ASSESSMENT OF THE IMPACTS OF BURNING REGIMES ON SOIL QUALITY IN THE KAKIRA SUGARCANE PLANTATION IN EASTERN UGANDA

BY

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DECLARATION

I BAMULANZEKI TIMOTHY , hereby declare that to the best of my presented knowledge, the information in this report titled "Assessment of the impacts of burning regimes on soil quality in the Kakira sugarcane plantation in Eastern Uganda" is my original work and has not been presented for an academic award in any institution.

Signature………………………………………… Date…26th/09/2019……

This special Project report has been submitted for examination with approval of the academic university supervisor

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DEDICATION

I dedicate this work to my parents, Kagodo Richard and Mbakile Sarah for supporting me and paying for me tuition ,to all family members for the financial support

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I wholesomely thank the Almighty God who has seen me through since when I was young up today for the gift of life, for the protection, guidance in everything and everything about me.

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ACRONYMS

SOM	-	Soil Organic Matter
SOC	-	Soil Organic Carbon
PEAP	-	Poverty Eradication Action Plan
FAO	-	Food and Agricultural Organization
SSA	-	Sub Saharan Africa
UN	-	United Nations
SDGs	-	Sustainable Development Goals
S.E.M	-	Standard error of means
N	-	Nitrogen
P	-	Phosphorous
K	-	Potassium
Mg	-	Magnesium
NEMA	-	National Environment management authority

ABSTRACT

Burning is a common practice used by farmers before harvesting sugarcanes. Fires cause major changes in soil properties in many agricultural ecosystems but little is known about the effects of burning regimes on soil quality in sugarcane. Such knowledge is important for providing a comprehensive understanding of burning regime effects on soil patterns and for planning appropriate long-termagriculturalland management in these sugarcane plantations. Changes in soil physical propertiesand chemical properties were investigated in sugarcane plantations and treatments included a recently burnt (RB), One year after burning(OYB) and a control of unburnt (NB). Soil samples were collected from 0–10 cm and 10-20 cm depths in order to understand the variations in soils properties with depth. The burning regime effect on physical and chemical soil properties were significantly different from among treatment variations while treatment and depth interaction effect was significant for physical and chemical properties except N and total P content in the soil. Significant short-term effects on soil chemical properties but there were no significant effects on physical properties but the soil structure was disturbed . Soil pH increased significantly in the soil one-year post-fire. SOM and Mg level were significantly lower in recently burnt soils and continued to reduce one year after burning. Total nitrogen (N) and phosphorus (P), increased significantly immediately after burning but significantly reduced one year after the burning and concentrations 10-20cm layer were lower than in the 0-10 cm spoil layer. Total potassium (K) decreased immediately after the burning and then increased one year after. Burning in sugarcanes significantly influences physical and chemical properties and therefore need to understand the long term effects of burning should be addressed to guide proper post burning soil management.

CHAPTER ONE: INTRODUCTION

1.1 Background

The main driver behind the expansion of land under sugarcane farming and increasing sugarcane monoculture is the constant rise in the world's demand for sugar. Sugarcane accounts for 80% of the amount of sugar produced worldwide. However, industrialization has led to more investments in sugarcane farming for production of clean fuels, namely; ethanol and biogas.   In 2010, sugarcane was cultivated on about 23.8 million hectares in more than 90 countries with a worldwide harvest of 1.69 billion tonnes (FAO, 2010). This acreage under sugarcane agriculture is set to expand as sugarcane monoculture is being favoured at the expense of other food crops with resulting impacts on food prices, availability and variability of food commodities in the market and the livelihoods of those who had previously depended on the substituted crops as a source of income. For instance, the encroachment of pastoral land by sugarcane in the Afar region of Ethiopia has forced pastoralists to supplement their livelihoods with subsistence oriented cultivation of maize and sorghum and/or low paid wage labour like the picking of cotton (Altare et al., 2010).

Further complicating this state of affairs is the sensitive nature of the sugarcane crop that limits crop diversification. Other crops such as beans, soya beans, garden peas would be grown in intercrop with sugarcanes due to their nitrogen fixing advantage. However, such crops are not favoured by the soil condition in sugarcane growing communities and practices such as pre harvest burning.

Burning is an old practice commonly carried out in the world, and in Uganda, pre-harvest cane burning has been one of the adopted practices in Sugarcane production. It was intended to get rid of cane trashes and thereby increase harvest efficiency. In addition, it reduces injury to workers from sharp foliage, insects and snakes, and improves economic returns (Allena et al., 2004). Burning of tropical biomass in forests and savannahs has long been recognized as an important factor influencing the composition of the lower troposphere (Allena et al., 2004). Likewise, sugarcane burning results in very large increases in concentrations of toxic gases in the lower troposphere (Kirchhoff, 1991). Burning also pollutes the surrounding village with smoke and ash. The gases emitted to the atmosphere during burning contribute to the greenhouse effect and global warming. The emissions of aerosol and trace gases during cane burning can affect the composition and acidity of rainwater (Lara et al., 2001). Aerosols produced from cane burning have also been reported to cause health problems.

On the other hand, pre-harvest cane burning is exceedingly harmful and eliminates what should be returned to the soil as organic matter. The resultant loss to the ensuing crop from lack of humus is immense, besides which, trash left on the field and ploughed in, naturally helps to hold moisture and check the growth of weeds. The ash that is left after burning can affect the chemistry of the soil as it is rich in several cations and anions. Burning can be detrimental to soil structure and nutrient availability due to the loss of soil organic matter. Substantial losses of C and N due to sugarcane residue burning have been reported (Wiedenfeld, 2009).

With all these implication as a result of pre-harvest cane burning, little is known by farmers on how such a practice affects soil quality in Uganda. Pre-harvest burning is a common practice in Eastern Uganda around the Kakira sugar works factory. This is commonly done in the factory sugar cane plantations to remove trash that is unmill able. In order to design post burning soil management, it is critical to have an understanding of the changes in soil quality after burning has been done. This research was therefore aimed at determining these changes over a one-year period.

1.2 Problem statement

Fire has been a tool of agriculture from earliest times. Man has used fire to clear land, remove weeds, dispose of waste, control diseases and pest. with improved technology, some of these practices have proved detrimental to sound land management. Air pollution aspects of agricultural burning have received attention in the past and it has been reported cause negative impacts to agricultural land. Inappropriate sugarcane growing practices including deforestation, burning are root causes of land degradation (NEMA 2001; Kazoora 2002)

In Uganda, pre harvest burning is a common practice amongst sugarcane growing communities. This is often done with the aim of reducing the trash on the sugar cane to ease harvest and reduce the cutting effect of sugar cane leaves on the harvesters. In other cases, burning in sugarcanes is done with the aim of producing bagasse from the sugar cane. However, the effect of this kind of burning remains unknown by farmers and sugarcane growing communities. In addition, little research has been carried out in Uganda to assess the impact that pre-harvest burning could have on soil quality. Even then, the available research does not consider the changes in soil quality with time after sugar cane burning has been done The aim of this current research was therefore, to evaluate the impact of burning regimes on the soil physical and chemical properties at Kakira sugar cane plantations in Eastern Uganda.

1.3 Objectives of the study

1.3.1 General objective

The general objective of this study was to assess the impacts of burning regimes on soil quality

1.3.2 Specific objective

i. To determine the effects of the sugarcane burning regimes on soil chemical properties

ii. To assess how soil chemical properties, differ with soil depth in different sugarcane burning regimes

1.3.3 Hypothesis

The hypotheses for this study will be

i. There will be no difference in chemical properties for different sugarcane burning regimes

ii. Soil chemical properties will not differ with soil depth for the different sugarcane burning regimes

CHAPTER TWO: REVIEW OF LITERATURE

2.1 Sugarcane growing and food security in Uganda

In Uganda, recent times have witnessed the central government encouraging farmers to invest in commercial agricultural enterprises as one of the efforts for poverty alleviation and wealth creation (PEAP, 2004). One of the major commercial agricultural enterprise practiced by farmers in Uganda is sugarcane growing. Sugar canes are grown in many parts of the country with many sugar processing factories being constructed all over the country. In areas close to sugarcane-processing industries in Uganda (e.g., Kinyara Sugar Works Ltd., Masindi, Mayuge Sugar Ltd., Mayuge, Kaliro Sugar Ltd., Kaliro, and Kakira Sugar Works Ltd., Jinja), sugarcane cultivation has been highly preferred relative to other more traditional crops (e.g., coffee, cotton) as well as plantation forests, as it is perceived to be more profitable and economically valuable (Mwavu and Witkowski, 2010).

As commercialization of sugarcane and other non-food crops cultivation increases in importance to rural households, the value of productive land and incentives to increase yields continue to escalate, resulting in further loss of natural vegetation, and a reduction of land available for food crop cultivation (Mwavu et al., 2016). Mwavu et al. (2018) states that, the reduction of land for food crops is of major concern, as producing more food for a growing population in the coming decades, while at the same time combating poverty and hunger and coping with the impacts of climate change is the major challenge facing agriculture in Africa. While according to Kung'u (2010) food insecurity has contributed to poor health, problems with learning in school, and lack of socio-economic development and it still remains a serious problem amongst poor households in Uganda just like in other African countries.

Elsewhere (Kennedy, 1989) suggests that commercial sugarcane growing, increases household income, thus indirectly addressing food security. Other studies however, have found that cash cropping undermines food and livelihood security particularly for smallholder farmers (Goldemberg, 2008). (Mwavu et al., 2018) also found that sugar cane growing significantly affects food security in Uganda. They also argue that generating income does not necessarily increase food security due to the inadequacy of food within some commercial sugarcane-cultivating households. The fight to eliminate hunger at the household level and reach the other UN Sustainable Development Goals (SDGs) targets in SSA will be won or lost in the rural areas where most the poor and hungry people live (Mwavu et al., 2018).

2.2 Pre-harvest burning as a method of harvesting sugarcanes

Traditionally, sugarcane has been burned prior to harvest in order to eliminate leafy non-sucrose containing material so that it does not have to be transported and milled. This burn, while quick, efficient and relatively clean in terms of air quality effects, has caused concern regarding the impact of smoke and ash on adjacent urban areas. In the past, harvesting equipment was not very efficient in removing the leaves from the stalks and leaving this dry mater in the field. In sugarcane growing areas like South Texas green harvesting was not a practical alternative until recently (Rozeff 1993). However, modern harvesters can separate trash from the millable cane much more efficiently.

Now the challenge is how to manage the trash and what impact this residue left in the field will have on the soil and on subsequent crops. Both retention of sugarcane residue in the field and pre harvest burning potentially have several effects both positive and negative. Substantial changes in soil quality due to sugarcane residue burning have been been observed. However, on the other hand, the retained mulch makes tillage operations more difficult, interferes with fertilizer and herbicide applications and can immobilize N and P. Extracts from sugarcane postharvest residue were found to increase bud germination at low concentrations, but delayed early leaf development at high concentrations on a subsequent sugarcane crop (Viator et al. 2006). Furrow irrigation is more difficult when residues remain on the soil surface. Fire may play a role in controlling insect populations and diseases.

Differences in sugarcane yields due to harvesting green vspreharvest burning have been inconsistent. In Brazil unburned mulching resulted in an increase in sugarcane yield in the subsequent crop which was attributed to increased soil moisture retention (Ball-Coelho et al. 1993). In Louisiana residues left on the surface had no effect on yields, but incorporation increased yields compared to burning over two years (Kennedy and Arceneaux 2006). In semiarid South Texas residues from green harvested sugarcane are typically chopped using some type of roller chopper, and partially incorporated using a cultivator, these operations are done to stimulate decomposition in order to facilitate furrow irrigation, and to allow herbicide and fertilizer applications (Wiedenfeld, 2009).

2.3 Comparison of the impact pre-harvest burning and other harvesting methods like green haresting

2.3.1 soil chemical properties

Pre-harvest burning in sugarcanes just like other types of burning affects the soil chemical properties. A number of research studies have been conducted to assess the effect of pre-harvest burning on chemical properties. Alemayehu and Lantinga (2018) compared the effect of green and harvesting on soil chemical properties. Results from their research show that total biomass per ha, percent trash in a cane before and after pre-harvest cane burning were significantly different ($P<0.01$) while no significant difference was observed in soil ph, loss of organic matter and N. The total weight of biomass and the trash percent biomass in the cane were dropped by 27% and 93%, respectively, following burning (Alemayehu and Lantinga 2018). As it was estimated by using equations 1-5, upon harvesting 120-ton fresh cane/ha, the total biomass decline due to burning was 15.6 ton/ha. The average loss of organic matter and N were also estimated to be 14.4 ton per ha and 66 kg per ha, respectively. Robertson (2003) observed a loss of about 48-55 kg N per 100-ton cane/ha in Australia. According to Alemayehu and Lantinga(2016) SOM and N contents of cultivated land were 53% and 56%, respectively, lower than the virgin land at 0-30 cm depth, indicating that pre-harvest cane burning plays a significant role for such a drastic plunge.Verma (2004) attributes the changes in soil chemical properties to the ash left behind after burning, which accounts generally for about 7% of the total biomass.

This is because of ash is rich in several cations like Fe, Mn, Zn, Cu, Ca, Mg, Na, S, K and P (Khan and Qasim, 2008). Change in soil pH before and after cane burning was not significantly different (Table 2). However, the pH was expected to rise due to the ash left behind after burning. According to Singh et al. (2007), ash consists of a large amount of CaO that along with water forms $Ca(OH)_2$ with concomitant increases in soil pH.However, according to Weaver et al. (2004), soils with high CEC have an eminent potential to buffer change in soil pH.

Telles et al. (2012) also studied effects of sugarcane harvesting with burning on the chemical and microbiological properties of the soil and found that Soil chemical fertility under the sugarcane without burning was better than under sugarcane with burn. The TOC (Total Organic Carbon) values for native forest and for the harvesting without burn were higher than those under the sugarcane with burn (148% and 54%, respectively) (Telles et al., 2012). This superiority was also confirmed for Total Nitrogen. Telles et al., (2012) concludes that microbial Biomass Carbon could be a reliable indicator of soil quality for monitoring soils under different sugarcane harvesting systems.

2.3.2 Environmental impacts

Sugarcane plantations have been known to flourish at the expense of natural resources, with additional land constantly cleared to facilitate their expansion. This has led to a total change in land use patterns in areas where sugarcane monoculture thrives. In North East Brazil, the Zona da Malta or Forest Region has been cleared continually, principally to be used for sugarcane production, since the 16th Century. In Pernambuco, Brazil, the forest region extends the entire north-south length of the state but is only about 80km wide (Schneider, 2010). Increased environmental degradation occurs over time due to exhaustion of nutrients, increased water usage and accumulation of chemical wastes and pre harvest burning ptractices. Since employment on sugar farms is reconcilable with severe income poverty, it is doubtful that the trade-off between environmental degradation and the expansion of the sugar industry seem likely to reflect existing patterns of wealth and patronage on the one hand and poverty and vulnerability on the other (Lorentzen, 2009).

Short-term and long-term studies are needed to evaluate the intensity and development of early impacts on the environment caused by changes in crop management such as pre harvest burning. Soil biological properties that indicate important soil functions can be sensitive to environmental changes, and are useful tools for monitoring immediate variations in soil management (Rao et al., 2014). Thus, it is important to monitor the early effects of sugarcane harvest without burning on soil microbial communities in order to predict possible changes in soil quality that might affect sugarcane yield. Considering the usefulness of soil biological properties and the importance of early monitoring of changes in management,Azevedo et al. (2015) evaluated metabolic diversity and the structure of the bacterial community in the soil after the first sugarcane harvest without burning compared to management with pre-harvest burningand found significant changes in bacterial community after pre harvest burning. These changes in communities do affect the functioning of the environment.

2.3.3 Social-economic impacts

Despite the fact that pre burning is cheaper and eases and reduces the cost of harvesting, it has been reported to have significant impacts on human livelihoods in many sugar cane growing societies. Studies have related pre- harvest burning to being a cause of respiratory illnesses. Alemayehu and

Lantinga (2018) found that numbers of patients hospitalized for upper respiratory infection during sugar cane burning period and non-burning period were significantly different from each other in different cane growing locations. During the non-burning period, the numbers of patients hospitalized for upper respiratory infection were 56% and 18% less than the burning period (Alemayehu and Lantinga, 2018).

The higher numbers of patients during burning period imply that the burning practices contributed substantially to respiratory problems of the residents living in the vicinity of sugar estates. Similar finding showed significantly higher numbers of respiratory hospitalizations during burning period in a Brazilian sugarcane plantation (Cançado et al., 2006). Ribeiro (2008) also reported that the burning practice during sugarcane harvesting was the main source of inhalable particles that caused respiratory problems. It is important to bear in mind that the observed higher respiratory cases during burning period might be also pronounced by other factors. The increase of dust and particulate matters from factories and combustions during burning period may also contribute for the observed higher number of patients. However, the concentrations of particulate matters emitted from cane burning are much higher than the other sources. According to Ribeiro (Ribeiro 2008) sugarcane burning is a source of 60% of the particulate matter while soil dust 14% and factories and combustions 12%. Therefore, cane burning plays an overriding role in contributing to the health problem.

The mechanisms of cane burning in causing respiratory problems were studied previously. According to Ribeiro(Ribeiro 2008) during cane burning incineration is incomplete that the particulate matters emitted into the air are not entirely oxidized. These particulate matters enter the alveoli, lungs and bloodstream of human in a great concentration and cause irritation of the respiratory system. The particulate matters are redox active and upon inhaling they stimulate inflammatory cells with concomitant productions of oxidants and radicals. These situations result in generation of oxidative stress and induction of pro-inflammatory responses. In addition, the interaction between particulate matters, O_3 and NO_2 results in reactive compounds such as radicals and organic compounds which can also cause pro-inflammatory effect (Bernstein 2008).

2.4 Soil management practices in sugar canes

Sugarcane is well grown in loam, clay loam, or sandy loam. The topographic area may be sloped, and hilly that may cause high erosion by forces of rain and wind. Furthermore, sugarcane requires big plantation. In such conditions, there is a need for conservation and nourishment to sustain soil fertility. Numerous practices have been adopted by sugarcane farmers to maintain soil fertility. The practices include; using leaves and debris for mulching to retain soil moisture or plow over to increase organic matter, to prevent weed germination and to reduce the infestation of stem borers, additions of organic fertilizer to increase organic matter,addition of chemical fertilisers, addition of farm yard manure to futher improve SOM, addition of soil amendment such as filter cake from sugar mill to prevent soil erosion and irrigation. Addition of fertilizers in sugarcane plantations has been reported to improve sugarcane yields. Studies of Bijay-Singh et al. (2011) and Ayoub et al.(1994) found that spilt fertilizer application has little effect on yield, but it is associated with decreased lodging and spike population, thereby indirectly contributing higher crop yield.

Nadia et al. (2017) examined the effect of potassium fertilization on sugarcane grown in clay loam soil and results indicated that decreasing amount of irrigation water by growing sugarcane on raised beds caused significantly reduction in stalk height and milleable cane yield of the plant cane and 1stratoon, while stalk diameter was significantly increased. Applying 24 kg K_2O significantly increased stalk height and millable cane yield compared with control (without K) and 48 kg K2O (Nadia et al., 2017).

Conclusion

Generally pre harvest burning has been a quick method of harvesting compared to all the other green harvesting alternatives,it has been observed that it significantly brought decline in soil quality all over the world where it is practised.comparably to all burning regimes ,there is change and disturbance in the soil structure and soil chemical properties due to the ash created after burning .some cations and anions are higher and lower respectively in different burning regimes.

CHAPTER THREE: METHODS AND MATERIALS

3.1 Description of area of study

This study will be conducted at Kakira sugar works plantations. Kakira is located in Jinja District approximately 14 kilometers East of Jinjatown along theJinjaIganga high way and 106km from Kampala city.Scattered hills make up the landscape with the highest being 1,279m above sea level, (4000ft). Kakira sugar plantation covers areas along the shores of Lake Victoria which is the main source of water used for irrigation in the farms. Most of the steep hill in Kakira are planted with Artificial forests to reduce the soil erosion rates in the plantations.

The soil of Kakira farms are clay-loam characterized by stickiness while wet during the rainy seasons and very dusty when dried. The farms receive a bimodal type of rainfall with two rainfall peaks in March to May and `September to November. The rains of the March-May season for 2019 delayed to start according to the farmers with onset of rains starting at the end of March.

Sugarcane growing is the major agricultural practice carried out in |by Kakira Sugar works Ltd. Growing sugarcanes in the area commenced in 1985 as a Joint Venture between the Madhvani Group and the Government of Uganda to take over the assets of Madhvani Sugar Works Ltd., which was the Group's flagship prior to 1972. Kakira sugar plantations cover over 9700ha of land. Farmers around Kakira grow other crops such as maize, Coffee, bananas, sweetpotatoes and other food crops majorly for food consumption and sugarcane growing remains the major economic activity for the surrounding population.

An aerial photography of Kakira Sugar Estate

3.2 Experimental design and set up

The experimental design used for this study was completely randomized block design. Three treatments were used for this study and each treatment was replicated three times.

3.2.1 Field reconnaissance and data collection

A reconnaissance trip of two days was carried out in a Kakira in order to acquire the general view of the soil geology and assess the way how activities associated with sugarcane growing are carried and select the, most suitable plantations for the study.

3.2.2 Treatment set up and soil sampling

Sugar cane plantations were purposively and randomly selected for the study. In order to assess the impact of burning regimes on soil quality, three sugarcane plantations under three burning regimes were selected with in the same soil type, topography and climate zone to avoid variability. Treatments used for this study included; a plantation that is not burnt (NB), a recently burnt (RB) and a plantation that had been burnt one year back (OYB).

Each selected block was of 18ha of land which was split into three plots to make three replicates. The litter was removed in the unburned plots, and the charred debris and the ash layer were removed in the burned plots, and then soil samples were collected from the upper 10 cm (0-10cm depth) and the lower 10cm (10-20cm depth) at 8 randomly located points in each plot. Each sample was bagged in polyethenpapers and marked for transportation to Makerere University Soil ,Plant and Water laboratory for analysis of the physical and chemical soil properties.

3.3 Laboratory soil analysis

All samples were air dried, pounded and sieved in order to determine the chemical and physical properties. The selected soil chemical properties for this study included; soil pH, SOM, Totalnitrogen, phosphorus (P), potassium(K) and exchangeable basesCa and Mg.

3.3.1 Soil chemical analysis

For soil pH, available N, available P, and exchangeable K, Ca and Mg analyses, the air-dried soil was passed through a 2-mm mesh sieve. For organic matter and total P and total K measurement, the air-dried soil was then further sieved to 0.15 mm. For total N analysis, the air-dried soil was passed through a 0.25-mm mesh sieve. The soil pH was measured in deionized water (1:2.5 w/w) at 20 °C. The soil organic matter (SOM) was analyzed using rapid dichromate oxidation of organic carbon. The soil total N was estimated by Kjeldahl digestion (Okalebo et al.,2002). Total P was determined by molybdenum blue colorimetry and total K, Ca and Mg by atomic absorption spectroscopy following NaOH digestion [41]. The available N was released and transformed to NH3 by reaction with 1.07 M NaOH and FeSO4 powder at 40 °C for 24 hours, and then absorbed with 2% (w/v) H3BO3 and titrated with 0.005 M H2SO4 [41]. The available P was extracted with a solution of Bray-1 (0.03 M NH4F–0.025 M HCl) and measured by colorimetry. Exchangeable K, Ca and Mg were extracted and then determined by atomic absorption spectroscopy (Okalebo et al.,2002).

3.4 Data analysis

Results from the lab will be entered into Excel sheets and analysis ofVariancewas done using Gen stat software 14th edition. Least significant differences were used to determine the significance between treatment means, correlation results were also used to determine the relationship between variables and standard error of the mean were used to determine the variations with in the treatments.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Results

Table 1 .Correlation for selected chemical properties

		1	2	3	4	5	6	7	8	9
Ca_cmol_kg	1	-								
K_cmol_kg	2	-0.1577	-0.7131	-						
Mg_cmol_kg	3	-0.9674	0.5039	0.2121	-					
N_%	4	-0.545	0.993	-0.7254	0.4739	-				
OM_%	5	-0.8326	0.9018	-0.3994	0.7801	0.8889	-			
P_ppm	6	0.7261	0.1481	-0.7747	-0.757	0.1729	-0.2596	-		
pH	7	0.6107	-0.9895	0.6593	-0.5272	-0.9894	-0.904	-0.0979	-0.5976	-

4.1.1 Effect of burning regimes on soil quality

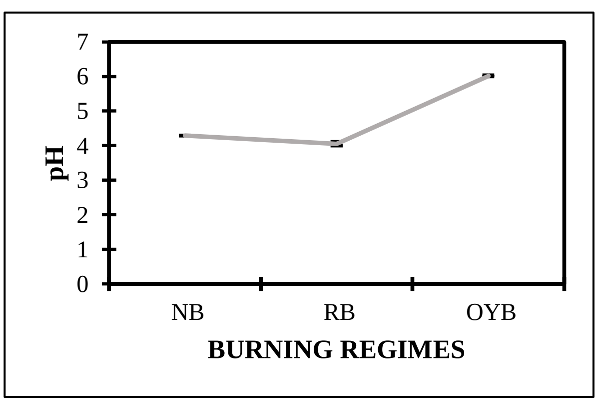
Soil Chemical properties

Generally, the soil from the plot that were not burnt had better chemical properties compared to those from recently burnt and burnt after one year. From table 2, the soil pH was significantly higher for treatment that is one year after burning (6.018) while the recently burnt treatment had the lowest pH (4.053). The soil organic matter is significantly higher for the plot that is not burnt (5.153) % compared to the plots that were recently burnt (4.3)% and that one year after burning (1.727)%. Soil from the one year after burning treatment had the lowest SOM.

Table 2: Mean soil chemical properties for different burning regimes

	BURNING REGIMES			
	NB	RB	OYB	LSD (5%)
pH	4.295	4.053	6.018	0.0618
OM %	5.153	4.3	1.727	0.0867
N %	0.3588	0.4167	0.1055	0.00938
P (ppm)	17.8	20.765	19.327	0.0971
K (cmol/kg)	0.9295	0.7967	0.9502	0.01018
Ca (cmol/kg	4.24	5.6417	6.1513	0.04887
Mg (cmol/kg)	2.157	1.9983	1.9622	0.01355

In addition, recently burnt treatment had the highest Nitrogen level (0.4167)% while soils from the one year after burning treatment had the lowest N content (0.1055)%. Recently burnt, also had a higher amount of available P (20.765)ppm compared to the unburnt soils (17.8)ppm. K and Ca content were highest for soils of one year after burning while magnesium levels were highest in the unburnt soils.



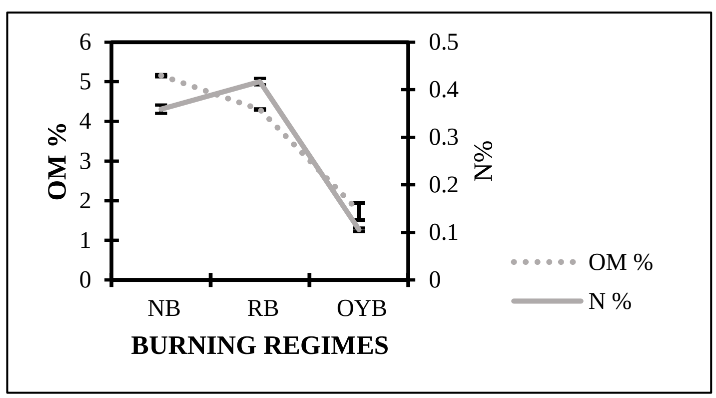


Figure 1: Soil pH of different burning regimes

Figure

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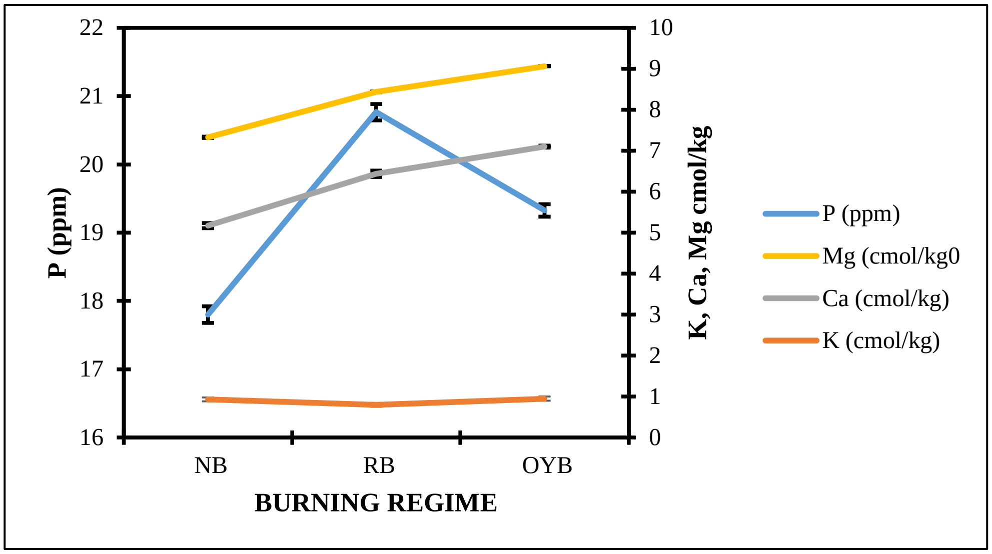

Figure 3: Soil chemical properties of different burning regimes

4.1.2 Effect of burning regimes on soil properties at different soil depths

i. Chemical properties

The highest pH (6.133) was observed at the 10-20cm depth in soils after one year of burning while the lowest pH was observed in soil from recently burnt soils at depth of 10-20cm (4.003). SOM matter content was highest (5.206)% in unburnt soils at a depth of 0-10cm and the soils form one year after burning had the lowest (1.263)% SOM content at 0-10cm depth. 0-10cm depth soils from one year after burning treatment had the highest K content (0.9613)cmol/kg and Ca content (6,2067)cmol/kg. Mg content was highest at 10-20cm depth of unburnt soils.

Table 1: Means of chemical properties for the interaction of soil depth with burning regimes

					CHEMICAL SOIL PROPERTIES			
TRTS	DEPTH	pH	OM %	N %	P (ppm)	K (cmol/kg)	Ca (cmol/kg	Mg (cmol/kg)
NB	0 to 10 cm	4.277	5.206	0.377	18.07	0.917	4.3767	2.13

NB	10 to 20 cm	4.313	5.1	0.3407	17.53	0.942	4.1033	2.184
RB	0 to 10cm	4.103	4.32	0.43	21.03	0.78	5.8133	2.01
RB	10 to 20cm	4.003	4.28	0.4033	20.5	0.8133	5.47	1.9867
OYB	0 to 10cm	5.903	1.263	0.1133	19.517	0.9613	6.2067	1.9533
OYB	10 to 20cm	6.133	2.19	0.0977	19.137	0.939	6.096	1.971
P-value		<0.001	<0.001	0.095	0.175	<0.001	<0.001	<0.001

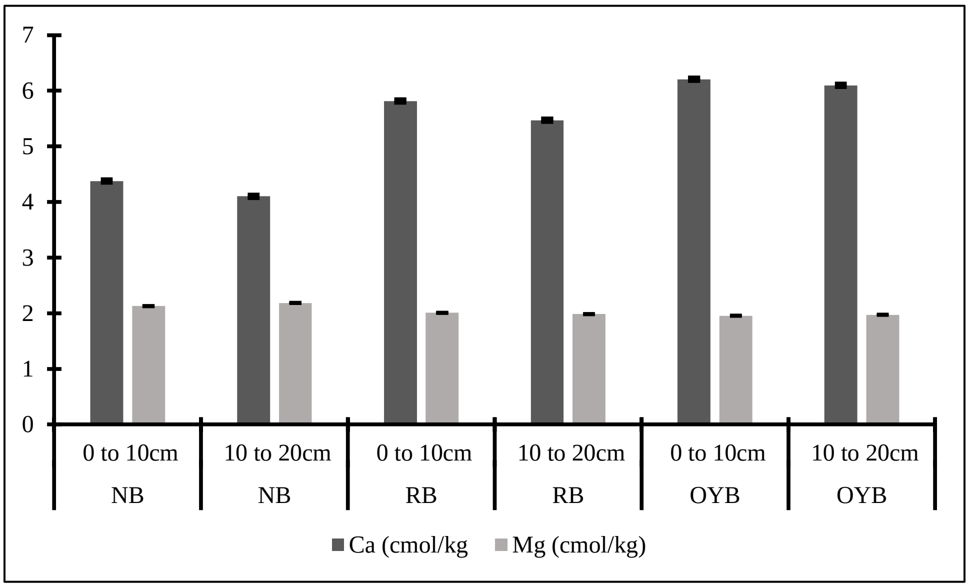

Figure 2: Mean Ca and Mg of different burning regimes

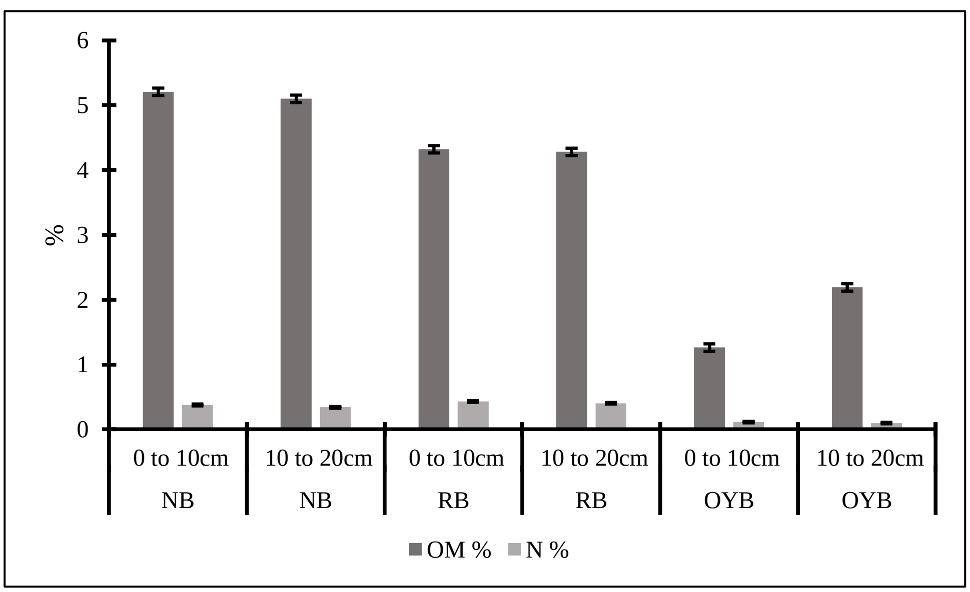

Figure 2: Mean SOM and N of different burning regimes

4.2 Discussions

4.2.1 Soil Chemical Properties

From figure 1, soil pH was lowest in soils that were recently burnt while soil after one year of burning had the highest pH.The pH of the recently burnt soil is slightly lower than that of soils that are unburnt. One year after burning, pH of the soil increases significantly. The lower pH in recently burnt soils could be attributed to the addition of acidic fertilizers such as Di-ammonium Phosphate that which leads to addition of more H^+ leading to an increase in pH. Most research results show that immediately after burning, soil pH increased significantly (Heydari et al. 2017; Li et al., 2014). Researchers do attribute the increase in soil pH to the combustion of organic matter and production of ashes (Li et al., 2014).

The increased pH one year after burning supports results from several authors who found increasing pH with increased pre burning time (Meigs et al 2009; Granged et al., 2014). Arocena and Opio (2003) also reported that soil pH increased by 2 or 3 pH units for two or three years after fires, and Rhoades et al. (2004) found that soil pH was higher in logged burnout areas for more than three years after combustion of downed logs compared with adjacent soil. Arocena and Opio (2003) attribute the increased pH to losses of un-dissociated organic acids in the litter and soil by combustion and their removal from the system. However, Li et al. (2014) attributed the increased pH after one year to the recovery period of one year, removal of removal of ashes by wind or rainfall (Jordán et al., 2010) could contribute to the increase in pH. In addition, the higher pH of the soils from 10-20cm depth compared to those of 0-10cm depth after one year could be attributed to the leaching of alkaline metals from the ash into the soil complex and the associated consumption of hydrogen ions in the formation of water could result in an increase in pH of the lower layer (Granged et al., 2011).

Burning significantly reduced the SOM content of the soil for the recently burned site. Organic matter content continued to reduce even one year after burning with more SOM in the 10-20cm depth than in the0-10cm depth. The reduction in soil organic matter could be attributed to the destruction of organc matter by the intense heat of burning. The soil microorganisms that help to decompose the organic matter on the soil surface are destroyed by the fire leading to a reduction in SOM in the soil. Results from this study are inconsistent with those from other burning study who observed an increase in soil organic matter on year from 0-1 year after burning (Lii et al., 2014; Zhang et al., 2011). This is attributed to the result of biochemically protected unburned residues being incorporated into the mineral soil and an increase in recalcitrant SOM, which slows SOM decomposition (Scharenbroch et al., 2012). Burning destroys the soil surface vegetation and litter increasing the possibility of erosion on the surface (Doerr et al., 2000). This could be the reason for the lower SOM for the 0-10cm layer compared to the 10-20cm soil layer.

Total N followed a similar trend as that of SOM matter as most of the nitrogen is contained in the SOM (Buse and Debano 2005). N content was higher for the unburnt site and in the top 10cm layer due to the higher SOM available in the soil. SOM content was highly correlated (r=0.8889) to N level in soil. However, after burning, the soil N content increased in the recently burnt site. The increased N could be attributed to the release of the inorganic nitrogen that s produced as a results of burning (Scharenbroch et al., 2012). The released N is highly susceptible to leaching if not protected or taken up by the plant (Wallbrink et al., 2005). This explains the reduction in N levels one year after burning.

The increase in the available P level in the recently burnt site was significant. According to Scharenbroch et al. (2012), burning significantly increases the available P by converting soil P to orthophosphate and has a positive effect on available P. the added P is majorly from the burnt organic litter on the soil surface that leads to an increase in available P. however, with high rainfall intensities and erosion, nutrients in the ash are washed away from the soil leading to a reduction in available P one year after burning. Results from this study support those of Lii at al. (2014) who also found an immediate enrichment in available phosphorus after burning.

The concentration of K and Mg is significantly lower in recently burnt site. However, one after burning, the concentrations of K in the soil increased to more than the initial level. K concentrations were also higher in the top 10cm soil depth compared to the 10-20cm depth. Results from this study dissent those of Zhang et al. (2011) who found that concentrations of exchangeable cations increased significantly immediately after burning. The variations in the cation concentration in the soil could be attributed to the changes in cation exchange capacity of the soil immediately after burning. SOM provides a significant number of cation exchange sites in the soil. The destruction of SOM by burning therefore reduces active exchange sites leading to a lower concentration of cations after burning. Further, the significantly higher Ca concentrations in recently burnt and one year after burning could be attributed to the ash that is deposited on the soil by burning. According to Khan and Qasim (2008), the ash deposited by burning is rich in cations such as Ca. This further explains the higher concentrations of Ca in the top soil layer compared to the 10-20cm soil layer.

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CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

In summary, it is clear from this study that burning regimes in sugarcanes have a significant impact on Soil chemical;

i. SOM, N, P, K, Ca and Mg were also significantly affected by burning regimes in sugarcanes. Unburnt soil had a significantly higher SOM and N content while soils one year after burning had the lowest SOMand N content. The level of P and Ca were significantly higher in soils immediately after burning while the concentration of K and Mg was lower in recently burnt soils compared to unburnt soils. in the burned soil compared with the unburned soil, and they also significantly decreased along the burned time-span.

Results from this study do indicate that even a slight burning before harvesting sugarcanes would lead to long-term changes in physical and chemical properties. It is therefore recommended that;

i. Further studies be conducted to track the long term effects of burning that is used by farmers before harvesting sugarcanes.

ii. Reduces use of burning method of harvesting to more ecologically friendly methods. Methods that do not involve burning before harvesting should be used by farmers to prevent such long term effects of burning on soil quality.

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APPENDICES

Appendix 1: Analysis of variance significance levels (two-way ANOVA) for treatment effects (different burning regimes) on physical and chemical soil properties

			Significance	
Soil Properties	Variables	Df	Treatment	Treatment. Depth
Chemical Properties	pH	2	<0.001**	<0.001**
	OM %	2	<0.001**	<0.001**
	N %	2	<0.001**	0.095ns
	P (ppm)	2	<0.001**	0.175ns
	K (cmol/kg)	2	<0.001**	<0.001**
	Ca (cmol/kg)	2	<0.001**	<0.001**
	Mg (cmol/kg	2	<0.001**	<0.001**
Physical properties	Clay %	2	<0.001**	<0.001**
	Sand %	2	<0.001**	<0.001**
	Silt %	2	<0.001**	<0.001**

** significant ns-not significant at P<0.05