can be proved that the better the oil reservoir quality is the slower oil production rate declines [18, 7, 15].

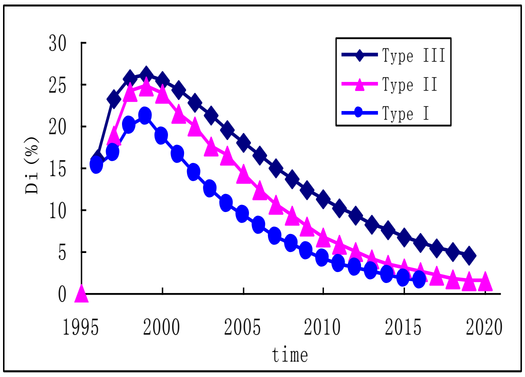


Figure 9 Different decline rate curves with three sets of oil reservoir properties

To validate the LL-model, we computed the predicted decline rates in 2007 and 2008 using equation 12 and compared with the field observed decline rates.

3 Results and discussions

Predicting decline rate D_i using LL-model

This part presents a new model called LL-model prepared by Xie (2010) to predict decline rate using integration and analyses of sub-surface information and dynamic data. As described, this new model puts into consideration some sub-surface information for the forecast of decline rate. Furthermore, this model will be used not only to predict decline rate and water cut but also oil production in Shuanghe oilfield. In this model the focus was put on advanced decline analysis using integration and analyses of sub-surface information and well performance data, and combined static (geological) and dynamic flow models to predict reservoir performance. The type curves based on the Arps equations are used for production decline analysis good for the pseudo steady-state phase. LL-model is an analytical model to predict decline rate with time for high water cut periods. It is expressed as shown in equation 11, where D_i is the decline rate at time *t* and D_o is the initial decline rate by the year when the production starts to decline.

Table 3.Shuanghe oilfield predicted decline rate D_i by LL-model

Time	Actual decline rate (D_i, %)	Predicted decline rate (D_i, %)
2000	7.29	5.2
2001	9.3	7.4
2002	14.34	12.6
2003	14.45	12.9

2004	17.8	16.4
2005	17.31	16.1
2006	16.42	15.3
2007	17.3	16.9
2008	13.86	13.6
2009	13.52	12.4
2010	12.45	11.3
2011		10.2
2012		9.2
2013		8.3
2014		7.5
2015		6.5
2016		6.2
2017		6.1
2018		5.9

Table 5 shows the results of a 10 year predicted decline rate D_i calculated using LL-model. The period from 2000-2008 is the comparison between actual rates and predicted rates and the period from 2009-2018 is only prediction. As it can be seen, taking into account reservoir subsurface information, the decline rate D varies more or less at constant rate. The predicted water cut using the same LL-model shows the highest value of 96.7% (Table 6), while the water displacement curve shows the value of 97% which is slightly high the offset is 0.3% only.

Table 4 Shuanghe oilfield predicted decline rate *Di* and water cut f_w

Time	Predicted decline rate (Di, %)	Water cut (f_w, %)
2009	12.4	95.8
2010	11.3	95.9
2011	10.2	96.0
2012	9.2	96.1
2013	8.3	96.2
2014	7.5	96.3
2015	6.5	96.4
2016	6.2	96.5
2017	6.1	96.6
2018	5.9	96.7

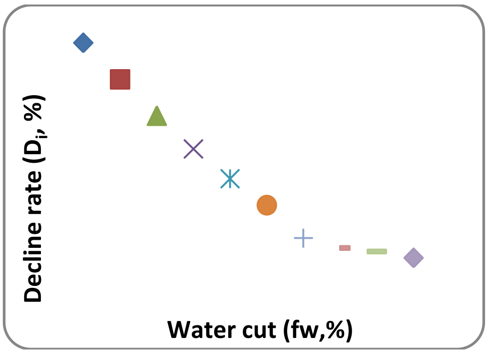


Figure 10. Shuanghe Oilfield predicted decline rate D_i versus water cut calculated using LL-model

As shows the Fig.5, decline rate D_i varies very fast but becomes moderate when the water cut f_w grows high above 96.4 % in Shuanghe oilfield. After the prediction of Decline rate D_i and f_w using LL-model, oil production need to be forecasted as well.

ii. Predicting oil production using LL-model

In previous parts of this section "*LL-model*" has been used to predict some useful parameters like f_w and *Di* for oil production prediction. Starting from the already calculated parameter we can calculate the remaining ones like exponent *b* and the initial flow rate q_i. Using multiple regression analysis for Shuanghe oilfield production data we calculated *b* which equals to 0.22 and the initial flow rate q_i =86.78. As mentioned the decline *Di* varies with time and its actual and predicted values were reported in table 5. The following prediction of oil production will follow the hyperbolic equation and results are shown in table below.

2.

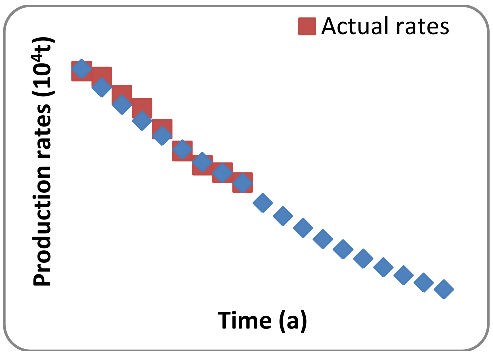
3.

4. Table 5 Shuanghe oilfield oil production predicted using LL-Model

Year	Time interval	Actual rates (10^4 tons/a)	Predicted Rates (10^4 tons/a)

2000	0	86.11	86.78
2001	1	84.46	81.36
2002	2	79.19	76.34
2003	3	75.32	71.70
2004	4	69.32	67.39
2005	5	62.96	63.40
2006	6	58.82	59.69
2007	7	56.71	56.62
2008	8	53.78	53.58
2009	9	51.86	47.83
2010	10	49.71	44.05
2011	11		40.57
2012	12		37.37
2013	13		34.42
2014	14		31.71
2015	15		29.20
2016	16		26.89
2017	17		24.76
2018	18		22.79

Table 7 reports the 10 year prediction of Shuanghe oilfield production rates. The first 9 years (2000-2008) showed the comparison between actual rates and predicted rates, which showed that both values were almost similar even though prediction is never the reality. The relative errors are very small, and we can conclude that our predictions are accurate. Based on this comparative period we can assume that if conditions remain unchanged in Shuanghe oilfield for the next 10 years (2009-2018) the production will continue to decline up to the rate of 22.79 (10^4 tons/a) by the year 2018.



5. Figure 11 Shuanghe oilfield predicted oil production rates calculated using LL-model.

The Figure 6 shows the prediction of oil production in Shuanghe oilfield for 19 years from 2000-2018 as far as LL-model is concerned. The blue dots represent the actual rates while red ones stand for predicted rates. During that first period of actual rates production was declining and LL-model predicted new values for the flowing 10 years as if reservoir conditions continued to behave and evolve in the same way. The innovation brought by this new model is the consideration of sub-surface information like formation factors: Kh (product of formation permeability and net pay), Φ (porosity) and so on. That sub-surface information was used to calculate the prediction of decline rate *Di* which later has been integrated in the equation to calculate the oil production prediction.

i. *Predicting oil production using simplified model*

The hyperbolic curve frequently yields an unrealistically high reserve estimate and lifetime because the curve continually flattens with time. To compensate for this problem, a solution has been implemented that limits the minimum decline rate value. Khaled (2006) developed a simple technique for evaluating production data by decline curves. Hyperbolic decline curve occurs when the decline rate is no longer constant. From the definition of the hyperbolic decline curve by different works, the value of decline rate D, at time t, can be determined from the equations 2, 3, 4 and 5:

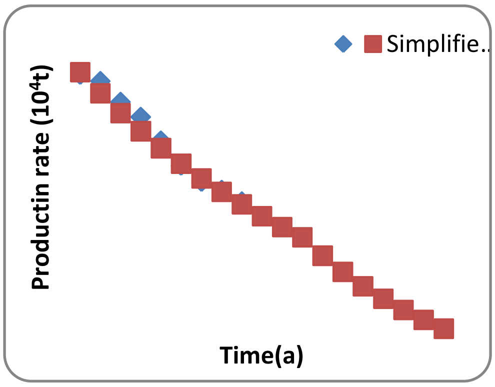
By differentiating equation 5 we can determine the time t_0, at which one must change the forecast from hyperbolic to exponential decline, this results in equation

6.

6 and 7 where $\frac{dD}{dt}$ is the rate of change of decline rate with time; which is constant noted as C. The time where the model shifts from hyperbolic to exponential decline is noted as t_0. The constant *C* should be close to zero where the decline rate of exponential decline is constant for all the time, to match the transition point to transfer from hyperbolic to exponential decline. If the transition point occurs at t_0, then from equation 8, t_0 can be expressed as shows equation 9. From this time value t_o, we can determine the corresponding exponential decline rate *D*, which will be constant over the next time period to the economic limit by substituting t_0 in equation 9. The initial exponential production rate may be obtained by substituting t_0 into the hyperbolic equation 9.Calculations gave the time t_o=3.6 years and the initial exponential rate q_i=44.67 as reported in table 8.

7. Table 6 Shuanghe oilfield oil production predicted using simplified model

Year	Time interval	Actual rates (10^4 t)	Predicted rates (10^4 t)
2000	0	86.11	86.78
2001	1	84.46	81.36
2002	2	79.19	76.34
2003	3	75.32	71.70
2004	4	69.32	67.39
2005	5	62.96	63.40
2006	6	58.82	59.69
2007	7	56.71	56.25
2008	8	53.78	53.04
2009	9	51.86	50.05
2010	10	49.71	47.27
2011	11		44.67
2012	12		39.97
2013	13		35.83
2014	14		32.18
2015	15		28.96
2016	16		26.11
2017	17		23.58
2018	18		21.34



8. Figure 12 Shuanghe oilfield oil production rates forecasted using the simplified model

Figure 7 shows the prediction of oil production in Shuanghe oilfield for 19 years from 2000-2018 as far as Simplified model is concerned. As clearly described above the prediction using the simplified model is used once the choice of one among three Arps decline methods is difficult to make. This model combines exponential and hyperbolic decline equations. It has an advantage when the production history curve did not fit any type of the three models (exponential, hyperbolic and harmonic). Nevertheless, this model was proved to predict fewer values comparatively to other methods. Relative errors calculation shows that this model can be effective.

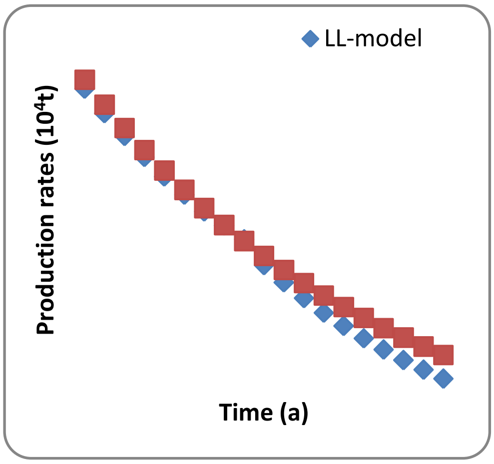
Comparative analysis and cross-checking of results from used models

This work presents three variable models of decline curve analysis; Exponential decline model, LL-model and simplified model. All these three models were used to predict mainly the oil performance of Shuanghe oilfield. In this section a comparison of produced results is reported in tables and figures and at the end analysis of variance and relative errors calculation are also made.

i. Comparative analysis between results from exponential decline and LL-model

As shown on the Fig.8, prediction made by LL-model and exponential decline model were almost the same for

the whole predicted period. However, the exponential decline model predicted slightly higher values comparatively to LL-model. The average offset between the two models was estimated at 2.69×10^4tons/a. Even though the offset looked to be minor; it is clear that these methods are different and LL-model was the most convincing because it included more reliable data and has lower relative errors.



9. Figure 13 Comparison of results for oil production forecast between LL-model and exponential decline model.

i. Comparative analysis of results produced by LL-Model and simplified model

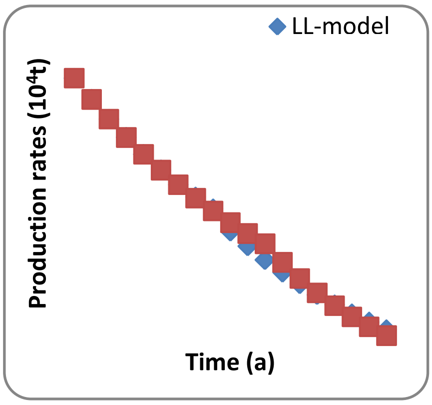
Table 9 shows that LL-model slightly predicts lower values than the new simplified model. However towards the end of prediction period, we observe quite the reverse; simplified model predicts slightly fewer values. Nevertheless, the difference is not so high for both models and we can say that each of the two is usable to forecast the performance of a given oilfield because each has its own advantages. For instance, the LL-model is the best forecast used when the water cut is higher and has the privilege of taking into account some geological parameters like permeability, porosity, Soi and so on. However, in some cases the geological information are not available to the engineer who must do the prediction therefore the simplified model or Arps decline can be used. The simplified model comes into account once the production history analysis is not clear about the equation to be used among three Arps decline equations. Further comparative analysis will show the relationship between all these methods.

Table 7. Comparison of the prediction results between LL-Model and simplified new model

Time	Actual rates (10^4 t)	Forecast by LL-model (10^4 t)	Forecast by Simplified model (10^4t)
2000	86.11	86.78	86.78
2001	84.46	81.36	81.36
2002	79.19	76.34	76.34
2003	75.32	71.70	71.70
2004	69.32	67.39	67.39
2005	62.96	63.40	63.40
2006	58.82	59.69	59.69
2007	56.71	56.62	56.25
2008	53.78	53.58	53.04

2009	51.86	47.83	50.05
2010	49.71	44.05	47.27
2011		40.57	44.67
2012		37.37	39.97
2013		34.42	35.83
2014		31.71	32.18
2015		29.20	28.96
2016		26.89	26.11
2017		24.76	23.58
2018		22.79	21.34

As shown by the Fig.9, the first part of the predicted rate curve had the same appearance as for the one of actual rates which may lead us to conclude that once the reservoir conditions remain unchanged the 10 year prediction curve also is very close to the reality or it is a very good prediction and further statistical analysis are conforming. We must note that more accuracy was observed on the LL-model results.



10. Figure 14 Comparison of results for oil production forecast between LL-model and new simplified model

i. *Comparative analysis of results produced by exponential decline model and simplified model*

The Figure 10 shows a comparative analysis between exponential decline model and simplified model prediction results. In the beginning (actual rate period) both trends were almost the same even though values were not very similar, however towards the end of the 10 years prediction period the simplified model predicts very lower values than exponential decline model. The average offset between two methods was about 2.19×10^4t/a. Further statistical analysis lead to the conclusion that the simplified model is relatively poor predictor in the reservoir where water cut is high like Shuanghe oilfield. The simplified model presented higher relative errors and standard deviations during this work.

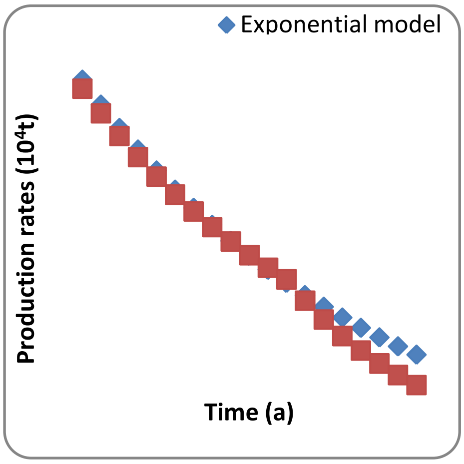
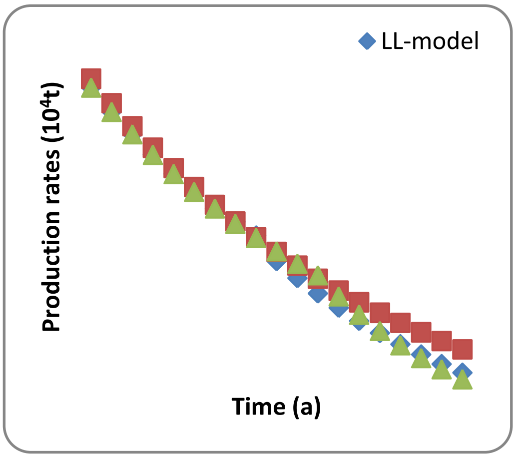


Figure 15 Comparison of results for oil production forecast between exponential decline and simplified model

Comparative analysis of results

11. *produced by all three models*

The Figure 11 shows the comparison of results from all three oil prediction methods. Generally, all three prediction methods were almost the same even though the exponential predicts slightly higher values than others. Furthermore the LL-model predicts slightly lower values but was almost similar to simplified model prediction. However, all these prediction models have one common condition which is actually their weakness: the reservoir must continue to produce in constant conditions for the prediction to be validated. So if the reservoir conditions would change due to any circumstance those predictions would not be verified as real. And it is not easy to have an environment very constant for so long in these days where environmental conditions change day and night because of climate change. Here we can cite some examples of earthquakes or flooding. Unfortunately, some of those climate change effects are unpredictable and that is why we have to rely on our prediction model because they are the only available at present. Comparative analysis showed the difference and the relationship between all those three production predictions. Table 10 reports all predicted values.



12. Figure 16 Comparison of production forecast results from all three prediction models

13. Table 8 Comparison of predicted results using all 3 models (Exponential, LL-model and Simplified)

Time	Predicted rates (10^4 t)		
	LL-model	Exponential model	Simplified model
2000	86.78	88.78	86.78
2001	81.36	83.27	81.36
2002	76.34	78.11	76.34
2003	71.70	73.27	71.70
2004	67.39	68.73	67.39
2005	63.40	64.47	63.40
2006	59.69	60.47	59.69
2007	56.62	56.72	56.25
2008	53.58	53.20	53.04
2009	47.83	49.91	50.05
2010	44.05	46.81	47.27
2011	40.57	43.91	44.67
2012	37.37	41.19	39.97
2013	34.42	38.63	35.83
2014	31.71	36.24	32.18
2015	29.20	33.99	28.96
2016	26.89	31.88	26.11
2017	24.76	29.91	23.58
2018	22.79	28.05	21.34

4 Conclusions

This work presents the results of a comparative study with regard to production analysis and forecast for Shuanghe oilfield. From this work, the following conclusions have been reached: On comparing the new simplified model and LL-model curves, it was observed that LL-model gives slightly lower predictions than the simplified model in terms of quantity.

Considering the slight difference between two methods there is an average offset of about (0.50×10^4 tons/a) in favor of the simplified model. The LL-model was the most reliable method because it involves subsurface information and the new simplified model which predicted almost same values is useful not only when geological data are not available but also when the decision to choose among Arps equation becomes difficult to make.The LL-model is the best method to forecast Shuanghe oilfield production, but one must be cautious to use it everywhere because the water cut has to be higher for this method to give worthy results. Exponential decline model predicts slightly higher values of oil production in Shuanghe oilfield comparatively to other methods used while the simplified model predicts medium values of oil production in Shuanghe oilfield. The LL-model looks to be the best forecast for decline rate because it takes into accounts more parameters than the remaining models used in this work. However, the subsurface information and parameters of the reservoir used in LL-model may not be available every time, for this reason exponential decline may apply the best to predict performance in Shuanghe oilfield.

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