EVALUATION OFSELECTED MANAGEMENT PRACTICES CONTRIBUTING TO PRIMARY SOIL GREENHOUSE GAS FLUXES IN SMALLHOLDER SUGARCANE FARMING IN LOWER NYANDO, WESTERNKENYA

BY

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THEDEGREE OF MASTER OF
SCIENCE IN CHEMISTRY

SCHOOL OF PHYSICAL AND BIOLOGICAL SCIENCES
MASENO UNIVERSITY

DECLARATION

This thesis is my original work and has not been presented for a degree award in Maseno University or in any other University.

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ACKNOWLEDGEMENT

I am grateful to the Almighty God for the inspiration, protection and guidance during the research period. I also sincerely thank the following organizations for their support and provision of funds to undertake this MSc degree: Climate, Agriculture and Food Security (CCAFS), Climate Food and Farming Research Network (CLIFF) for grants and Center for International Forestry Research (CIFOR). My acknowledgements also go to my supervisors especially Prof. P. Okinda, Dr. Mariana C. Rufino, and Dr. Sylvia Opiyo whose continuous support and encouragement led to the completion of this research work and thesis. Sincere gratitude to CIFOR and Standard Assessment of Mitigation Potentials and Livelihoods in Smallholder Systems (SAMPLES)laboratory staff and all field assistants of World Agro-Forestry Centre (ICRAF) for their support during the research period. Finally, I thank my family and friends for their encouragement during this study period.

DEDICATION

To my dear mother Zilpa Akumu Ogalo, daughter Marion Okombo, sons Powell Okombo, Warren Okombo and beloved husband Naaman O. Okombo.

ABSTRACT

Human activities (including agriculture) contribute to enhance release of primary greenhouse gases (GHGs) (CH_4, CO_2, N_2O) into the atmosphere leading to global warming. Sugarcane is an important economic crop in Kenya being third highest contributor to gross domestic product (GDP) after tea and coffee. About 90% of Kenya's production is contributed by smallholders. To improve/maximize sugarcane yields, farmers convert natural vegetation to sugarcane farms; apply nitrogen fertilizers; retain residues *in-situ* to return nutrients, and organic carbon to the soil or burn residues to ease management. High GHGs emissions have been observed in temperate countries due to such agronomic activities. However, contribution of these activities to GHGs fluxes in smallholder sugarcane sector in tropical countries, especially along the equator is not documented. This study evaluated contribution of smallholder sugarcane farming management practices to GHGs fluxes in Lower Nyando, western Kenya and compared fluxes with those from high agronomic input large-scale sugarcane farming in temperate countries. Cross-sectional survey in Lower Nyando Block revealed that smallholder sugarcane growers' management practices included; period of land conversion to sugarcane farming, nitrogen fertilization and trash management. From survey, six sugarcane farms:-three with less than and three with more than 10 years conversion period to sugarcane production were selected to conduct trials on soil GHG flux measurement. Each farm was subjected to burned and unburned treatments with three rates of nitrogen fertilizer 0, 50, 100 kg N / ha/ year in factorial three design in randomized complete block design arrangement, replicated three times in three separate farms. Soil gas samples were collected weekly for 37 weeks and analyzed using gas chromatography. There was CH_4 absorption in all treatments. Conversion period from natural vegetation/other cropping systems to sugarcane cultivation did not influence GHGs fluxes. Nitrogen fertilization and burning residues increased ($p \leq 0.05$) N_2O and CO_2 emissions between weeks 12 to 14 and 3 to 10 respectively. Cumulatively, treatments did not cause significant differences in GHGs fluxes. Levels of GHGs fluxes were much lower than those from large-scale sugarcane production systems in temperate countries. The low levels indicate use of Tier 1 factors to estimate GHG emissions in the tropics may produce inaccurate data. The results demonstrated that smallholder sugarcane management systems in Lower Nyando Block do not contribute significantly to GHGs emissions and hence climate change. Farmers can continue with these management practices to limit GHGs emissions to mitigate climate change.

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LIST OF ABBREVIATIONS AND ACRONYMS

AOA	Ammonia oxidising archea
AOM	Ammonia oxidising bacteria
AOM	Anaerobic oxidation of methane
ANOVA	Analysis of variance
CCAFS	Climate, Agriculture and Food Security
CIFOR	Center for International Forestry Research
CLIFF	Climate, Food and Farming Research Network
CO_2	Carbon (IV) oxide dioxide (Carbon dioxide)
ECD	Electron Capture Detector
EF	Emission Factor
FID	Flame Ionization Detector
GC	Gas chromatography
Gt	Gigatonnes
GWP	Global warming potential
GDP	Gross domestic product
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
LUC	Land use change
CH_4	Methane
Mt	Metric tonnes
N_2O	Nitrous oxide
PVC	Polyvinyl chloride
RCBD	Randomized Complete Block Design
SOC	Soil organic carbon
SOM	Soil organic matter
SAMPLES	Standard Assessment of Mitigation Potentials and Livelihoods in Smallholder Systems
SRB	Sulphate - reducing bacteria
TAR	Third Assessment Report
ICRAF	World Agro Forestry Centre

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Parts of the earth's atmosphere of the right thickness acts as insulating blanket, trapping solar energy to keep the global temperature in suitable range. The 'blanket' is a collection of atmospheric gases called 'greenhouse gases' (GHGs) based on the idea that the gases also 'trap' heat like the walls of a greenhouse. GHGs absorb and emit radiation within the thermal infrared range (IPCC, 2007). The rise in greenhouse gases (GHGs), since the late 19th century has been of anthropogenic origin. According to the third Assessment Report (TAR) of Inter governmental Panel on Climate, the increase in the concentration of GHG in the atmosphere (for example, CO_2 by 29%, CH_4 by 150%, and N_2O by 15%) in the last 100 years, has caused mean surface temperature to rise by 0.4 – 0.8ºC globally (Sharma *et al.*, 2006). Precipitation has become spatially variable and the intensity and frequency of extreme weather events have increased. The sea level has witnessed an average annual rise at rate of 1 – 2 mm during this period. The continued increase in concentration of GHGs in the atmosphere has caused climate change resulting in large changes in ecosystems, leading to possible catastrophic disruptions of livelihoods, economic activity, living conditions and human health (Sharma *et al.*, 2006).

Agriculture is directly responsible for 14% of annual GHG emissions and induces an additional 17% GHGs emission through land use change, mostly in developing countries (Vermeulen *et al.,* 2012). Agricultural intensification and expansion in the developing countries is expected to catalyze the most significant relative increases in agricultural GHG emissions over the next decade (Smith, 2008; Tilman *et al.,* 2011). Farms in the developing countries of sub-Saharan Africa and Asia are predominately managed by smallholders, with 80% of land holdings smaller than ten hectares (FAO, 2012). Smallholder farming therefore may significantly impacts the GHG balance of these regions. Usually, smallholder farming systems are characterized with low agronomic inputs. However, the effect smallholder farming has on the earth's climate system is limited. Data quantifying existing and reduced GHG fluxes from the smallholder farming systems are available for only a handful of crops, livestock, and agro ecosystems (Herrero *et al.,* 2008; Verchot *et al.,* 2008; Palm *et al.*, 2010). Indeed , fewer than fifteen studies of nitrous oxide emissions from soils have taken place in sub-Saharan Africa, leaving the rate of emissions virtually undocumented (Rosenstock *et al*., 2013). Due to a scarcity of data on GHG sources and sinks, most developing countries currently quantify agricultural emissions and reductions using IPCC Tier 1 emissions factors. However, current Tier 1 emissions factors are either calibrated to data primarily derived from developed countries, where agricultural production conditions are dissimilar to those in which the majority of smallholders operate, or from data that are sparse or of mixed quality in developing countries (IPCC, 2006). The farming in developed countries is characterized with intensive agronomic inputs and high level of mechanization. For the most parts, there are insufficient emissions data characterizing smallholder agriculture for use to evaluate the level of current emissions estimates (Rosenstock *et al.*, 2013). Furthermore, data describing smallholder farming systems, their relative distribution in space and time, and typical management practices are largely unavailable for smallholder agriculture in developing counties. It is therefore not clear if use of Tier 1 emissions data is relevant and accurate under tropical smallholder agricultural systems.

Climate Change, Agriculture and Food Security (CCAFS) carried out household baseline surveys in seven villages, with 139 households, in the Katuk – Odeyo CCAFS bench mark site, located in the Lower Nyando River Basin, in western Kenya. The survey revealed that majority (90%) of surveyed households in Lower Nyando produce food crops mainly maize, sorghum and beans, while only 16% produce some type of cash crops (coffee, tea, sisal, sugarcane and others) and most of them rely on livestock production for their livelihood (Mango *et al.*, 2011).. Most of the households work in sugarcane plantations in the neighboring communities within the Lower Nyando site (Mango *et al.*, 2011). In Nyando, sugarcane is ranked as the most important cash crop (Wawire *et al.*, 2006; Odenya *et al.*, 2007). Sugarcane crop can produce large amount of biomass under tropical and high input conditions (Robertson *et al.* 1996). Burning and decomposition of above and below ground biomass releases CO_2 to the atmosphere (Guo and Gifford, 2002). Loss of carbon as CO_2 in turn, affects soil properties, soil structure and long-term soil fertility potentially modifying soil GHG emissions. Sugarcane production requires substantial amounts of nitrogen fertilizer, may result in N_2O emissions from soils (Thornburn *et al.*, 2009). These GHG emissions are the sources of anthropogenic climate change (Lal, 2004). However, there has been no survey of sugarcane management practices by smallholder sugarcane farmers contributing to GHG emissions in Lower Nyando.

When previously uncultivated land is brought into production, the expansion of cropped area can result in GHG emissions, as carbon is released from vegetation and soil organic matter (Kindred *et al.*, 2008). The observed increase in atmospheric concentration is not only a result of fossil fuel combustion but also of volatilization of carbon stocks following conversion from natural to agricultural land (IPCC, 2007). When an ecosystem is transformed to crop land, GHGs, especially CO_2 emission occur during land clearing and land preparation through biomass burning and/or decomposition (Agus *et al*., 2009). The amount of carbon stock of the biomass of initial land use determines the amount of CO_2 emissions associated with land clearing and land preparation (Agus *et al*., 2009). The change in soil carbon content is determined by factors such as soil tillage and organic matter input. Therefore, with the assumed initial carbon stock of 120 ± 60 t/ha in the forest soil, the reduction can be up to about 40.8 ± 20.4 t / ha when the land is converted to plantation (Agus *et al*., 2009). Conversion of primary forests to plantation results in average CO_2 emissions ranging from 40 tons /ha/year for rubber to 49 t / ha / year for sugarcane in Indonesia. This is because sequestrations by the plantation crop as biomasses are too small to compensate for the loss of carbon from the initial land use biomass (Agus *et al*., 2007). Conversion of secondary forests to oil palm, coconut, rubber, coffee agro forestry, or cocoa results in the net CO_2 emission of less than 12 t / ha / year. Conversion of secondary forests to *Jatropha*, tea or sugarcane results in a much higher CO_2 emission ranging from 15 to 18tonns/ha/year (Agus *et al*., 2007) in Indonesia. However, these data were quantified in temperate countries whose conditions are vastly different from those observed along the equator. Because of the increased demands in crop production, the high population growth rate and the economic dependence on agriculture, large forest areas in Kenya have been and are being replaced by major cash crops such as sugarcane (Agroforestry, 2009). Most of the sugarcane expansions are taking place in the smallholder sector. However, it is not known how the conversion of forest lands to sugarcane with time influences GHGs fluxes under smallholder ecosystems with time along the equator in Kenya and how these compare with results observed in temperate countries.

Sugarcane production requires substantial amounts of nitrogen fertilizer. This may result in N_2O emissions from soils (Thornburn *et al*., 2009). However, there are relatively few studies in N_2O emissions from sugarcane and most of the studies have been made in Australia (Weier *et al*., 1996, Weieret *al*., 1998; Demead *et al*., 2008; Wang *et a*l., 2008; Macdonald *et al*., 2009). Despite widespread use of nitrogen fertilizer in sugarcane production, influence of nitrogen on GHGs fluxes has not been assessed in the tropical areas.

Among the main practices that have caused concerns in sugarcane agricultural areas are the harvest systems, which in most regions are still based on residues burning. Sugarcane residues represent 11% of the worldwide agricultural residues (IPCC, 1996) and while sugarcane areas have increased rapidly, limited studies have quantified its impact on air quality due to the land use (Oliveira *et al*., 2007; Cancado *et al.,* 2006; Goldemberge *et al*., 2008). Post harvest burning is done to clean fields and to facilitate ratooning operations (Mendoza, 2014). Substantial losses of carbonand nitrogen due to sugarcane burning have been reported (Ball-Coelho *et al*., 1993). Burning also destroys the rotting organic matter in the sugarcane soils. This may influence GHG fluxes in harvested cane farms. In contrast, green harvesting, without burning, keeps large amounts of crop residues in the soils surface (Cerri *et al*., 2007). Retention of unburned residues can increase nutrient conservation, reduce weed growth and conserve soil moisture (Wiedenfeld, 2009). However, the retained mulch makes tillage operations more difficult, interfere with fertilizers and herbicide application and can immobilize nitrogen and phosphorus (Ng Kee Kwong *et al*., 1987). Incorporation of residues into the soil is difficult and energy consuming, however in high rainfall areas, tropical warm areas, the trash can be left on the surface since it decomposes quickly (Spain and Hodgen, 1994). Residues left on the surface improve organic matter content and soil moisture holding capacity in the long term, compared to incorporation (Samuels *et al*., 1952). The decomposition of the organic matter is usually accompanied by production of GHGs fluxes. However, it is not documented how the organic matter left *in situ* or burning (trash management) in sugarcane farming influences GHG fluxes in the Western Kenya Sugar Belts, especially among the smallholder farmers.

1.2 Statement of the problem

Due to lack of data, Tier 1 emission factors developed under intensive input, large-scale agricultural systems in developed / temperate countries have been used to estimate the GHGs emission, even in the tropical environment under small scale farming systems. There is limited data on GHGs fluxes under low input smallholder agriculture in tropical countries. The use of the Tier 1 factors may therefore be over or under estimating the GHGs emissions in the tropical smallholder agricultural systems. Smallholder farm management practices are characterized with low agronomic inputs. Although sugarcane cultivation under large scale intensive farming system may be different, survey of management practices by smallholder sugarcane farmers in Lower Nyando that may influence GHG fluxes is not documented. Conversion from forests to sugarcane can result in variations in the GHGs fluxes, especially higher CO_2 emissions compared to other crops. The conversions are still continuing in Lower Nyando. This may be causing changes in the GHGs fluxes in lands converted to sugarcane farming from other activities. Smallholder sugarcane farmers apply varying amounts of nitrogen fertilizers to improve yields. Although the use of nitrogen fertilizer cause GHG fluxes, the contribution of nitrogen fertilization to GHGs fluxes in Lower Nyando has not been quantified. Among the main practices that have caused concern in sugarcane agriculture is the harvest system / trash management, which in most regions is still based on residue burning or retention of crop residues in the fields. Post harvest burning cleans fields and facilitates ratooning operations. Retention of crop residues increases nutrient conservation, reduce weed growth and conserve soil moisture. On other crops and under intensive high agronomic input sugarcane production systems, retention of crop residues and / or burning the residues cause changes in the GHGs fluxes. However, effects of post harvest trash management under low agronomic inputs smallholder sugarcane production systems in Lower Nyando have not been established.

1.3Research objectives

1.3.1 Broad objective

To assess management practices influencing primary soil GHG fluxes in smallholder sugarcane farming in Lower Nyando.

1.3.2Specific objectives

1. To identify sugarcane management practices that may influence GHG fluxes in Lower Nyando and compare the fluxes with those observed under high input large scale sugarcane production systems in developed countries.
2. To evaluate the contribution of the duration of conversion from natural vegetation to sugarcane production on primary soil GHGs fluxes in Lower Nyando and compare the fluxes with those observed under high input large scale sugarcane production systems in developed countries.

3. To determine the contribution of nitrogen fertilization on primary soil GHGs fluxes in Lower Nyando and compare the fluxes with results from large scale sugarcane production systems.
4. To establish the contribution of trash management on primary soil GHGs fluxes in Lower Nyando and compare the values with GHGs fluxes from other agricultural crops in developed countries.

5. To evaluate if Tier1 emission factor is relevant in estimating GHGs fluxes under tropical low input smallholder sugarcane productions systems.

1.3.3 Research question

Which smallholder sugarcane production practices have potential to contribute to soil greenhouse gas fluxes?

1.3.4Null hypotheses (H_o)

1. Time from conversion from natural vegetation to sugarcane farming has no influence on soil GHGs fluxes in Lower Nyando and GHGs fluxes are not equivalent to those observed under high input large scale sugarcane production systems in developed or temperate countries.

2. Nitrogen fertilization does not influence primary soil GHGs fluxes in Lower Nyando and the levels do not match those from large production systems in developed countries.
3. Trash management has no effect on primary soil GHGs fluxes in Lower Nyando and GHGs fluxes under small scale agricultural systems are not equivalent to those under large scale high input agricultural systems.
4. Tier 1 factors are not appropriate / accurate in estimating the GHGs fluxes under tropical small scale sugarcane production systems.

1.4 Justification of the study

Continued use of Tier 1 emission factor from developed countries in tropical agricultural system may be causing inaccurate estimations of GHGs fluxes under smallholder agricultural systems leading to wrong policies on mitigating climate changes. Data that will lead to accurate estimation of the contribution of smallholder farming system will help in development of appropriate policies to mitigate climate change. Smallholder sugarcane farming is associated with management practices that may be associated with soil GHG emissions. Continued increase in concentration of soil GHGs in the atmosphere leads to climate change leading to possible catastrophic disruptions of livelihoods, economic activity, living conditions and human health. Small-scale sugarcane production may be releasing huge amounts of soil GHGs that could be contributing to climate change. This research may produce data leading to formulation of policies on smallholder sugarcane farming to create mitigation options of climate change in Lower Nyando, western Kenya.

1.5 Limitation of the study

- **i.** Soil-atmosphere GHG emission are highly variable in time (so-called time moments). Therefore, there were challenges in obtaining reliable estimation of the GHG emissions. For example missing hot moments (short-lasting pulse emissions) would result in underestimations of the total GHG emissions. On the other hand, detecting an emission pulse and extrapolating this value to periods between measurements may lead to overestimation of fluxes.

ii. Soil-atmosphere GHG emissions are highly variable in space with coefficient of variations over 100% within several meters (Arias-Navarro *et al*., 2013). In addition, complexity of the system in terms of patchy land covers and heterogeneous physiography contributes to source of variability. Therefore, there was a challenge in accurately studying GHG emissions.

CHAPTER TWO

LITERATURE REVIEW

Over the past 50 years, average surface temperatures have increased by approximately 0.2 °C per decade (SA DNT, 2010). The increase has been attributed to GHG emissions, causing climate change. Greenhouse gas emissions and climate change are therefore demanding increased research attention (Rein, 2010) in order to mitigate carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) emissions into the atmosphere. CO_2, N_2O and CH_4 differ in atmospheric lifespan and thus have different GHG potencies. Carbon dioxide is the least potent of the three and is the GHG against which all other GHGs are compared. Nitrous oxide and CH_4 are considered 296 and 23 times more potent than CO_2 respectively, over a 100-year period (Dalal *et al*., 2003). These values are referred to as global warming potentials (GWPs) and are used to convert emissions into carbon dioxide equivalents (CO_{2eq}). A number of studies have shown that human activities (including agriculture) contributed to enhanced release of GHGs into the atmosphere and accelerated climate change (Weier *et al*., 1998; Park *et al*., 2003). Agriculture contributes significantly to anthropogenic emissions of carbon dioxide, methane, and nitrous oxide. Land-use changes related to agriculture especially in the tropics, including biomass burning and soil degradation, are also major contributors (IPCC, 1994). These GHGs cause global warming / climate change. There is evidence that human activities that emit greenhouse gases cause global warming / climate change (IPCC, 2007).

All countries that are party to the United Nations Framework Convention on Climate Change (UNFCCC) are required to provide national inventories of emissions and removals of greenhouse gases due to human activities. These inventories form the basis for monitoring the progress of individual countries in reducing emissions and for assessing the collective effort of countries to mitigate climate change. The inventories provide self-reported estimates of selected anthropogenic greenhouse gases for four sectors: energy; industrial processes and product use; agriculture, forestry, and other land use and waste. Countries prepare the estimates using methods developed by the Intergovernmental Panel on Climate Change (IPCC) and approved by the UNFCCC (UNFCCC, 2010).

UNFCCC reporting and review requirements for national inventories differ for developed (Annex I) and developing (non-Annex I) countries. As a result, the scope and quality of national inventories vary greatly. Developed countries annually report calendar-year estimates for all sources and sinks of the six greenhouse gases specified by the UNFCCC (carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, per fluorocarbons, and hydro fluorocarbons going back to 1990 (UNFCCC, 2010). Reporting requirements are much less rigorous for developing countries. Emission inventories are reported only periodically in conjunction with a broader national report of climate change programs and activities. There is no set frequency for these national reports and their submission often depends on the provision of international funding. As a result, most developing countries have submitted only one national inventory to date. Reporting of only CO_2, CH_4, and N_2O is required and only at the sector level, not for categories within each sector. Developing countries are not required to provide emissions trends over time or to document methods and data sources, and their inventories are not reviewed (UNFCCC, 2010).

The IPCC methodologies are intended to yield national greenhouse gas inventories that are transparent, complete, accurate, and consistent over time, and comparable across countries. Because different countries have different capacities to produce inventories, the guidelines lay out tiers of methods (typically three) for each emissions source, with higher tiers (Tier 3 is normally the highest) being more complex and / or resource intensive than lower tiers. The higher-tier methods usually incorporate country-specific conditions, data, and emission factors and are thus considered more accurate than the lower-tier methods. The Tier 1 method uses default emission factors whereas the Tier 2 method requires each country to develop and use country-specific emission factors. The Tier 3 method uses emission factors that are not only country-specific, but also differentiated by technology and operating conditions. Countries are not expected to use higher-tier methods if doing so would jeopardize their ability to estimate other important emissions sources (UNFCCC, 2010).

The IPCC Tier 1 method for fertilizer induced emissions. Most biofuel Life – Cycle Assessment studies apply the Tier 1 method from the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) to account for direct N_2O emissions from fertilizer application. The IPCC has proposed that 1% of all nitrogen applied to the soil, either in the mineral or the organic form, is directly emitted in the form of N_2O. However, this factor proposed by the IPCC is rather broad and is subject to large variations due to the local conditions of each study and to the different forms of nitrogen applied to the soil. However, several studies have indicated that the emission factor for the application of nitrogen fertilizers on agricultural soils proposed by the IPCC is overestimated (Dobbie and Smith, 2003; Jantalia *et al.*, 2008; Rochette *et al.*, 2004), especially when dealing with soils in regions with a tropical climate. The current IPCC Tier 1 approach for N_2O from agricultural soils, i.e. the default EF1 of 1%, does not account for effects of crop type, climatic conditions and crop management. As a result, the methodology omits factors that are crucial in determining current emissions, and has no mechanism to assess the potential impact of future climate and land-use change (Flynn *et al.*, 2005). Additionally, a Tier 1 approach does not provide many incentives to apply mitigation measures, since the effect is in many cases not expressed in the national GHG emissions inventory. The default value for EF_2 is 8 kg N_2O–N / ha / year for temperate climates. Because mineralization rates are assumed to be about two times greater in tropical climates than in temperate climates Alm *et al.*, 1999; Laine *et al.*, 1996; Martikainen *et al.*, 1995; Minkkinen *et al.*, 2002: Regina *et al.*, 1996; Klemedtsson *et al.*, 2002), the emission factor EF_2 is 16 kg N_2O–N /ha/ year for tropical climates (Klemedtsson *et al.*, 1999, IPCC, 2000). Despite an exhaustive data collection of N_2O field emissions all over the world (1978–2004) that was carried out to reduce the uncertainty in IPCC Tier 1, subtropical and tropical systems remain clearly underrepresented (Bouwman *et al.*, 2002, Stehfest and Bouwman 2006).

When applying the Tier 1 method to a consideration of the nature of sugarcane fields and cultivation patterns, it was assumed that:

1) The net CO_2 emission from soil is zero. This is because there is no carbon input into soil from agricultural activities except for leaves and cane top removed from the cane at harvesting, and the carbon absorption from the atmosphere into soil is negligible;
2) In general, CH_4 is primarily emitted from rice paddies and enteric fermentation in domestic livestock. CH_4 emission from sugarcane fields is negligible; and therefore
3) The primary GHG from soil during sugarcane cultivation is N_2O. Nitrogen sources are the nitrogen fertilizer and crop residues (i.e., cane top and leaves), as well as the nitrogen gas in the atmosphere fixed by the microorganisms (Fukushima *et al*., 2009).

IPCC tier 1 emission factor has been used to estimate N_2O emissions from nitrogen fertilizer and vinasse applied in the field (Macedo *et al*. 2008; Boddey *et al*. 2008; Galdos *et al*. 2010), however it is not well accepted to represent real emissions (Smith *et al*. 2012). N_2O emission factor for nitrogen fertilizer application to sugarcane of 3.87 %(3.87 kg of N_2O-N are emitted for each 100 kg of fertilizer nitrogen applied) but the estimate was a mean based on studies in Australia and Hawaii (Lisboa *et al*., 2011). Emission factors of 0.24% and 0.84% for the application of 60 kg /ha of ammonium nitrate and urea, respectively have been obtained in an area with sugarcane crops (Signor, 2010). Annual application of 46 kg of N/ ha in the form of vinasse has resulted in N_2O emission factors on the order of 0.68% and 0.44% for burnt and unburnt sugarcane areas, respectively. These emission factors are significantly lower than those proposed by the IPCC, which have been used as the standards in studies on the balance of GHG emissions during the production of ethanol (Oliveira *et al*., 2013). The average EF for nitrous oxide emissions in Mediterranean cropping systems was found to be 50% lower than the IPCC Tier 1 default value (1%), which is largely based on values observed in temperate regions (Cayuela *et al*., 2017).

Sugarcane is a commercial crop grown in tropical and subtropical regions ranging from hot dry environments at sea level to cool and moist environments at high elevations (Plaut *et al*., 2000). More than 20 million hectares of land are cropped with sugarcane, mostly as monoculture. There is intensive use of agricultural inputs such as fertilizer, herbicides, ripeners, to improve sugarcane production. Their use raises concerns about environmental impact issues and sustainability (Meyer *et al*., 2011). Certain field practices such as cane burning directly emits CO_2 and other greenhouse gases (GHG) methane, and nitrous oxide (Weir, 1998; Mendoza and Samson, 2000). Despite evidence that sugarcane production can emit GHGs to the atmosphere, levels of GHGs emissions due to sugarcane production practices have not been documented in the tropics.

2.1 GHG emissions due to conversion from natural vegetation to sugarcane cultivation

Fossil-fuel emissions are clearly the dominant factor responsible for the enhanced greenhouse effect (Forster *et al*., 2007), but land-use change (LUC) also leads to important additional greenhouse gas (GHG) exchanges between the atmosphere and the terrestrial biosphere (Houghton *et al*., 2012; Kirschbaum *et al*., 2013). Biomass burning and loss of soil carbon associated with the conversion of native ecosystems to agricultural use in the tropics is believed to be the largest non-fossil fuel source of CO_2 input to the atmosphere. Carbon dioxide is released from the soil through soil respiration, which includes three biological processes, namely microbial respiration, root respiration and faunal respiration primarily at the soil surface or within a thin upper layer where the bulk of plant residue is concentrated (De Jong *et al*., 1974; Jorgensen *et al*., 1973; Edward, 1975) and one non-biological process, i.e. chemical oxidation which could be pronounced at higher temperatures (Bunt *et al*., 1954). Soil micro flora contributes 99% of the CO_2 arising as a result of decomposition of organic matter (Reichle *et al*., 1975), while the contribution of soil fauna is much less (Macfadyen, 1963). Root respiration, however, contributes 50% of the total soil respiration (Macfadyen, 1963). The net release of CO_2 from land-use conversion is thought to be in the range of 1.6 ± 1.0 Gt C / yr (IPCC, 1994). Of the carbon losses attributed to land use, soil carbon loss has been estimated to account for 20–40% (Detwiler, 1986; Houghton and Skole, 1990).

Recent data, however, suggest that soil carbon losses following deforestation may have been overestimated, particularly for forest conversions to pasture, where soil carbon can recover to levels equal to or higher than native forest within a few years (Lugo and Brown, 1993; Cerri *et al*., 1994). Globally, 13 million hectares were deforested annually between 1990 and 2009 (FAOSTAT, 2013), with annual mean global carbon emissions from land-use change estimated to be 4.0 Gt CO_2/year between 1980 and 2000 (Houghton *et al*., 2012) and 4.1 Gt CO_2/year between 1870 and 2013 (Le Quéré *et al*., 2013). Such land use changes may have large environmental impacts, including changes in the net flux of CO_2, CH_4 and N_2O through altered biogeochemical processes (Forster *et al*., 2007; Kirschbaum *et al*., 2012; Wang *et al*., 2012). The enhanced greenhouse effect is currently dominated by the increase in CO_2 concentration, which contributes a radiative forcing of about 1.66 W m^{-2}, and increases in CH_4 and N_2O add a further 0.48 W m^{-2} and 0.16 W m^{-2}, respectively (Forster *et al*., 2007). With on-going concern about global climate change, the effect of LUC on the emission of all these GHGs needs to be critically established.

The effect of LUC on CO_2 fluxes is directly related to changes in soil organic carbon (SOC) and carbon in vegetation since any loss of biospheric carbon stocks increases atmospheric CO_2. Soil organic carbon stocks are representing the largest terrestrial organic carbon pool (41550 Pentagram of C) followed by the vegetation pool (500–650 Pentagram) (Lal, 2008). The capacity of soils to store carbon is affected by land use and management (Trumbore, 1997; Lal, 2003). Conversion from primary forest and secondary forest to cropland resulted in SOC loss of 35.3 ± 4.9% and 50.6 ± 3.4%, respectively, and most SOC losses occurred over the initial 10 years after conversion. The pattern is usually considered to be linked to intensive agricultural land management, including soil disturbance so that croplands lose SOC until a new balance between carbon inputs and outputs is re-established (Kim *et al*., 2010). Switching between different agricultural land-use types, such as between cropland and grassland, also showed clear patterns in SOC changes. Converting cropland to grassland increases SOC by nearly 50%, whereas converting grassland to cropland decreases SOC by about 45% and is largely completed within the first 10 years after conversion. This difference is usually attributed to loss of SOC in cropland due to cultivation and soil disturbance (Mann, 1986; Lal, 2004). Any changes in land use and management may feedback on SOC and nitrogen dynamics potentially altering stocks. Thus, CO_2 emission resulting from clearing of land for the expansion of sugarcane production may represent one of the major sources of GHG emissions. In Brazil, the increasing demand for bio ethanol from sugarcane led to a continuous expansion of land for sugarcane production. About 69% of the most recent sugarcane expansion in Sa˜o Paulo state took place on pastures, 17% in annual crops (soybean and corn) and 2.2% on new lands. For Mato Grosso state, 31% of sugarcane expansion occurred on pasture, 68% on former arable land cultivated with soybean and 1.3% on new lands (CONAB, 2008). Conversion of natural vegetation to croplands in East Africa has been ongoing (Brink *et al*., 2014). However, CO_2 emissions resulting from clearing land for sugarcane cultivation in Kenya have not been documented.

The effect of land-use change on CH_4 fluxes is related to any soil processes that produce or consume CH_4. Possible mechanisms for CH_4 emission from soil to the atmosphere include i) diffusion of dissolved CH_4 along the concentration gradient, ii) release of CH_4-containing gas bubbles (ebullition), and iii) transport *via* the aerenchyma of vascular plants (plant-mediated transport).These three mechanisms control the spatial and temporal variations in CH_4 production(Lai, 2009). The first process, diffusion, takes place because of the formation of a CH_4 concentration gradient from deeper soil layers, where the production of CH_4 is large, to the atmosphere, while oxidation of CH_4 occurs in upper layers (10%-40% in rice paddies) (Kruger *et al.*, 2002; Lai, 2009). Diffusion is a slow process compared to the other two transport mechanisms, *i.e*., ebullition and plant-mediated transport, but it is biogeochemical important because it extends the contact between CH_4 and methanotrophic bacteria in the upper aerobic layer, promoting CH_4 oxidation (Whalen, 2005).

The net CH_4 flux in the soil is the result of the balance between methanogenesis (microbial CH_4 production mainly under anaerobic conditions) and methanotrophy (microbial CH_4 consumption) (Dutaur and Verchot, 2007; Kirschbaum *et al*., 2012). Methanogenesis occurs via the anaerobic degradation of organic matter while methanotrophy occurs by methanotrophs metabolizing CH_4 as their source of carbon and energy (Hanson and Hanson, 1996). Methane undergoes chemical and photochemical oxidations in the atmosphere and stratosphere, and their products, mainly the hydroxyl radical, have a direct or indirect effect on the global warming (Saarnio *et al.*, 2009). However, biological oxidation of CH_4 is of great importance for the global CH_4 balance. Biological CH_4 oxidation is done by methano- trophic microorganisms (methanotrophs), either aerobic methanotrophic bacteria or a consortium of anaerobic archaea in association with anaerobic bacteria (anaerobic CH_4 oxidation) (Ettwig *et al.*, 2010).

Although anaerobic oxidation of CH_4 (AOM) has been described, it is not well understood so far, but it is considered to contribute substantially to the reduction of CH_4 globally (Orphan *et al.*, 2002). It is estimated that more than 50% of the gross annual production of CH_4 in the oceans is consumed by anaerobic methanotrophs, before it diffuses to the atmosphere (Offre *et al.*, 2013). The mechanisms proposed for this process are reverse methanogenesis, acetogenesis, and methylogenesis (Caldwell *et al.*, 2008). The most investigated mechanism is the reverse reaction of methanogenesis, which takes place when sulfate-reducing bacteria (SRB) deplete the concentration of hydrogen, thus CH_4 concentration becomes higher than that of hydrogen, making the reverse reaction thermodynamically possible, *i.e.*, oxidation of CH_4 to CO_2(Caldwell *et al.*, 2008; Wendlandt *et al.*, 2010). This process is also called sulfate-dependent CH_4oxidation, which is done by archaea in a syntrophic association with SRB and the formation of hydrogen is a key step (Valentine and Reeburgh, 2000). One mechanism proposed for this process is as follows:

$CH_4 + 2H_2O \longrightarrow CO_2 + 4H_2$ (CH_4 oxidation)

$SO_4^{-2} + 4H_2 + H^+ \longrightarrow HS^- + 4H_2O$ (sulfate reduction)

$SO_4^{-2} + CH_4 \longrightarrow HCO_3^- + HS^- + H_2O$ (Net)

On the other hand, a process of AOM coupled to nitrate reduction denitrification, has been described. In this process CH_4 is used as an electron donor for the needed reduction power (Islas-Lima *et al.*, 2004). The following equation has been proposed:

$5CH_4 + 8NO_3^- \longrightarrow 5CO_2 + 4N_2 + 8OH^- + 6H_2O$ $\qquad \Delta G = -960\ \text{kJ mol}^{-1}$

Where ΔG is the standard Gibbs free energy change.

Methanotrophs can be found in a variety of environments where an interface between oxic and anoxic conditions exists (Wendlandt *et al.*, 2010) i.e. including among others cold environments, and even from highly acidic and thermophilic environments (Semrau *et al.*, 2010).

Soils under native vegetation can be either sources or sinks of atmospheric CH_4 (Lisboa *et al.*, 2011). Generally, forest soils are the most active CH_4 sink followed by grasslands and cultivated soils (Topp and Pattey, 1997; Le Mer and Roger, 2001; Dutaur and Verchot, 2007). Most agricultural soils, due to frequent soil management mostly show little to no CH_4 uptake activity (Levine *et al.*, 2011, Tate, 2015). Conversion of forest to cropland or grassland tended to increase net CH_4 emissions, and conversion of cropland or grassland to secondary forest tended to decrease it (Kirschbaum *et al.*, 2012). While most well drained soils can act as either a sink or source of CH_4 (Price *et al.*, 2010), CH_4 oxidation generally tends to dominate, and changes in net fluxes tend to be mainly related to changes in a soil's CH_4 oxidation potential. Forests create favourable soil conditions for CH_4 oxidation that can remove ≈ 1–5 kg CH_4 ha^{-1} y^{-1} from the atmosphere (Smith *et al.*, 2000). However, it may take over 100 years to recover maximal CH_4 oxidation rates after disturbance by deforestation (Smith *et al.*, 2000; Allen *et al.*, 2009; Singh and Singh, 2012). Changed CH_4 fluxes after LUC are related to changes in the composition (Singh *et al.*, 2007, 2009) and abundance (Menyailo *et al.*, 2008) of the methanotroph communities, and various studies found increased CH_4 oxidation following a forestation was directly linked to a shift towards type-II methanotrophs (grow in the temperature range of 5-37 ◦C)(Singh *et al*., 2007; Dörr *et al*., 2010; Nazaries *et al*., 2011).

There are only a few studies covering tropical and subtropical regions in which CH_4 exchange rates were quantified. Published data is inconclusive for both net CH_4 uptake (Steudler *et al*., 1989; Keller and Reiners, 1994; Verchot *et al*., 2000; Kiese *et al*., 2008; Castaldi *et al*., 2006; Carvalho *et al*., 2009) and net CH_4 emissions from tropical and subtropical soils. For savannah, CH_4 fluxes could possibly range from 632 to 98 µg CH_4- C / M^{-2} / hour (Castaldi *et al*., 2004, 2006). In Australia, conversion from forest to cropland realized CH_4 emissions of 1.25 kg CH_4 / ha / year in Victoria (Galbally *et al*., 2010) and 4.88 kg CH_4 / ha / year in Queensland (Rowlings, 2010). In Indonesia, conversion form secondary forests to cropland realized CH_4 up take by the soil of 0.59 kg CH_4 /ha/year (Veldkamp *et al*., 2008). In East Africa, the extensive conversion of natural vegetation to croplands and rangelands has been ongoing for the last 20 years (Brink *et al*., 2014). However, CH_4 fluxes resulting from conversions of forests to cropland due to expansion of sugarcane production in Kenya are not quantified.

Conversion of forests to cropland or grassland tends to increase N_2O emissions, which is reversible when cropland or grassland is converted to secondary forests (Kirschbaum *et al*., 2012). Nitrogen input, land use and its management are the major controlling factors of N_2O fluxes in soils (Snyder *et al*., 2009; Smith, 2010; Kirschbaum *et al*., 2012).N_2O emissions are associated with the turnover of nitrogen in the soil (Bouwman, 1996; Kim *et al*., 2012). These natural processes have been intensified through human interventions, mainly through agricultural activities, and principally through the increased use of nitrogen fertilizers (Del Grosso *et al*., 2009; Kirschbaum *et al*., 2012; Kim *et al*., 2012). Changes in N_2O emissions following LUC can thus be principally related to changes in the amount of nitrogen inputs. Cropland and grassland usually receive larger nitrogen inputs than forests through applied organic and inorganic nitrogen fertilizers and animal excreta. Consequently, nitrification and denitrification processes are intensified, and more N_2O can be produced during N-transformation processes in the soil (Robertson and Tiedje, 1987; Bouwman, 1996; Kim *et al*., 2012). In addition, any increase in soil acidity due to excessive synthetic fertilizer use can increase N_2O emissions by decreasing N_2O reductase activity (Barak *et al*., 1997; Bulluck *et al*., 2002). Increased soil compaction by intensive soil management can further increase N_2O emissions by increasing the rate of denitrification (Bilotta *et al*., 2007).

Nitrification is performed by two functionally defined groups of microbes, referred to together as nitrifies. The first group of nitrifies is the ammonia oxidizers, which oxidize ammonia to nitrite. Ammonium is present predominantlyas the positively charged ion, ammonium (NH_4^+), but the enzyme responsible for the first step of the reaction uses the gaseous form, NH_3, which is usually a minor component at equilibrium. There are two very different groups of ammonia-oxidizing microbes. One is the well-known bacterial group (ammonia oxidizing bacteria, AOB), which includes a few different kinds of bacteria that all make a living by generating reducing power from the oxidation of ammonia and using that energy to fix carbon dioxide (Bock and Wagner, 2006). Ammonia is their only energy source, and their main metabolic product is nitrite. Nitrous oxide is a minor product of ammonia oxidation, and is produced by two different pathways.

A second distinct group of - ammonia oxidizing microbes has recently been recognized and brought into culture in 2005 (Konneke *et al.*, 2005). These are not bacteria, but archaea (ammonia-oxidizing archaea, AOA). Like AOB, AOA oxidize ammonia to nitrite and produce nitrous oxide and nitrite from ammonia, but the enzymatic pathways are quite different. Although the enzymes and pathways differ for the AOA and AOB, aerobic ammonia oxidation in both groups apparently proceeds by the same stoichiometry:

$NH_3 + 1.5O_2 \longrightarrow NO^-_2 + H_2O + H^+$

In addition to the net production of nitrite by the above equation, AOB are also capable of producing nitrous oxide (N_2O) by two distinct pathways. Most AOB investigated to date possess the genes and enzymes necessary for the partial denitrification pathway that reduces nitrite to nitric oxide (NO) and then to N_2O (Casciotti and Ward, 2001, 2005).

Both ammonia-oxidizing and denitrifying bacteria can carry out the reduction of nitrite to N_2O. For denitrifies, this is part of the usual pathway from nitrate to N_2:

$NO_3^- \longrightarrow NO_2^- \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$

For AOB, the pathway is analogous but includes only the steps:

$NO^-_2 \longrightarrow NO \longrightarrow N_2O$

Most of the N_2O produced by ammonia oxidation is probably produced by AOA via a so far undescribed pathway (Santoro *et al.*, 2011). Especially in low oxygen conditions, substantial nitrogen can be lost as N_2O. Not only is this nitrogen lost from the bioavailable pool, but it plays a very important role in the atmosphere as a greenhouse gas.

In contrast, conversion of cropland and grassland to forest is usually associated with reduced nitrogen inputs to soils, leading to less N_2O being produced in soils (Kirschbaum *et al.*, 2012). In Australia, conversion from forest to cropland realised N_2O emissions of 0.28 kg N_2O - N / ha / year in Victoria (Galbally *et al.*, 2010) and 4.70 kg N_2O - N / ha / year) in Queensland (Rowlings *et al.*, 2010). In Indonesia, conversions from secondary forest to cropland realised N_2O absorption of 1.40 kg N_2O - N / ha / year by the soils (Veldkamp *et al*., 2008). Extensive conversion of natural vegetation to croplands in East Africa has been ongoing (Brink *et al*., 2014). It is however, not known how conversions from natural forests to cropland contribute to N_2O fluxes in Kenya.

2.2GHG emissions due to fertilization of sugarcane fields

Fertilizer application is a regular practice in agricultural enterprises to increase biomass production and yields and maintain soil fertility. Nitrogen-use efficiency in sugarcane production is in the range of 6–40% (Reichardt *et al*., 1982; Ng Kee Kwong and Deville, 1984; Salcedo *et al*., 1988; De Oliveira *et al*., 2002), i.e. more than 60% of applied nitrogen fertilizer is lost to the environment. Part of this loss occurs directly – i.e. from the soil of the fertilized field or indirectly i.e. following cascading of reactive nitrogen compounds downwind and downstream of the application site. The main source of N_2O emissions in sugarcane fields is the application of nitrogen fertilizers, mineral nitrogen fertilizer and/or organic fertilizers such as bagasse, vinasse or manure (Lisboa *et al*., 2011). Nitrogen oxides are released from soil-plant systems into the atmosphere as a result of biological nitrification and denitrification processes (Bouwman, 1998, Stevens and Laughlin, 1998). Soil NO_3^{-1}, NH_4^+, soluble and readily decomposable carbon, temperature, water and oxygen availability all play major roles in influencing the quantities of N_2O lost from the soil (Dalal *et al*., 2003). Many other factors are involved in estimating the amount of N_2O emitted, including (i) management practices (e.g., fertilizer source, rate, placement, timing, other chemicals, crop, irrigation, presence of plant residues) and (ii) environmental and soil factors (e.g., temperature, rainfall, soil moisture, organic carbon, oxygen concentration, porosity, pH, and microorganisms) (Carmo *et al*., 2013; Eichner, 1990; Snyder *et al*., 2009; Vargas *et al*., 2014).

Recommendations for the use of nitrogen fertilizers for sugarcane production cover a wide range of 45–300 kg N ha^{-1} (Srivastava and Suarez, 1992). The average application rates in Australia and South Africa are higher than 100 kg N / ha / year (Bholah and Ng Kee Kwong, 1997; Hartemink, 2008; Denmead *et al*., 2010) and less than100 kg N / ha / year for China and Brazil (Macedo *et al*., 2008; Zhou *et al*., 2009). In Brazil, sugarcane varieties and soil conditions had significant influence on the amount of their nitrogen demand met by biological nitrogen fixation (Do¨bereiner *et al*., 1972; Boddey *et al*., 2001; Medeiros *et al*., 2006). Biological N_2 fixation in Brazilian sugarcane plantations whereas high as 150 kg / N ha / year, thus covering up to 60% of the nitrogen demand of the crop (Lima *et al*., 1987). As with other GHGs, lack of past research and the existence of challenges associated with measuring N_2O emissions from sugarcane cropping systems means that only limited data is available to guide estimates of the emissions of this gas for sugarcane.

In GHG balance studies, calculating the global warming contribution from nitrogen fertilizer is uncertain and dependent on the fate of applied nitrogen. In Brazil, N_2O is the most important GHG emitted from agricultural soils (Cerri *et al.*, 2009; MCTI, 2013). In addition, N_2O is the main source of nitric oxide, which causes depletion of the stratospheric ozone layer (IPCC, 2007). Annual N_2O emissions from Brazilian sugarcane cultivation of 1.7 - 0.5 kg N_2O-N ha^{-1} were also reported (Macedo *et al.*, 2008). A 5 month period of N_2O measurement including full reformation package of sugarcane field such as stalk destruction, ploughing, sub soiling harrowing and application of fertilizer cake resulted in an emission of 2.1 kg N_2O- N ha^{-1} in Brazil. In another study in Brazil, an emission factor (EF) for N_2O emissions from sugarcane fields due to nitrogen fertilization was 3.87 Kg N_2O - N (1800 kg CO_2 / ha) per 100 kg N fertilizer application (Lisboa *et al.*, 2011). The default value for N_2O emitted by nitrogen fertilizers is 1% of the nitrogen applied (IPCC, 2006), but the actual percentage can vary. Emission factors of 3% to 5% of the total nitrogen applied has been reported (Crutzen *et al.*, 2008).Data compiled from Australia, Hawaii, and Brazil, suggested a mean emission factor of 3.9% of nitrogen applied in sugarcane fields (Lisboa *et al.*, 2011).These N_2O emissions may represent40% of the total GHG emission for systems in which ethanol is produced from sugarcane (Lisboa *et al.*, 2011).In two of the Australian studies, N_2O emissions were assessed over an entire year with annual emission rates ranging from 2.8 kg N_2O – N / ha for unfertilized sugarcane fields (Allen *et al.*, 2010) to 445 kg N_2O – N / ha for a sugarcane field fertilized with 160 kg nitrogen applied in form of urea (Denmead *et al.*, 2010). N_2O emissions of 45–78% due to denitrification of applied nitrogen following nitrogen fertilization were reported (Weier, 1998). It is known that N_2O emissions are often limited by nitrogen availability in soils (Butterbach-Bahl *et al.*, 2013). There is evidence in Brazil and in Australia, where sugarcane is cultivated with high inputs, that nitrogen fertilization and burning of residues leads to high GHG emissions (De Figueiredo and La Scala, 2011), in some cases up to 45 kg N_2O-N / ha / year (Denmead *et al.* 2010). High soil emissions following high nitrogen fertilizer application rates that maintained high N availability in the soil has also been observed (Allen *et al.*, 2010). Also in Australia, N_2Oemissions following fertilization rates of 160 kg N ha^{-1} have been realized (Denmead *et al.*, 2010). Past studies, which have included a land use change for bio ethanol from sugarcane, are based on the default value from IPCC where the direct emission of N_2O due to nitrogen fertilizer use is 1% (IPCC,2006) or 1.25% (IPCC, 2001). In Kenya, response to nitrogen fertilizer rate of 120 kg N ha^{-1}has been recorded in some cane varieties (Achieng' *et al*., 2013). But, N_2O emissions from fertilized sugarcane fields in Kenya have not been quantified.

Under conditions of high soil moisture sugarcane fields can be significant emitters of CH_4 with annual fluxes being in a range of 0–19.9 kg CH_4 / ha (0–458.12 kg CO_2eq / ha) (Denmead *et al*., 2010, Crutzen and Andreae, 1990). In addition, effect of ammonium-based fertilizer on soil CH_4 uptake has been reported (Mosier *et al*., 1991). Whereas nitrate fertilizer forms stimulated soil CH_4 uptake (Nesbit and Breitenbeck, 1992), sugarcane fields functioned either as net sinks or sources for CH_4 over a 104 days period of measurements. CH_4 emissions after urea application (at 160 kg N / ha) were 297–1005 g CH_4–C / ha (6.8–23.1 kg CO_2 eq ha^{-1}) whereas at a site receiving ammonium sulphate (160 kg N ha^{-1}) CH_4 uptake was in a range of 442– 467 g CH_4 – C / ha (10.2–10.7 kgCO_2eq/ha) (Weier, 1999). In Kenya, significant ($p \leq 0.05$) sugarcane responses have been observed between 0 kg N ha^{-1} and 150 kg/N ha (Ochola, *et al*., 2014). But CH_4 fluxes from fertilized sugarcane fields in Kenya are not known.

Application of nitrogen fertilizer plays a significant role in the soil carbon sequestration (Lal, 2004). Nitrogen fertilizers increase the crop biomass and influence the microbial decomposition of crop residues by affecting the nitrogen availability (Green *et al*., 1995). In China, the use of nitrogen fertilizers in a hydromorphic paddy soils did not increase the soil organic carbon (SOC) as compared with no fertilizer use in Human Province (Tong *et al*., 2009). On the contrary, increased nitrogen fertilization increased the SOC sequestration in paddy soils in the same province (Shang *et al*., 2011). Application of nitrogen fertilizer increases plant biomass production, stimulating soil biological activity and consequently CO_2 emission (Dick, 1992). Reduced extracellular enzyme activities and fungal populations resulting from nitrogen fertilization, on the contrary, results in decreased soil CO_2 emission (Burton *et al*., 2004), DeForest *et al*., 2004). Of the various operations and inputs used in cane production in Eastern Batangas, Philippines, nitrogen - fertilizer applied at 300 kg / ha had the highest emission at 3,927 kg CO_2 / ha and 3,834 kg CO_2 / ha for plant and ratoon cane respectively. On the average, the Carbon Foot Print of fertilizer was 77% of the cane production or 12% of the total emission (Mendoza, 2014). Nitrogen fertilization sugarcane fields have realized CO_2 emissions in the range 1800 ± 540 kg CO_{2eq} / ha / year for burnt and unburnt canes (Lisboa *et al*., 2011). In Kenya, benefits of nitrogen fertilizer rate application have been reported to realize high yields (Achieng' *et al*., 2013). However, the influence of nitrogen fertilization on CO_2 fluxes in sugarcane fields in Kenya has not been documented.

2.3GHG emissions from trash management practices in sugarcane fields

A conservative practice such as leaving crop residues on the soil surface instead of burning them has been introduced in an effort to achieve sustainable agriculture. The left crop residue cover reduces fluctuations in soil temperature, keeping soil layers cooler, and retains moisture, especially during the hotter and drier seasons (Andrade *et al*., 2003). Maintaining crop residues on the soil surface are thought to have great benefits in terms of soil carbon storage, a process called soil carbon sequestration (Razafimbelo *et al*., 2006; Galdos *et al*., 2009; Ussiri and Lal, 2009). In addition to the benefits of soil temperature and moisture, plant residues on the soil surface affect other soil properties, and consequently, the microbial habitat, microbial activity and soil carbon dynamics (Franchini *et al*., 2007). Until the 1980s, soil carbon (C) research was focused mainly on its role in maintaining optimal soil physical, chemical and biological properties. Thereafter, because of increasing concerns on larger-scale environmental issues, research has seen a shift to soil carbon sequestration and greenhouse gas (GHG) emissions (Eustice *et al*., 2011). Information is available in the temperate regions on the emission of CO_2 from sugarcane fields, following leaving trash *in situ* (Weier, 1998). Such data are not available for sugarcane production within the tropics.

Crops are often assumed to be CO_2 neutral, as they sequester similar amounts of carbon as are returned to the atmosphere over the growth cycle (Denmead *et al*. 2010). In the Brazilian GHG inventory, sugarcane burning was responsible for 98% of total GHG emission from agricultural burning activities (Lima *et al*., 1999). Carbon release into the atmosphere was estimated at a rate of 4810 kgCO_2eq/ha by burning 10.4 t of biomass (Marques *et al*., 2009). In Eastern Batangas, Philippines, estimated direct CO_2 emission from cane burning was 10,410 kg CO_2eq / ha (Mendoza, 2014). CO_2 - C emissions were higher from a trashed treatment (ranged from 175-290 kg / ha) than from a burnt treatment (from 83-182 kg / ha) over a 10-day period for a sugarcane field in Hawaii in (Weier, 1996). These emissions appeared to be reduced by the presence of nitrogen fertiliser (Eustice *et al*., 2011). Studies on the conversion of natural grassland to sugarcane under burning (bare soil conditions) demonstrated that organic carbon decreased in soils regardless of texture (Domniny *et al*., 2002; Li and Mathews, 2010). This indicates that, despite being a grass, sugarcane under burnt conditions is not able to maintain the same soil organic matter (SOM) levels as natural grassland. On the other hand, a comparison of grassland and trashed sugarcane shows that the SOM under trashed sugarcane soils is higher than under grassland (Haynes and Graham, 2004), implying that soils under trashed sugarcane production may be an effective carbon sink. Few studies compared CO_2 emissions from burnt and trashed sugarcane cropping systems (Weier, 1996).

The IPCC emission factors to quantifyCH_4 emission due to burning of biomass is 2.7 kg CH_4 / ton dry matters burnt (IPCC, 2006). For example, burning a sugarcane field with 10–20 ton dry matter/ha produce approximately 162 kg CH_4 (or 3726 kg CO_2eq ha^{-1}) (Lisboa *et al.*, 2011). Crop residue burning can release significant quantities of CH_4. Burning of trash yielded CH_4 emission factor of 0.4% from an original sugarcane fuel carbon content (Galbally *et al.*, 1992). CH_4 emissions of 19.9 kg / ha over a period of 392 days were measured under burnt sugarcane production in Australia as compared to trash blanking that yielded a net emission that was essentially zero (Denmead *et al*. (2010). In contrast, trash-blanketed soils acted as a sink for CH_4 (Weier, 1996). In a study in which sugarcane trash was applied to the surface, CH_4 emissions were observed when plots were fertilised with urea (Weier, 1999).In another study, unburnt sugarcane residues exhibit higher CH_4 uptake rates of 0.8 kg CH_4 / ha / day (Weier, 1998). IPCC emission factors to quantify N_2O emission due to burning of biomass is 0.07 kg N_2O / ton dry matter burnt) (IPCC, 2006). Burning a sugarcane field with 10–20 tons per dry matter per hectare produced approximately 4.2 kg N_2O (or 1243 kg CO_{2eq} / ha) (Lisboa *et al.*, 2011). Higher N_2O emissions from unburnt fields (36.5 g N_2O – N / ha / day) have been reported compared with burnt fields (31 g N_2O – N / ha / day) (Weier, 1996). The smallholder sugarcane producing systems in Kenya are characterized by the practices of burning and trashing cane residues. But not much is known about how trash blanketing and burning of sugarcane residues affect CO_2, $CH_4$and N_2O fluxes in Lower Nyando, western Kenya.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site description

The study region Lower Nyando Block is located in the Lake Victoria basin in Nyando and Kericho sub counties, western Kenya. The Climate Change Agriculture and Food Security (CCAFS) (Sijmons *et al.,* 2013) program of the CGIAR established the site as a benchmark site covering an area of 10 km by 10 km (centred at 0°31'S, 35°02'E), (Figure1), to assess technologies to adapt and mitigate climate change (Sijmons *et al*., 2013). Climate change and variability is evident in Nyando Basin in western Kenya. There is an increase in droughts, floods and unpredictable rainfall which affect agriculture and food security (Macoloo *et al*., 2013). The Lower Nyando Block has three landscape topographies – the highlands, mid slope and lowlands, which are similar to most Kenyan regions. It has divers types of livelihood, ecological and smallholder stratifications ideal for smallholder farming system of developing countries.

The climate in Nyando basin is humid with temperature of approximately 23°C and an average annual rainfall of about 1150 mm. Temperatures tend to be slightly cooler and precipitation slightly higher in the highlands compared to the lower regions of the study site (Sijmons *et al.,* 2013). Precipitation patterns are typically bimodal with the "long rains" occurring from April to June (42% of annual precipitation) and the "short rains" occurring from October through December (26% of annual precipitation) (Sijmons *et al.,* 2013).The population is about 750,000 mainly living in the Nyando Sub County as well as in Kericho sub counties. More than 80% of the people formally or informally depend on agriculture for their livelihood (Sijmons *et al.,* 2013). The population survive on subsistence agriculture, consisting of mixed cropping systems. Main crops are maize, beans, sorghum, tea and sugarcane, with sugarcane mainly concentrated in the mid slopes where the crop is grown on lands converted directly or indirectly from natural vegetation, with some proportion grown in the highlands. The highlands have continued to experience conversion from natural Afro-montane forests about 40-50 years ago, fields with natural vegetation adjacent to the sugarcane fields. The experimental work was located on the mid - slope production systems, (Figure 2), where the conversion of natural vegetation is still on - going.

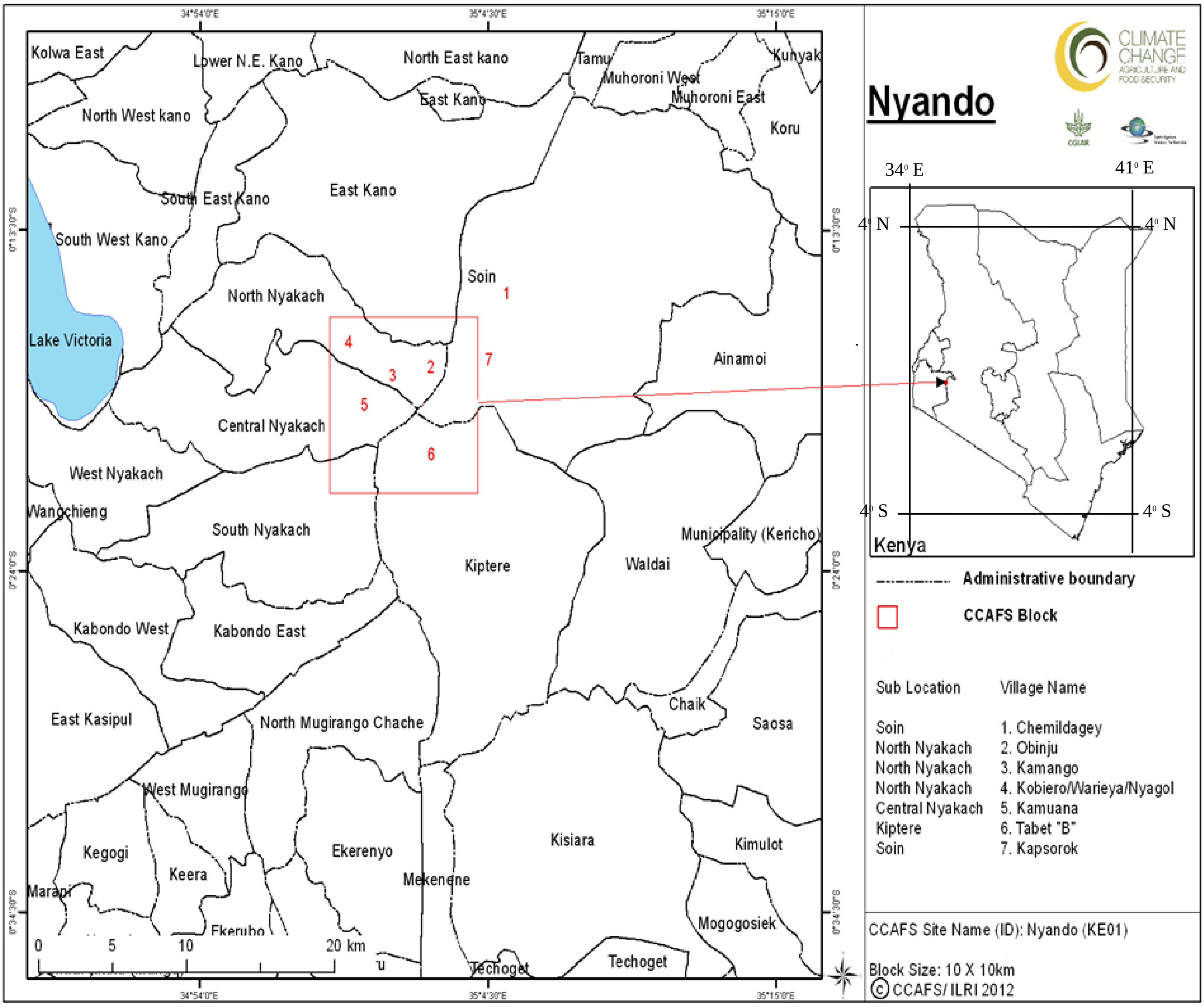

Figure1: The study area (Lower Nyando Block, western Kenya

(Source:Sijmons*et al*., 2013).

3.2 Survey sugarcane management practices in Lower Nyando

A cross-sectional survey at the study site (0°17'S, 35°01'E), (Figure 2) was conducted between March 2014 and April 2014 in the highlands and the mid-slope slope where sugarcane is produced. There was no sugarcane in the lowlands. Sugarcane production was first characterized by mapping all sugarcane farms using a non-probability sampling procedure; saturated sampling (Gall *et al*., 1996), because they were too few. Questionnaire (Appendix 1) was used to gather data (Cresswell, 2003). Questionnaires were designed, pretested, using test retest method producing value of 0.8 and validated using eight people. The purpose was to understand land use change and to characterize sugarcane management associated with sugarcane farming, which could influence GHG fluxes in sugarcane production. Data collection was done through structured interviews by first interviewing key informants (village chiefs).One hundred and fifty farmers were interviewed. Every plot was geo-referenced using a tablet provided with a global-positioning system (GPS). Every sugarcane field included in the survey was visited. Each sugarcane field close to bush land (Figure 2), that had similar slope, age, soil type (Haplic Luvisols) and texture were selected.

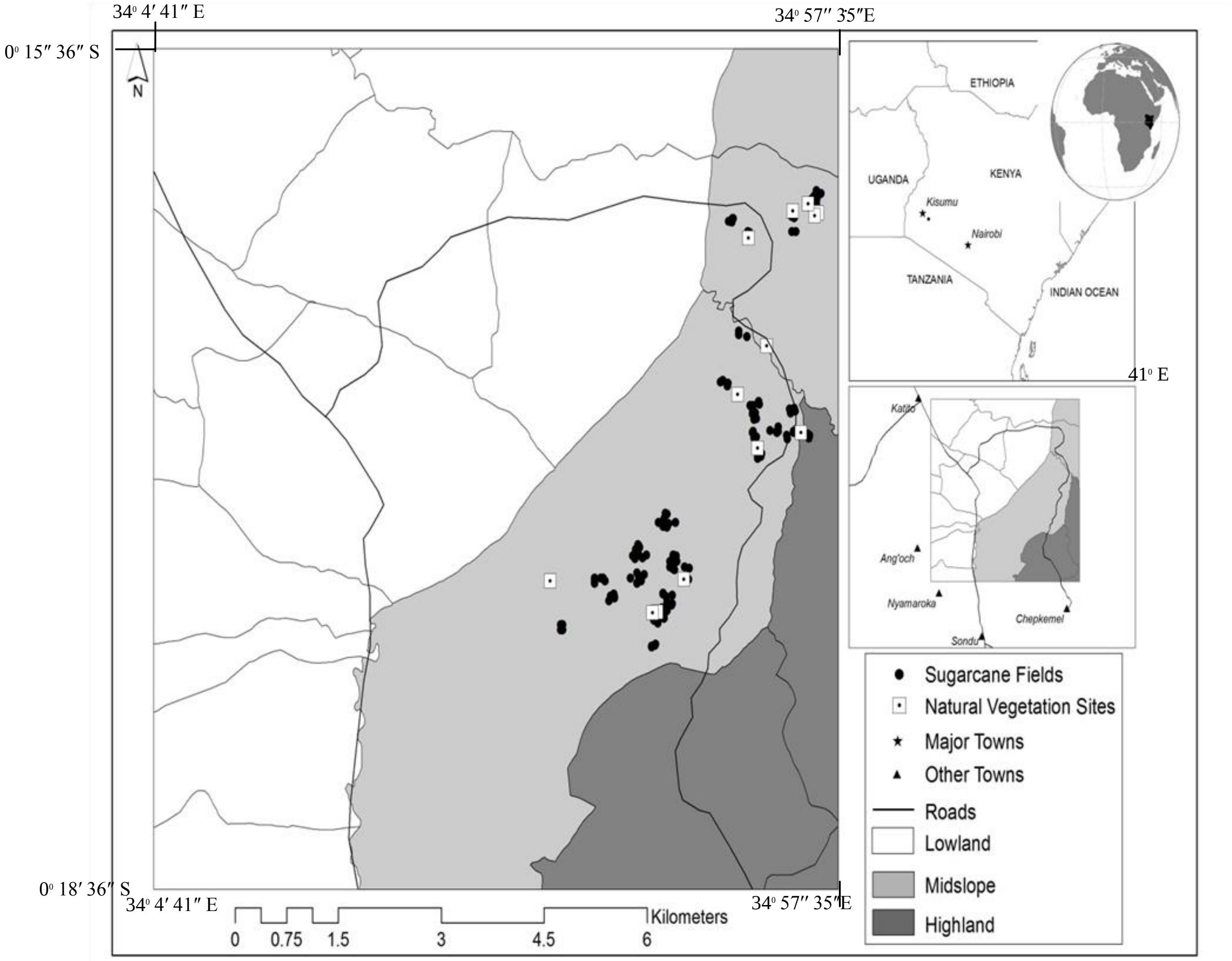

Figure 2: Sugarcane and adjacent native vegetation fields in the Nyando sugarcane producing area of western Kenya (Source: Rufino *et al*., 2017)

3.3 Experimental layout

The trials were superimposed on the existing sugarcane farms established by farmers. Six farms and natural vegetation adjacent to each farm were selected for GHG monitoring. Harvesting was done in March 2015 (between 10th and 21st March 2015 in the 1st and 2nd week of the trial). After harvesting, each farm was subdivided into six plots each measuring 8 rows by 10 meters (70m^2 for 1m row spacing and 42m^2 for 0.6m row spacing and 20% buffer round each plot). Three plots were burnt while in the other three trashes were left *in situ*. Burning was done in the morning to avoid fire spreading into the trashed plots or in other farms. Four chamber frames were fixed (two row, 2 inter row) in each plot a day after burning when the soil had cooled down. Gas sampling commenced a day after fixing chamber frames and continued weekly. Two months after ratooning, three rates (0, 50, and 100 kg N/ha/year) of nitrogen fertilizer from urea source were applied between May 18th and 21st in the 10th week of the trial. Gas sampling commenced again a day after fertilizer application and continued weekly for a period of 9 months. The treatments were laid in a 3 factor Randomized Complete Block Design arrangement with variable 1: time from conversion from natural vegetation to sugarcane cultivation (T_1<10years and T_2>10 years) as the main treatment and replicated 3 times in three different sugarcane farms (S)as follows: V_1R_1 (T_1S_2, T_2S_3), V_1R_2 (T_1S_4, T_2S_6), V_1R_3 (T_1S_5, T_2S_8). Variable 2: Nitrogen fertilization(N_1, 0 kg N/ha/year, N_2, 50 kg N/ha/year, N_3, 100 kg N/ha/year)as sub- treatment, replicated as: V_2R_1 (N_1S_2, N_2S_2, N_3S_2 and N_1S_3, N_2S_3, N_3S_3), V_2R_2 (N_1S_4, N_2S_4, N_3S_4 and N_1S_6, N_2S_6, N_3S_6), V_2R_3 (N_1S_5, N_2S_5, N_3S_5 and N_1S_8, N_2S_8, N_3S_8). Variable 3: Burning (B) / trashing (T) as sub- sub- treatment replicated 3 times as: V_3R_1 (BS_2, TS_3), V_3R_2 (BS_4, TS_6), V_3R_3 (BS_5, TS_8). Four chamber frames were also fixed in the natural vegetation adjacent to each farm and gas sampling was done the same day the farms were sampled.

3.4 Data Collection

3.4.1Gas Sampling

Soil CO_2, N_2O and CH_4 fluxes were measured weekly, from March 2015 through to 24th November 2015 using non-flow-through non-steady-state chambers (Rochette, 2011). Briefly, four rectangular (0.35m x 0.25 m) hard plastic frames per site were inserted 0.10 m into the ground, two rows and two inter row after the burning/ trashing treatment. On each sampling date, an opaque, vented and insulated lid (0.125m height) covered with reflective tape was tightly fitted to the base (Rochette, 2011). The lid was also fitted with a small fan to ensure proper mixing of the headspace air. Air samples (15L) were collected from the headspace immediately after closing the chamber (time 0), then at 15 minutes (time 1), at 30 minutes (time 2), and finally at 45 minutes (time 3) after deployment using a syringe through a rubber septum. Samples were pooled from the four replicated chambers at each plot (Arias-Navarro *et al*., 2013) to form a composite air sample of 60mL. The first 40 ml of the sample was used to flush a 10 mL sealed glass vial through a rubber septum, while the final 20 mL was transferred into the vial to achieve an overpressure to minimize the risk of contamination by ambient air. The gas samples stored in the glass vials closed with rubber stopper were taken to the laboratory for gas samples analysis using gas chromatography. The lids were removed, but the frames remained uncovered until the next gas collection.

Figure 3: GHG measurement in burnt sugarcane fields in Lower Nyando

Figure 4: GHG measurement in trashed blanketed sugarcane fields in Lower Nyando

3.4.2 Gas chromatography (GC) analysis

The gas samples were analyzed within 10 days of sample collection for CO_2, CH_4 and N_2O in an SRI 8610C gas chromatograph (2.74m Hayesep-D column) fitted with a ^{63}Ni-electron capture detector (ECD), cell temperature of 350º C and ignition flame of 613ºC for N_2O and a flame ionization detector (FID) for CH_4 and CO_2 (after passing the CO_2 through a methanizer) at a column oven temperature of 75ºC. The flow rate for the carrier gas nitrogen (N_2) was 28 mL / min. Every fifth sample analyzed on the gas chromatograph was a calibration gas (gases with known CO_2, CH_4 and N_2O concentrations in synthetic air) and the relation between the peak area from the calibration gas and its concentration was used to determine the CO_2, CH_4 and N_2O concentrations of the headspace samples.

3.4.3 Calculation of soil GHG fluxes

Soil GHG fluxes were calculated by the rate of change in concentration over time in the chamber headspace (corrected for mean chamber temperature and air pressure) after chamber deployment, as shown in Equation (1). (Butterbach-Bahl *et al.*, 2011).

$$F = \frac{b * Mw * V_{Ch} * 60 * 10^6}{A_{Ch} * V_m * 10^9} \quad \text{...Equation 1}$$

Where F is the CO_2, N_2O or CH_4 flux rate (µg/M^2/hour),b is the slope of increase/decrease in concentration (ppb/min for CH_4 and ppm / min for CO_2 and N_2O with high concentration of standards at 1ppb for CH_4 and 400 ppm for CO_2 and N_2O. Low concentration of standards at 1ppb for CH_4, 4ppm for CO_2 and N_2O), Mw is molecular weight of C-CO_2, N-N_2O or C-CH_4 (g/mol), V_{Ch} is chamber volume (m^3), A_{Ch} is chamber area (m^2), V_m is the corrected standard gaseous molar volume (m^3/mol) $V_m = (22.41*10^{-3}\ m^3\ mol^{-1}*(273.15 + temp) / 273.15*(1013/air\ pressure)$. The formula is multiplied by 60 to express the fluxes per hour, multiplied by 10^6 to convert g to µg, and by 10^9 to convert ppb to µg. CO_2 fluxes are given in g C m^{-2} h^{-1}, N_2O in µg N / M^2 / hour and CH_4 in µg C / M^2 / hour. Cumulative fluxes were calculated as an integration of the flux traces for 9 months

3.5 Statistical analyses

The data for GHG fluxes from Lower Nyando, western Kenya was analyzed using MSTATC – statistical package (Michigan State University, MI). Least significant differences (LSD) tests techniques were employed for separation of means of treatments, effects at the $p \leq 0.05$. The means were subjected to General Linear Model (GLM) and bar graph procedures with accurate LSD bars inserted using Microsoft windows Excel 2007 (Fatunbi, 2009)

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Sugarcane field management practices in Lower Nyando

Sugarcane field management practices were as summarized in (Table 1). Conversion from natural vegetation to crop production had been ongoing for a period of ± 10 years. Weed control is done manually, and carried out three times during the growing cycle of the crop, with 2-3 tillage operations. About 60% of the fields did not receive any mineral fertilizers. Fertilized fields received at most 50 kg N/ha/year once after weeding.

Table 1: Main characteristics of Nyando sugarcane belt

Descriptors	Mid-slopes
County	Kericho
Division	Soin and Sigowet
Elevation (range m.a.s.l)	1266 – 1416
Conversion from natural vegetation (years)	14.0 ± 11.7
Conversion to sugarcane (years)	3.0 ± 2.7
Crop cycle length (months)	17.0 ± 2.6
Row spacing (meters)	1.0 ± 0.4
Age of plantations (years)	1.7 ± 1.1
Weeding frequency (#)	2.6 ± 0.6
Weeding methods – Mechanical (%) of fields)	93
-Chemical (% of fields)	1
Fertilization (% of fields)	39
Range of fertilizer application (% of field):	
- 50 kg N ha/year	86
-100 kg N ha/year	11
Method of fertilizer application: - Band (% of field)	84
-Broadcast (% of fields)	10
Fertilizer type on planting (% of fields): - DAP	23
-CAN	1
-NPK	16
Fertilizer type for top dressing (% of fields): - NPK	5
-Urea	7
-CAN	5
Burning of crop residues (% of fields)	81
Trashing of crop residues (% of fields)	11
Crop residues used as feeds (% of fields)	31

Most farmers (84%) used band method of fertilizer application along the sugarcane rows. In all cases, harvesting was done manually, and burning of crop residues after harvest was a common practice in the area (81% of the respondents). Some farmers were reported using sugarcane tops as animal feed, which were collected before burning the crop residues. There were no large differences in distance between rows, length of crop cycle or varieties across sugarcane fields in the study area. The common row spacing was 0.6 m, the growing cycle 18 months and replanted every 3-5 years. Conversion of natural vegetation to sugarcane cultivation, nitrogen fertilization and trash management may be some of the management practices influencing GHGs fluxes in this region of Lower Nyando, western Kenya.

4.2 GHG fluxes

The contribution of selected management practices to primary soil greenhouse gas fluxes in smallholder sugarcane farming in Lower Nyando was evaluated and results are presented in Figures 5 to 22 and Appendices 2 to 115. The data were highly variable; this was typical of soil-atmosphere GHG emissions, which are highly variable in time (so-called time moments). For example missing hot moments (short-lasting pulse emissions) result in underestimations the total GHG emissions. But sampling during an emission pulse may lead to overestimation of fluxes. Indeed, coefficients of variations of over 100% within several meters are common (Arias-Navarro *et al.*, 2013). Again, there is complexity of the system in terms of variable land covers and heterogeneous physiography which contributes to the variability. Transformation of the data to absolute figures does not make much sense where some figures are positive while others are negative. The conversion makes them equal. On the whole the data demonstrated that under smallholder sugarcane production in Lower Nyando, the fluxes were much different from those observed in the large scale temperate agricultural systems. The large coefficient of variations did not obscure the value of the data.

4.2.1 GHG fluxes due to conversion period from natural vegetation to sugarcane cultivation

There was no significant CH_4 absorption by the soil in different times of conversion (less than and more than 10 years conversion periods) in weekly measurements (Figure 5) and in cumulative CH_4 absorption. The cumulative CH_4 absorption ranging between -0.55 and -0.60 kg CH_4 ha/ year (Figure 6) were low compared with low absorption of -0.59 kg CH_4 ha/year in Indonesia (Veldkampt *et al.*, 2008). However, CH_4 emissions of 1.25 kg CH_4 ha / year (Galbally *et al.*, 2010) and 4.8 kg CH_4 ha / year (Rowlings, 2010) were realized when forests were converted to cropland in Australia. Most agricultural soils due to frequent soil management mostly show little CH_4uptake activity (Levine *et al.*, 2011; Tate, 2015). Smallholder sugarcane farming systems studied here were weeded three times during the growing cycle of the crop. Unlike studies under temperate conditions (Veldkampt *et al.*, 2008), in Lower Nyando Block, irrespective conversion period to sugarcane production, there was CH_4absorption. Indeed, there was no difference in the CH_4 absorption caused by conversion period. Thus conversion period was not a factor influencing CH_4 fluxes in the Lower Nyando Block.

CO_2absorption by the soil was none significant between different times of conversion for weekly measurements (Figure 7) and cumulativeCO_2 (Figure 8) emissions. Cumulative CO_2emission of 7 tons CO_2 ha / year was low compared with 49 tons CO_2 ha/year conversions to sugarcane (Agus *et al*., 2007), 4.0 Giga tons CO_2 ha/year (Houston *et al*., 2012) and 4.1 Giga tons CO_2 ha / year (Le Que're *et al.*, 2013) estimated as annual global carbon emissions from land use change. Conversion of primary and secondary forests to cropland results in soil organic carbon loss (carbon respiration as CO_2) and most SOC losses occur over the initial 10 years after conversion. This loss is attributed intensive agricultural land management including soil disturbance (Mann, 1986; Lal, 2004). The lack of differences in CO_2 emissions due to conversion period to sugarcane production demonstrates that the soil activities within the smallholder framing systems could be very different from those under intensive high input production systems where. Conversion of primary forests to plantation (sugarcane) results in a much higherCO_2 emissions. In Kenya, biomass production and sugarcane yields in the smallholder sector are low ranging between 15–30 tons / ha due to low inputs (Mulianga *et al*., 2013). The low agronomic input levels may explain low CO_2 emissions observed in this study.

N_2O emissions were none significant between different times of conversions in weekly measurements (Figure 9) and in cumulative N_2O emissions (Figure 10). Cumulative emissions ranging between 0.8 and 1.2 kg N_2O-ha / year was low compared with emissions of 4.7 kg N_2O-ha / year in Australia (Rowlings, 2010). Changes in N_2O emissions following land use changes are related to changes in the amount of nitrogen inputs, crops usually receive large nitrogen inputs than forests through applied nitrogenous fertilizers. Consequently, nitrification and denitrification processes are intensified, and more N_2O are produced during nitrogen transformation in the soil (Robert and Tidje, 1987; Bowman, 1996; Kim *et al*., 2012). Smallholder farming systems studied here are characterized by low nitrogen fertilizer inputs of 50 kg N / ha / year (Table 1), thus the low cumulative N_2O emissions observed in this study. In Brazil and Australia, there is evidence that sugarcane is cultivated with high inputs of nitrogen fertilizer, this leads to high N_2O emissions (De Figueiredo and La Scala, 2010), thus the high emissions due to conversion period realized in these countries. Low CH_4, CO_2 and N_2O fluxes measured in this study implies that time from conversion from natural vegetation to sugarcane cultivation by smallholder farmers is not a significant contributor of GHG fluxes in Lower Nyando, western Kenya.

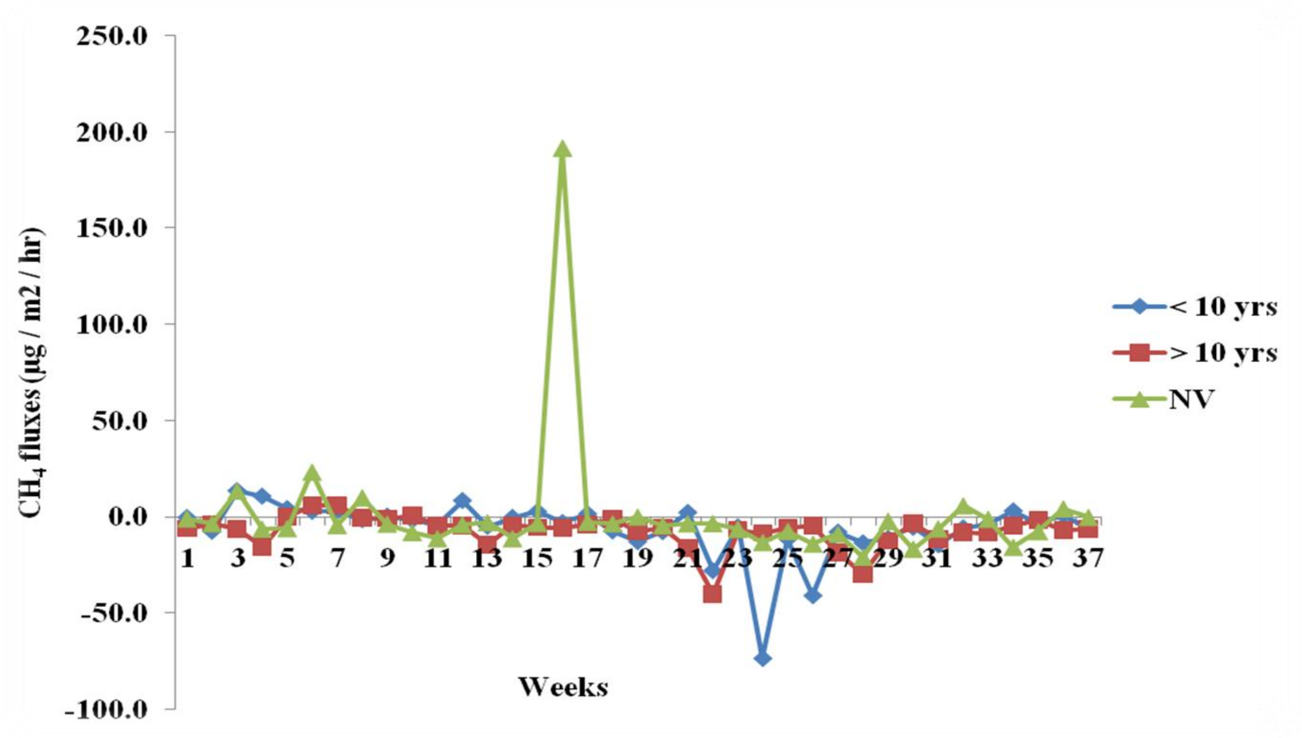

Figure 5: Influence of duration since conversion to sugarcane farming on methane fluxes

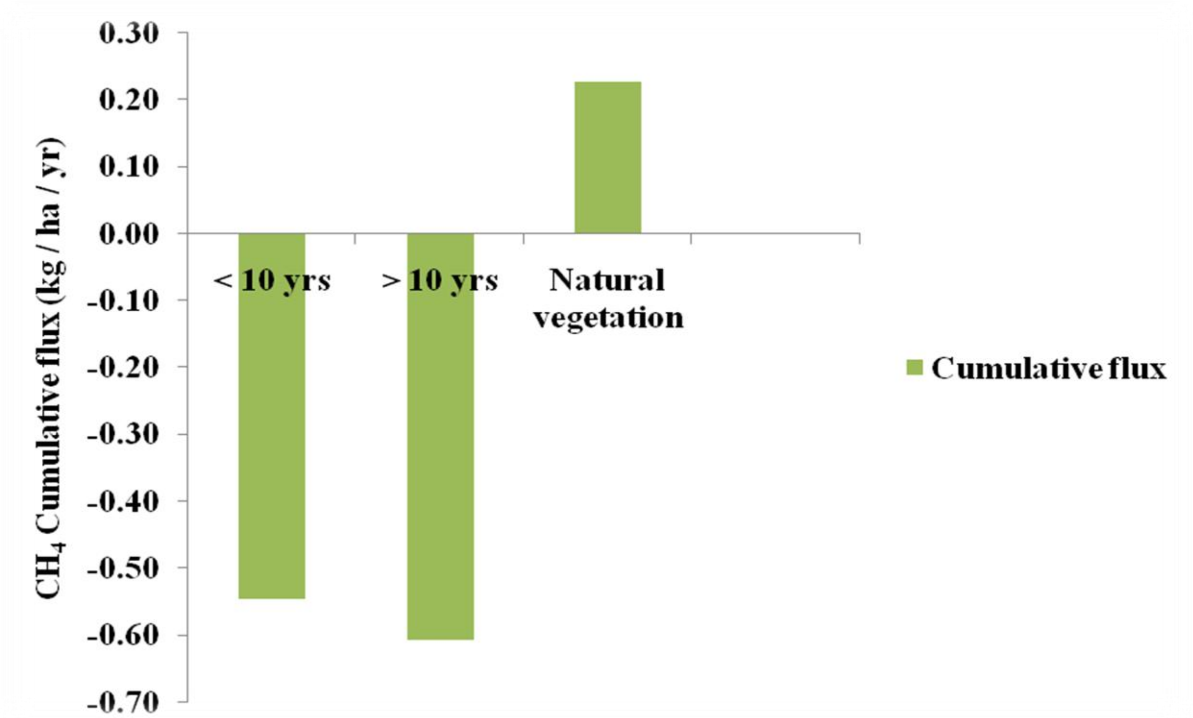

Figure 6: Cumulative fluxes of methane due to duration of converting fields to sugarcane farming

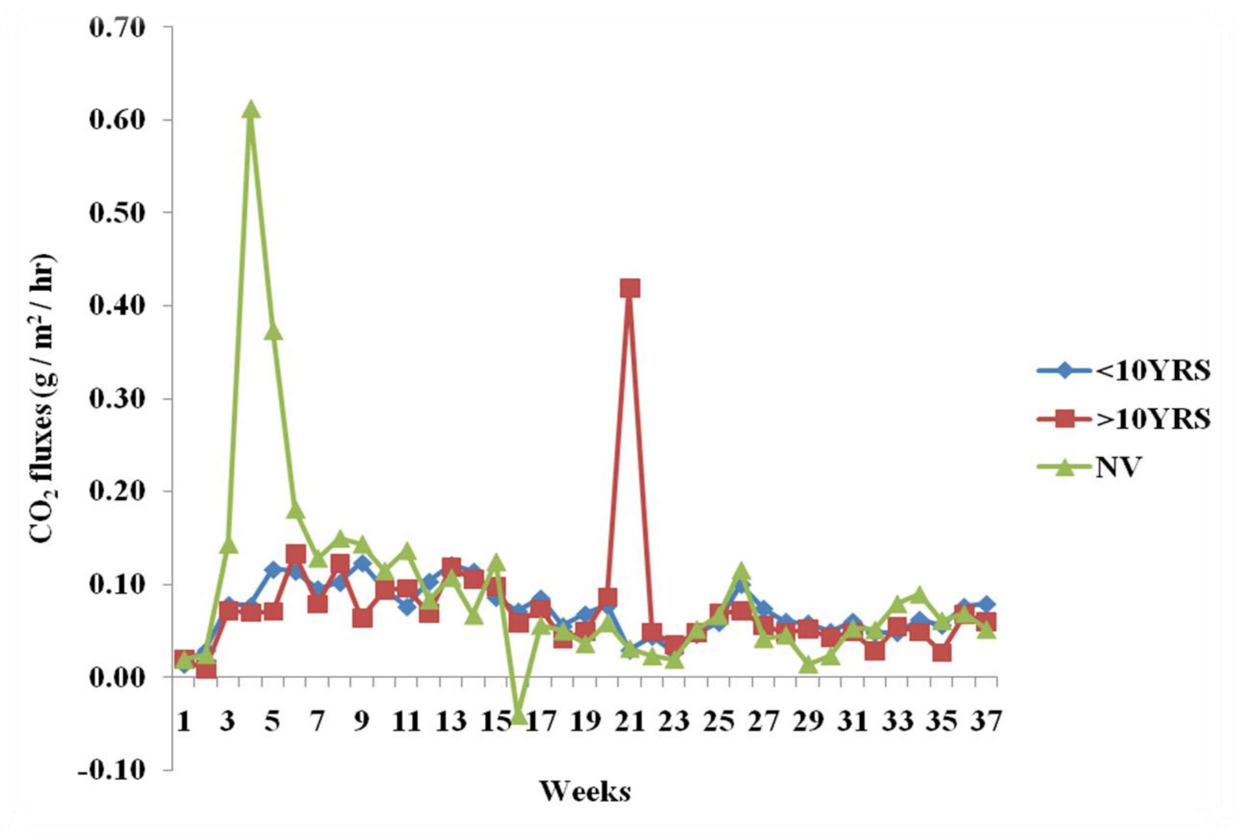

Figure 7: Contribution of conversion period on carbon dioxide fluxes

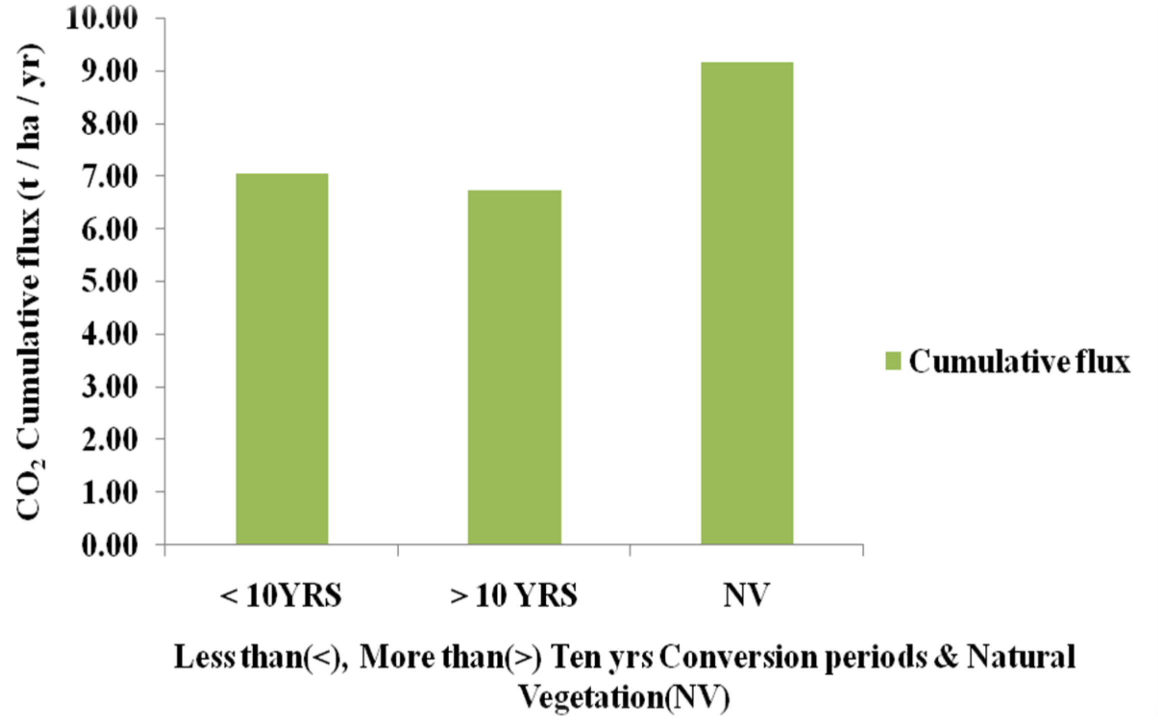

Figure 8: Cumulative fluxes of carbon dioxide due to conversion period

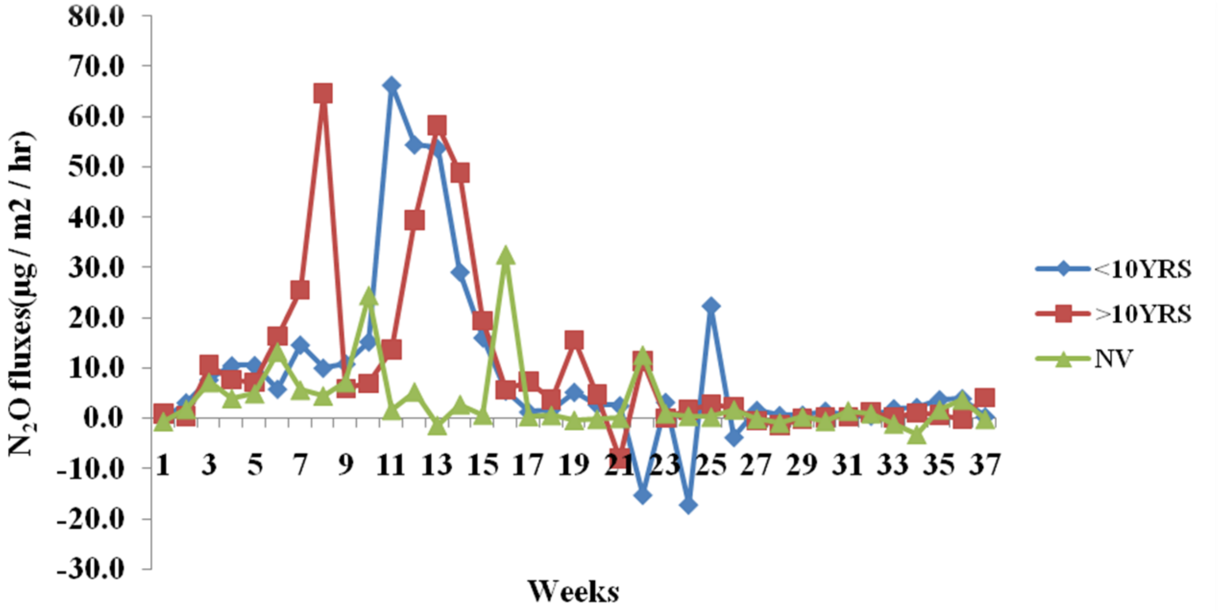

Figure 9: Influence of duration since conversion to sugarcane farming on nitrous oxide fluxes

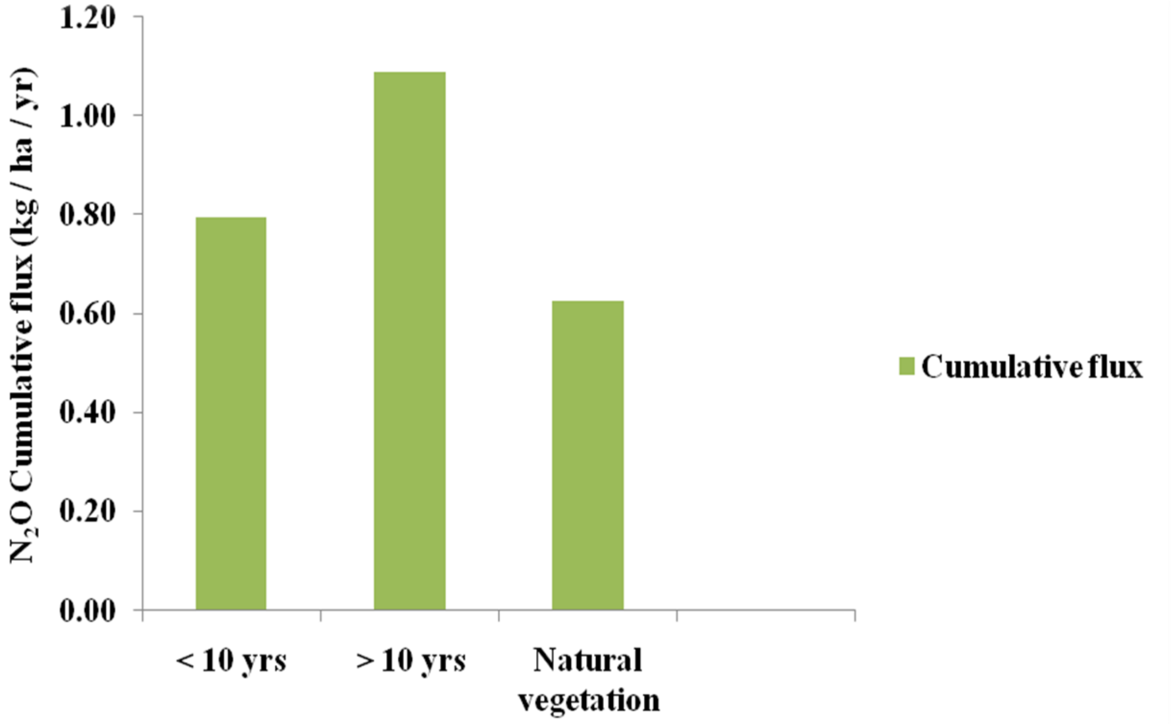

Figure 10: Cumulative fluxes of nitrous oxide due conversion period to sugarcane farming

4.2.2 Influence of nitrogen fertilization on GHG fluxes

None significant CH_4 absorption by the soil resulted in weekly measurements (Figure 11) and in cumulative (Figure 10) CH_4 absorption. Cumulative CH_4 (Figure 10) uptake by the soil in the range -0.5 and -0.6 kg CH_4 – C ha / year observed in this study was low compared with -0.442 and -1.6 kg CH_4 – C ha/year (Weier, 1999) that was also low after application of ammonium sulphate fertilizer (at 160 kg N / ha). However, CH_4 emissions ranging between 1.02 and 3.45 kg CH_4 – C ha / year have also been observed after urea application (at 160 kg N /ha) in Australia (Weier, 1999). Nitrate fertilizer forms stimulate soil CH_4 uptake by the soil (Nesbit and Breitenbeck, 1992). Soils in the study area were mostly free draining, with minimal; water logging. Anaerobic activities were therefore low. Thus, like in Australia (Weier, 1999), these soils were CH_4 sinks.

There was none significant CO_2 emissions in weekly measurement (Figure 13) and in cumulative CO_2 emissions (Figure 14). But the cumulative CO_2emissions in the range 5.48 and 7.2 tonnes CO_2 ha / year was high compared to 3927 kg CO_2 / ha for plant cane and 3834 kg CO_2 $ha^{-1}$for ratoon cane realized after nitrogen fertilizer application of 300 kg N / ha in Philippines (Mendoza, 2014) and 1800 ± 540 kg CO_2eq / ha / year for burnt sugarcane fields (Lisboa *et al.*, 2011). Application of nitrogen fertilizer increases plant biomass production, stimulating soil biological activity and consequently CO_2 emissions (Dick, 1992). Smallholder farming systems studied here apply low nitrogen fertilizer of 50 kg N ha^{-1} (Table 1), thus low biomass yields. However, data from the experimental plots show that with proper management and controlled nitrogen application, CO_2 emissions can be very high under tropical agricultural systems. The results demonstrate that despite the sugarcane yields (Mulianga *et al.*, 2013) the smallholders realise, their lack of high inputs is reducing CO_2 emissions and thus reducing the rate of climate change.

Significant ($p \leq 0.05$) N_2O emissions were observed in weeks 9, 10, and 11 (Figure 15) after the application of nitrogen fertilizer with rates 0, 50, and 100 kg N / ha / year in week 10. Cumulative N_2O emissions (Figure 16) ranging between 0.62 and 1.2 kg N_2O ha / year were however, none significant and low compared with very high emissions of 445 kg N_2O ha / year and 45kg N_2O ha / year (Denmead *et al.*, 2010). Low N_2O emissions in the range 0.5 and 1.7 kg N_2O ha / year have also been realized in Brazil when 75kg N ha / year was applied (Macedo *et al.*, 2008). There is evidence in Brazil and in Australia, where sugarcane is cultivated with high inputs that nitrogen fertilization leads to high N_2O emissions (De Figueredo and La Scala, 2011). High soil N_2O emissions following high nitrogen fertilizer application rates maintains nigh nitrogen availability in the soil (Allen *et al.*, 2010). This explains the high N_2O emissions observed in these countries. The levels on nitrogen applied in the trials were not causing high emissions of N_2O compared to those observed in Brazil (Denmead *et al*., 2010, Macedo *et al*., 2008 and Australia (De Figueredo and La Scala, 2011). The IPCC has proposed that 1% of all nitrogen applied to the soil, either in the mineral or the organic form, is directly emitted in the form of N_2O. However, several studies have indicated that the Tier 1 emission factor for the application of nitrogen fertilizers on agricultural soils proposed by the IPCC is overestimated (Dobbie and Smith, 2003; Jantalia *et al*., 2008; Rochette *et al*., 2004), especially when dealing with soils in regions with a tropical climate.N_2O emission factor for nitrogen fertilizer application to sugarcane of 3.87 %(3.87 kg of N_2O-N are emitted for each 100 kg of fertilizer N applied) but the estimate was a mean based on studies in Australia and Hawaii (Lisboa *et al*., 2011).The average emission factor for nitrous oxide emissions in Mediterranean cropping systems was also found to be 50% lower than the IPCC Tier I default value (1%), which is largely based on values observed in temperate regions (Cayuela *et al*., 2017).

Low CH_4 andN_2O fluxes realized in this study due to nitrogen fertilization are therefore an indication that the management practice as currently practiced by smallholder farmers in Lower Nyando is not a significant contributor of GHG fluxes.

4.2.3 GHG fluxes from trash management

CH_4 absorption by the soil was none significant in the weekly measurement (Figure 17) and in cumulative CH_4 uptake by the soil (Figure 18) for burnt and unburnt sugarcane fields. Cumulative CH_4 absorption ranging between -0.35 and -0.45 kg CH_4 ha / year for burnt and unburnt sugarcane fields respectively were low compared with high CH_4 uptake by the of -288 kg CH_4 ha / year from unburnt field (Weier, 1998). However, CH_4 emissions of 160 kg CH_4 ha/year in Japan (IPCC, 2006) and 162 kg CH_4 ha/year in Australia (Lisboa *et al*., 2011) have been realized. Crop residue burning can release significant quantities of CH_4 (Weier. 1998; Mendoza and Samson 2000). This may explain CH_4 emissions in these countries in contrast, trash–blanketed soils can act as a sink for CH_4 (soil bacteria oxidize CH_4 to CO_2 which is a much less potent greenhouse gas (Weier, 1996). Low CH_4 uptake by the soil observed in this study was probably because soil environmental conditions under burnt and unburnt sugarcane fields were not conducive enough for the existence of methanotrophs (Wendlandt *et al*., 2010). The IPCC Tier 1 emission factor also assumes that CH_4 emission from sugarcane fields is negligible (Fukushima *et al*., 2009).

Significant ($p \leq 0.05$) CO_2 emissions were realized between week 3 and 10 after burning/ trash–blanketing treatment in week 3 (Figure 19). Cumulative CO_2 emissions (Figure

20) between burning and trashing treatments were not significant and low ranging between 6.5 and 7.3 t CO_2 ha^{-1} yr^{-1} for unburnt and burnt sugarcane fields respectively compared with direct CO_2 emission 10.41 t CO_2 eq ha^{-1} (Mendoza, 2014) in Pillipines. Field agronomic practices such as cane burning trashing of cane residues directly emit CO_2 (Weier, 1998); Mendoza and Samson, 2000). This probably explains significant ($p \leq 0.05$) CO_2 emissions after burning / trashing treatment in weekly measurement observed in this study. Maintaining crop residues in the soil surface store soil carbon (soil carbon sequestration) (Razafimbelo *et al.*, 2006; Galdos *et al.*, 2009; Ussiri and Lal, 2009). But crops are often assumed to be CO_2 neutral as they sequester similar amounts of carbon as are returned to atmosphere over growth cycle (Denmead *et al.*, 2010). Most likely reason for none significant difference between the burning / trashing treatment realized in this study. The IPCC Tier 1 method applied to a consideration of the nature of sugarcane fields and cultivation patterns, also assumes that the net CO_2 emission from soil is zero. This is because there is no carbon input into soil from agricultural activities except for leaves and cane top removed from the cane at harvesting, and the carbon absorption from the atmosphere into soil is negligible (Fukushima *et al.*, 2009). Sugarcane crop can produce large amount of biomass under tropical and high input conditions (Robertson *et al.*, 1996). In Kenya, biomass yields are much lower due to low inputs (Mulianga *et al.*, 2013). Thus may explain the low CO_2 emissions measured in this study.

There was none significant N_2O emissions between burning and trashing treatments in weekly measurement (Figure 21) and in cumulative N_2O emissions (Figure 22). Cumulative N_2O emissions measuring 0.71 kg N_2O ha/year for burnt and 0.82 kg N_2O ha / year for unburnt were none significant and low in comparison with 11.16 kg N_2O ha / year from burnt sugarcane fields and high emissions of 13.14 kg N_2O ha / year from unburnt sugarcane fields in Australia (Weier, 1996).burning and retention of trash in sugarcane fields emit N_2O (Weier, 1998; Mendoza *et al.*, 2000). N_2O emissions are also limited by nitrogen availability in soils (Butter bach- Bahl *et al.*, 2013). In Brazil and Australia where sugarcane is cultivated with high inputs, nitrogen fertilization and burning of residues leads to high GHG emissions (De Figueirodo and La Scala, 2011). Smallholder farming systems in this study apply low rates of nitrogen fertilizer; hence none significant and low N_2O emissions due to burning and retention of trashes observed is this study.

Low CH_4, CO_2, and N_2O fluxes obtained in this study as a result of burning and retention of trash in the sugarcane fields therefore implies that this management practice is not a significant contributor of GHG fluxes in the smallholder sugarcane production in lower Nyando.

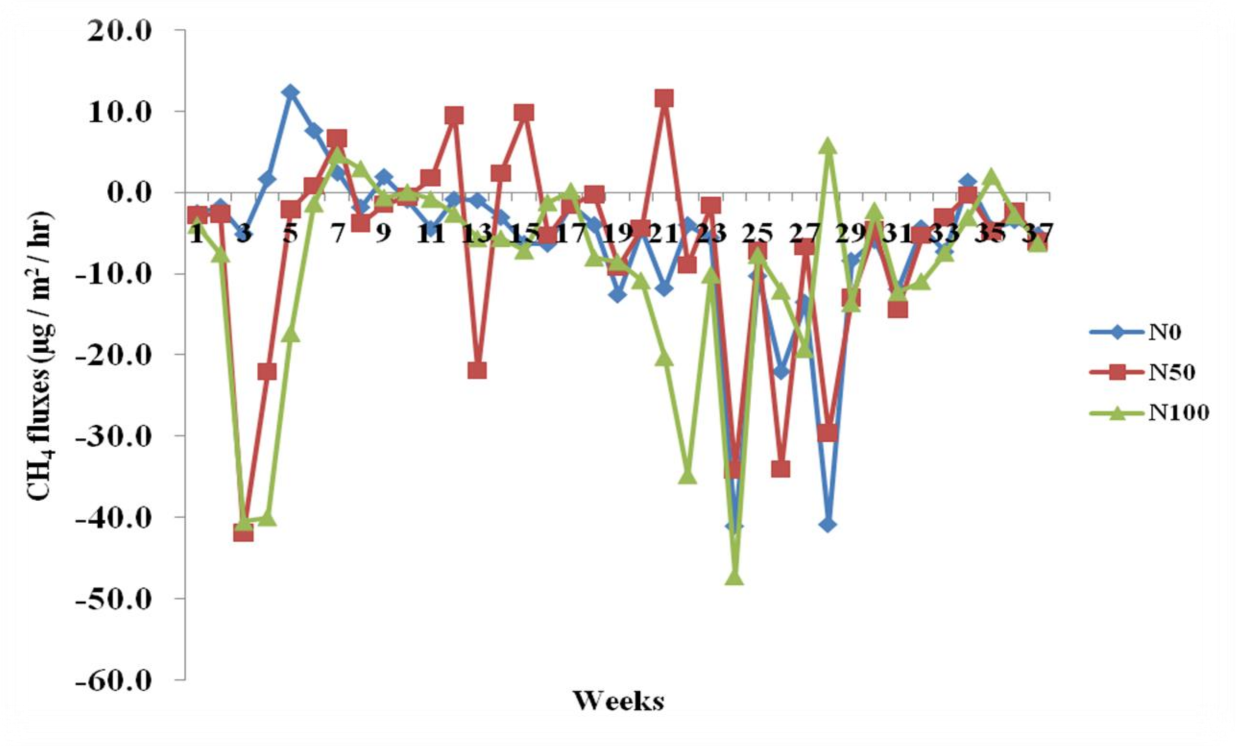

Figure 11: Influence of nitrogen fertilizer application on methane fluxes

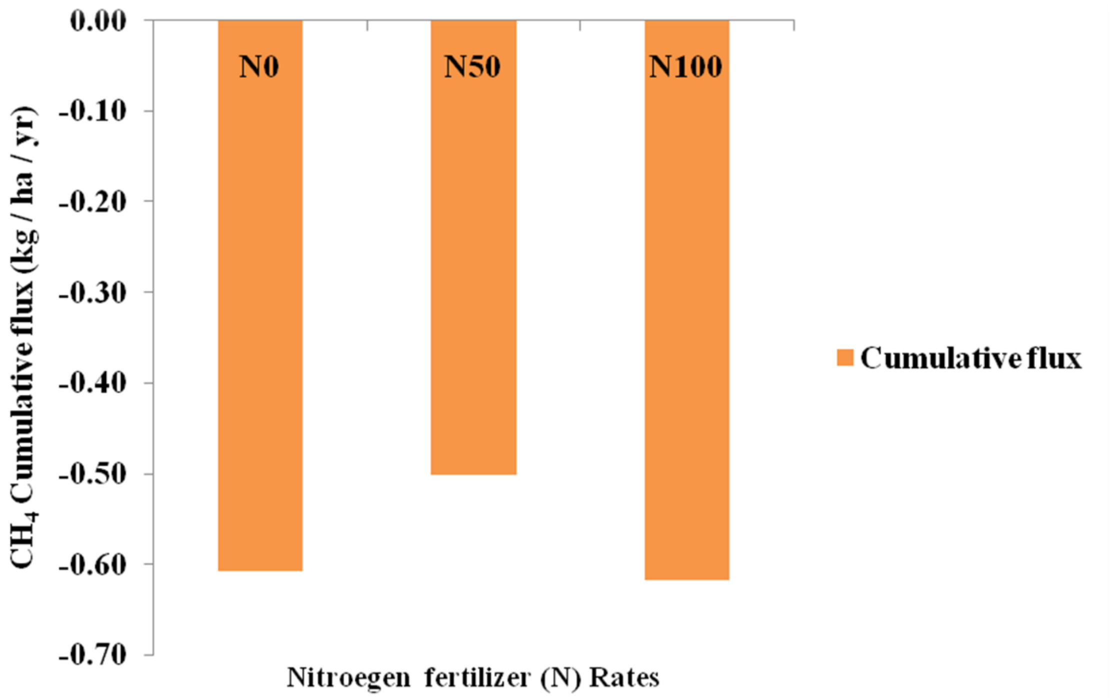

Figure 12: Cumulative methane absorption due to nitrogen fertilizer application

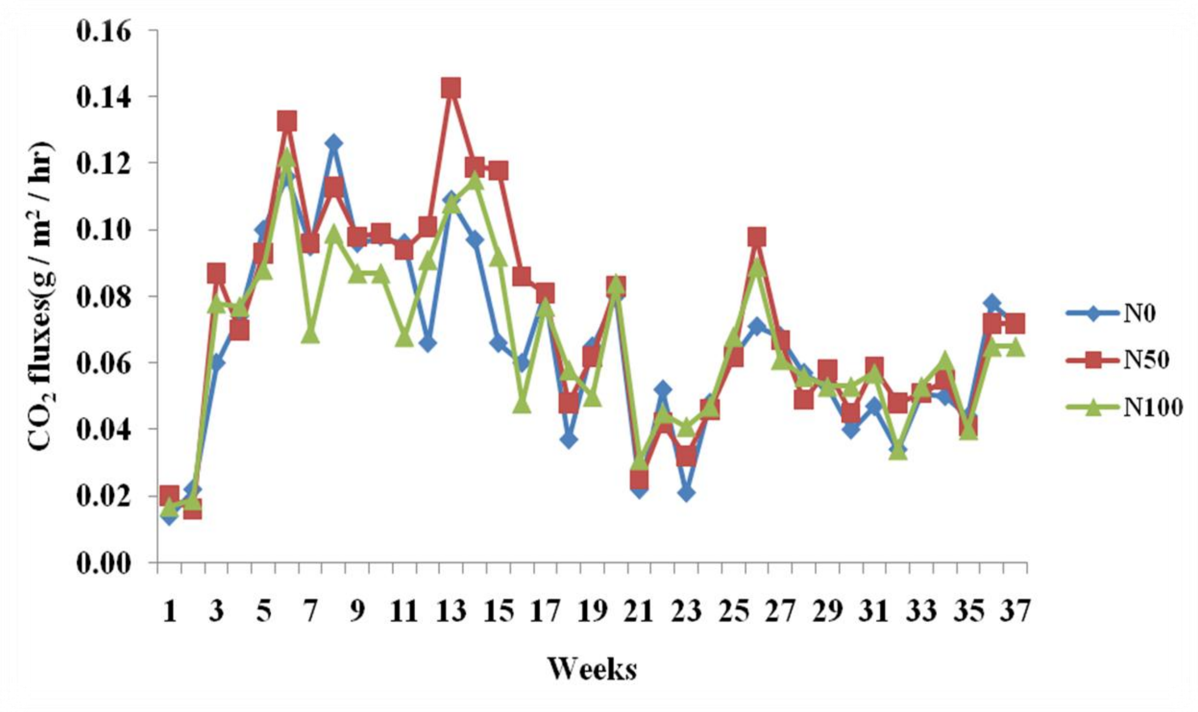

Figure 13: Contribution of nitrogen fertilizer application on carbon dioxide emissions

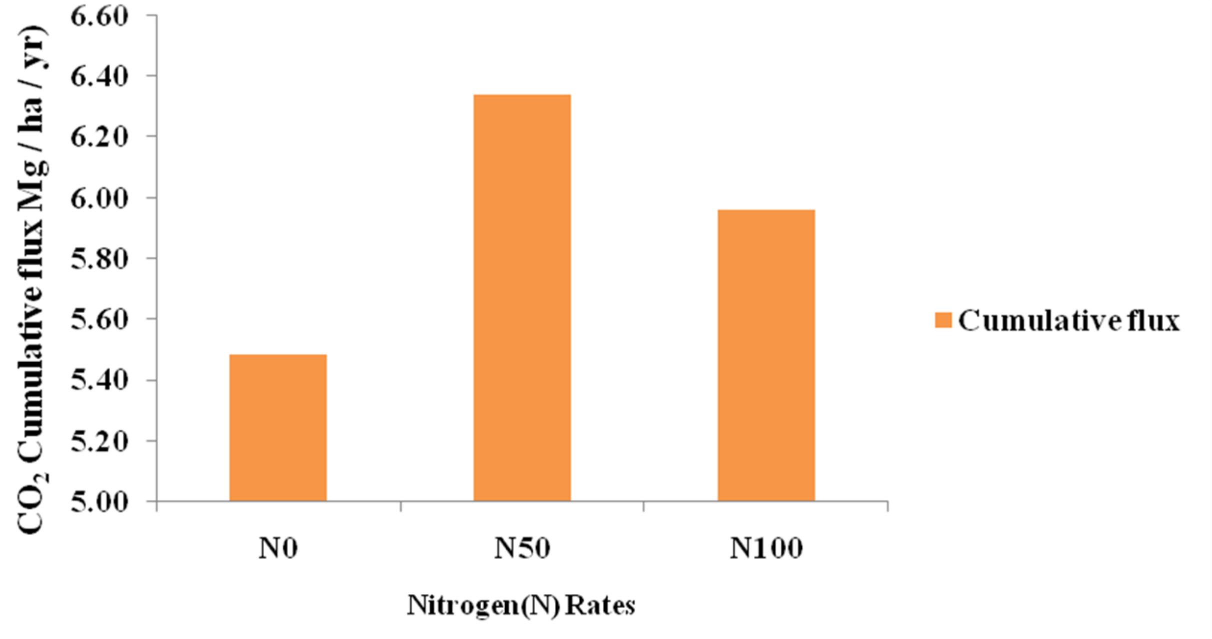

Figure 14: Cumulative carbon dioxide emissions due to nitrogen fertilizer application

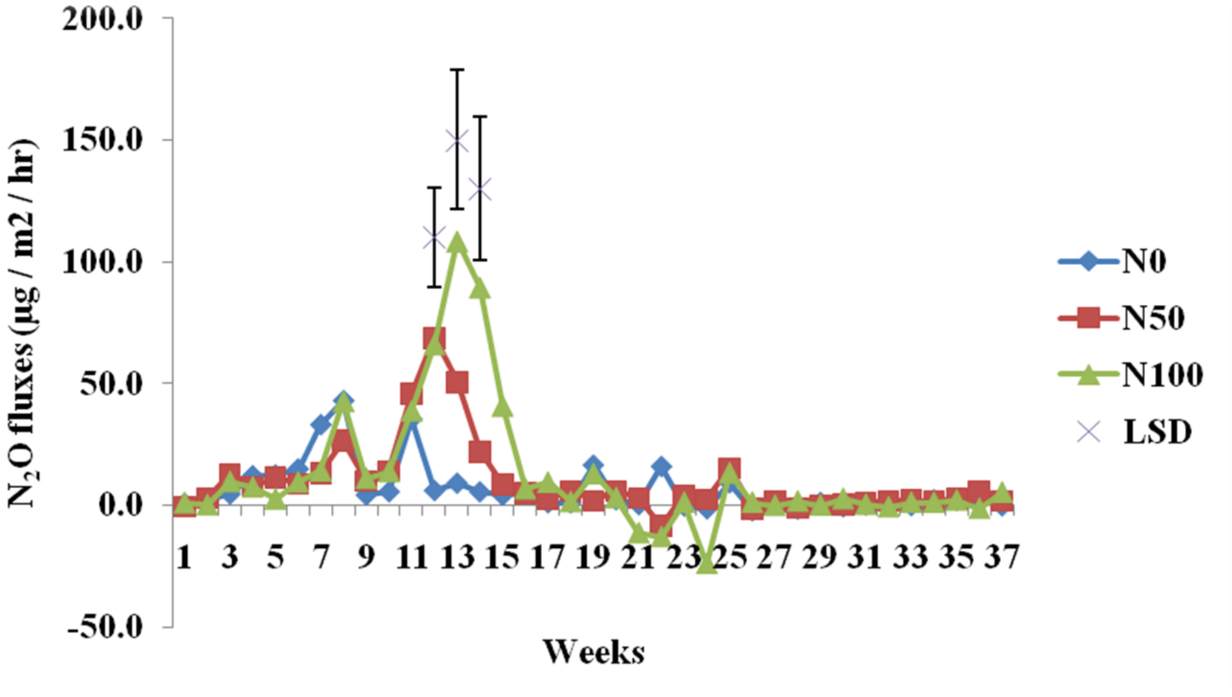

Figure 15: Influence of nitrogen fertilizer on nitrous oxide fluxes

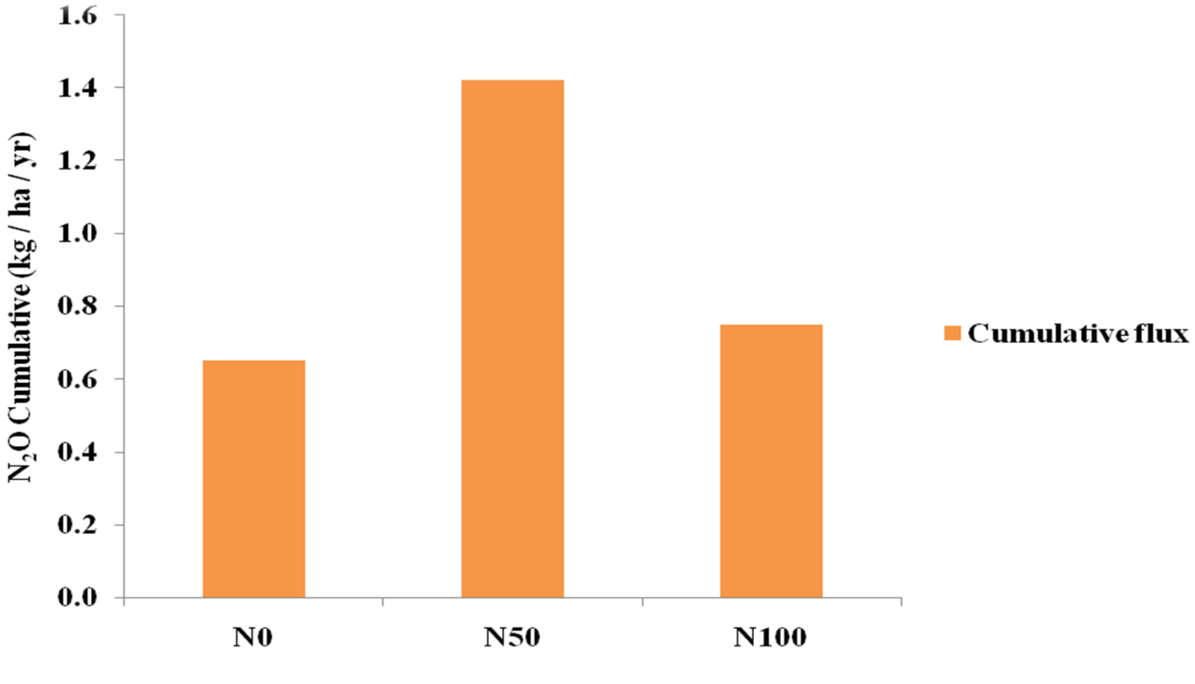

Figure 16: Cumulative nitrous oxide emissions due to nitrogen fertilizer application

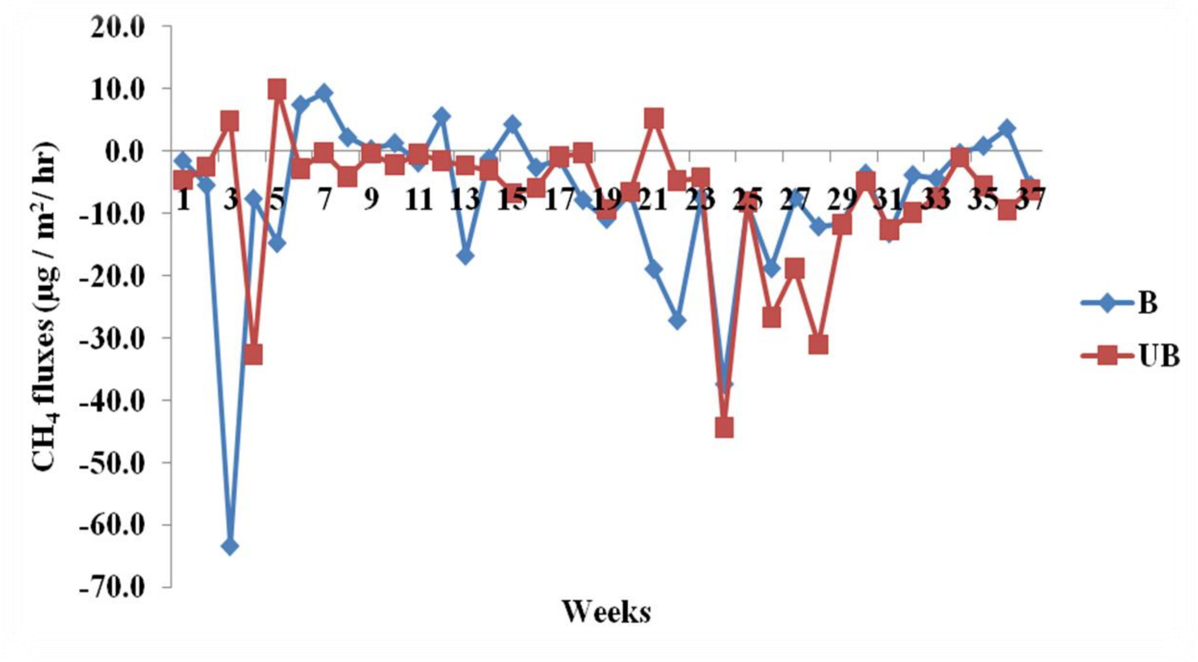

Figure 17: Contribution of trash management on methane fluxes

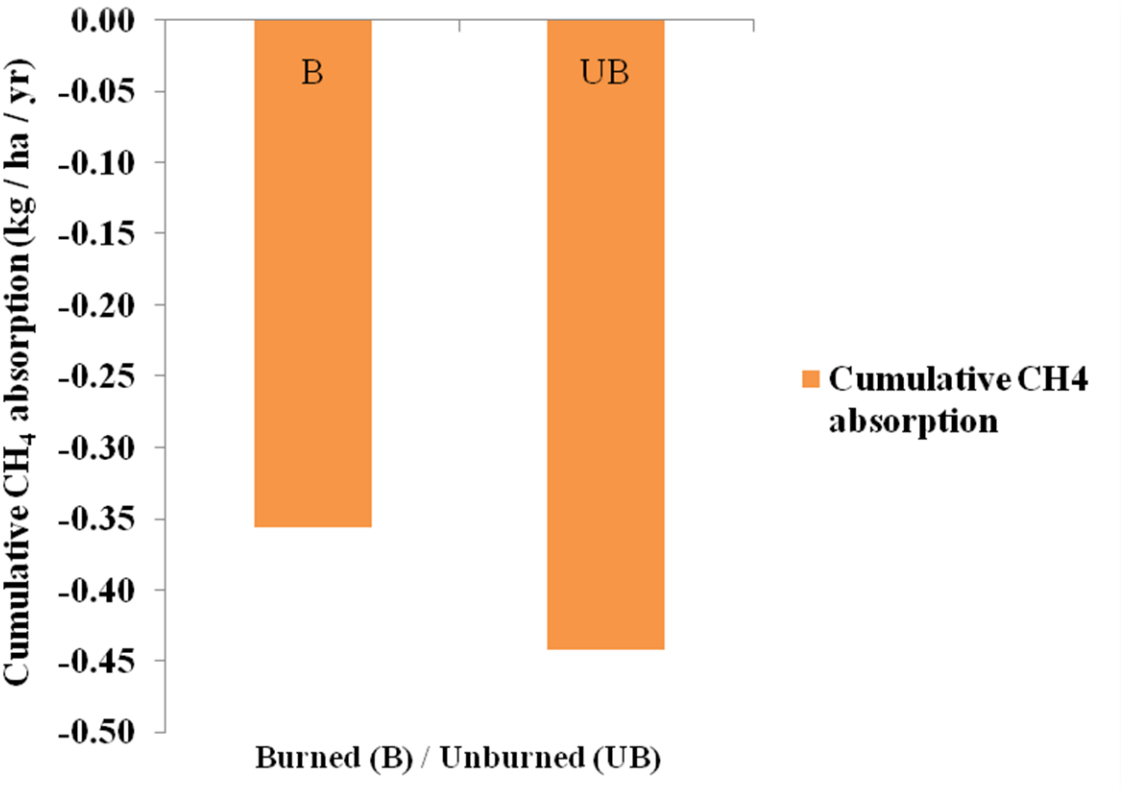

Figure 18: Cumulative methane absorption due to trash management

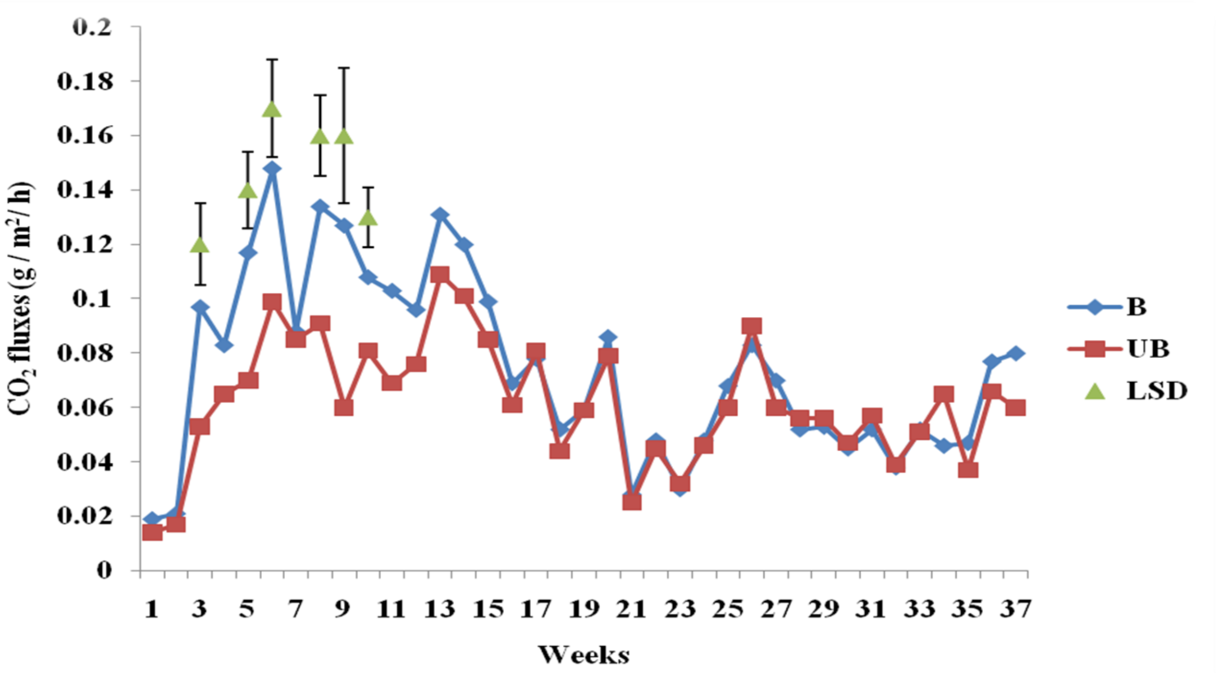

Figure 19: Influence of trash management on carbon dioxide emissions

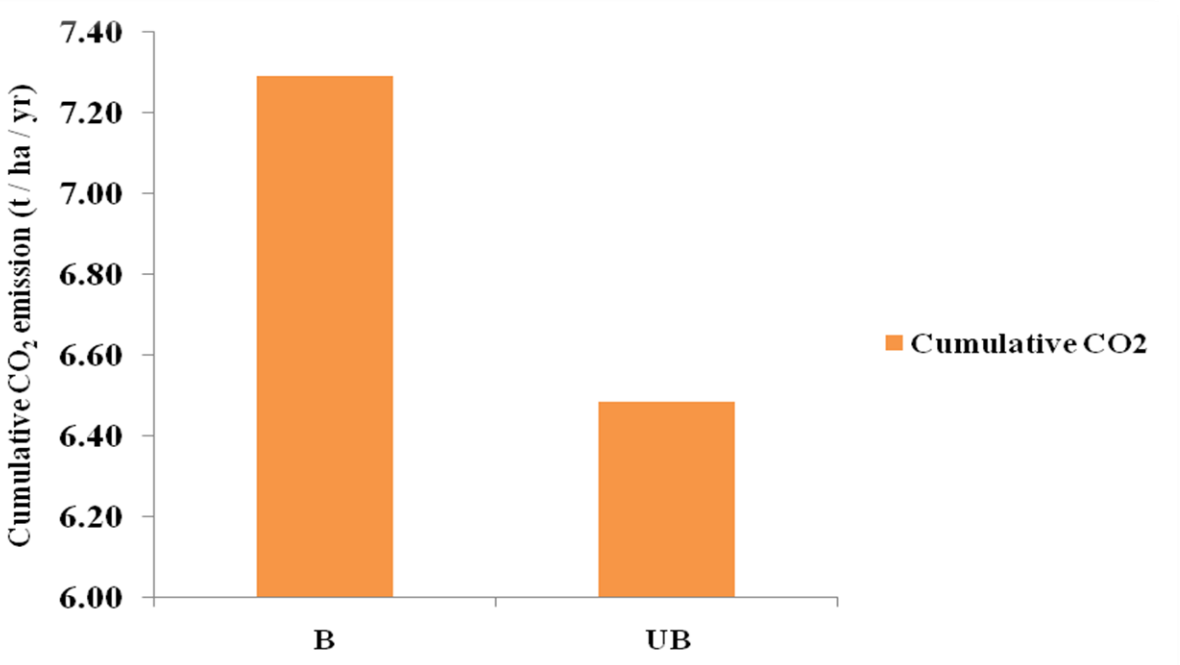

Figure 20: Cumulative carbon dioxide emissions due trash management

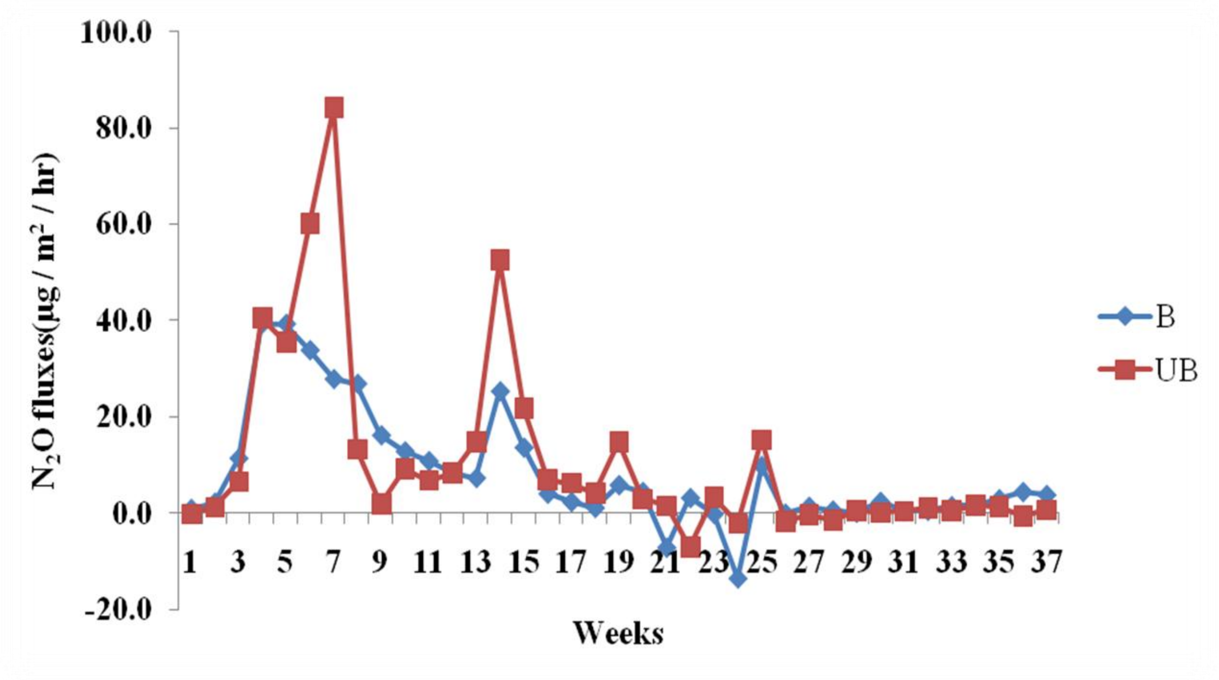

Figure 21: Contribution of trash management on nitrous oxide fluxes

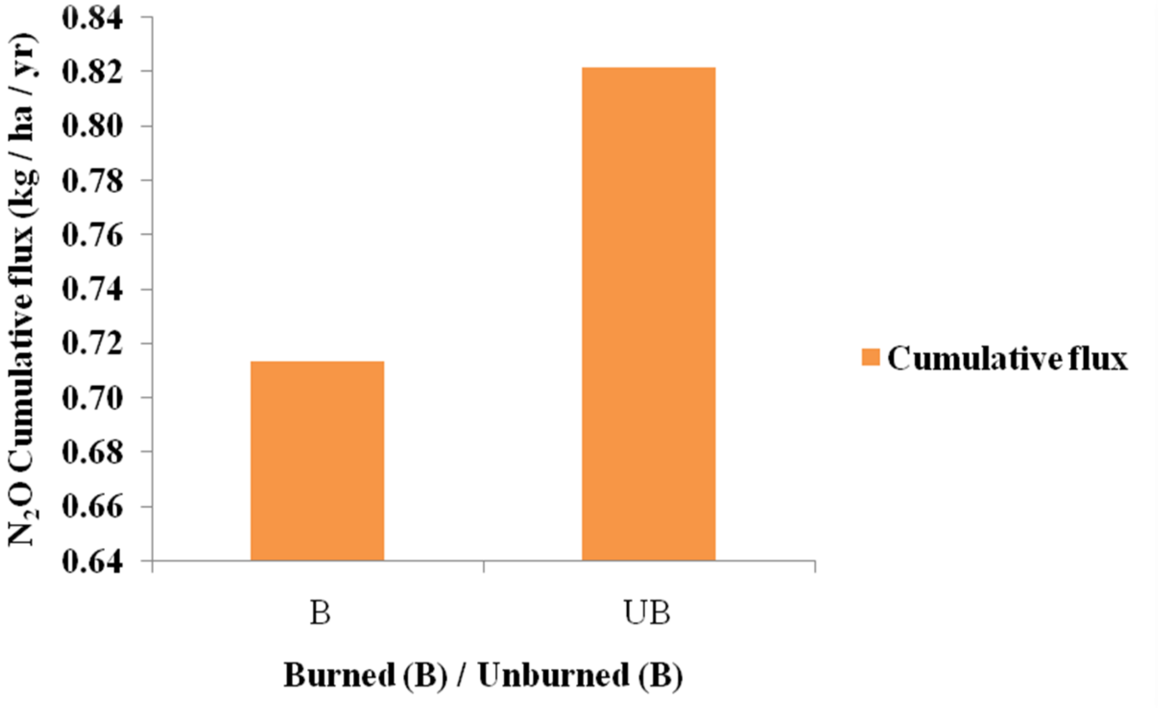

Figure 22: Cumulative nitrous oxide emissions due to trash management

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Summary.

1. The following are some of the management practices in the study area: conversion of natural vegetation to sugarcane cultivation, nitrogen fertilization and trash management by burning or retention.

2. CH_4, CO_2 and N_2O fluxes were low and not significantly different due to periods of conversions from natural vegetation or other crops to sugarcane cultivation.

3. Nitrogen fertilization (rates 0, 50, and 100 kg N ha^{-1} yr $^{-1}$)significantly ($p \leq 0.05$) influenced N_2O emissions in week 12, 13 and 14 after application in week 10. CO_2 and CH_4, weekly fluxes were however not significant. Cumulative N_2O was low and not significant compared to IPCC tier 1 default value for N_2O from agricultural soilswhich is largely based on values observed in temperate regions. CH_4, CO_2, and fluxes due to nitrogen fertilization were also low and not significant.

4. Trash management significantly ($p \leq 0.05$) increased CO_2 emissions between weeks 3 to 10 after the burning/ trashing treatment in week 3. CH_4 and CO_2fluxes were not significant during the weekly measurements. Cumulative N_2O fluxes were low and not significant compared to Tier 1 method that assumes net $CO_2$from soils in sugarcane fields to be zero, CH_4, and N_2O fluxes were also low and not significantly different due to trash/residue management.

5. Tier 1 emission factor assumed N_2O as the primary GHG emitted from sugarcane soils in the tropics, but zero net CO_2 and negligible CH_4emissions.

5.2 Conclusion

1. The management practices in Lower Nyando include fertilizer application, conversion from natural vegetation to sugarcane cultivation and trash management practices (burning or trash retention).
2. Conversion Period from natural vegetation to sugarcane cultivation was not a significant contributor of CH_4, CO_2, and N_2O fluxes in Lower Nyando.
3. Nitrogen fertilization (rates 0, 50, and 100 kg N ha^{-1} yr $^{-1}$) was not a significant contributor of N_2O, CO_2 and CH_4 fluxes in Lower Nyando, contrary to Tier 1 emission factor for the

application of nitrogen fertilizer that is overestimated especially with soils in regions with tropical climate.

4. Trash management of burning and retention of cane residues after harvest was not a significant contributor of CH_4, CO_2, and N_2O fluxes in Lower Nyando. Tier 1 emission methods also assume zero $CO_2$and negligibleCH_4 emissions from sugarcane fields.
5. Tier 1 emission factor for the application of nitrogen fertilizer was overestimated especially soils in the tropical climate, but assumed zero $CO_2$and negligible CH_4 emissions from sugarcane fields.

5.3 Recommendations

Smallholder sugarcane farmers in Lower Nyando should continue with:

1. The management practices of conversion from natural vegetation to sugarcane cultivation.
2. Applying recommended nitrogen fertilization (rates 0, 50, and 100 kg N ha^{-1} yr^{-1})
3. Trash management, since these practices do not emit GHGs into the atmosphere that causes climate change, as with the case of Tier 1 emission factor that assumes net zero emissions of CO_2 and negligible CH_4, but overestimates N_2O emissions from soils in sugarcane fields in the tropical regions.

5.4 Suggestion for further Studies

It is recommended that GHGs emissions in Nyando Basin under intensive commercial agronomic management including high inputs should be evaluated.

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APPENDICES

Appendix 1. Sugarcane survey Instrument

General household information

Date (dd/mm/yyyy)	
Name of household head	
Gender of household head	
Name of respondent	
Gender of respondent	

Geographical location (provided by the site coordinator)

Country	
Province	
State/District	
Division	
Location	
Sub-Location	
Village	
Latitude	(N), …(S)ºM
Longitude	(E), (W)ºM
Elevation(meters)	
Production system	

Form 2: Sketch of the farm

Indicate here the sketch of the plots and sizes (measure) where sugarcane appear in the farms appear in plot.

Items	Changes in the Land use				Crop characteristics					Observations
1.Number of plots cultivated with sugarcane	2.Time from conversion from natural vegetation	3.Type of previous vegetation (bush/forest/ other)	4.Crop before sugarcane	4.1Time from conversion to sugarcane	6.Distance between rows (m)	7.Crop cycle length (months between harvests)	8.Time of last harvest	9.Time of the last planting	9.1.Yield (tones/acre)	9.2. Soil Type (General Characteristics)

Sugarcane management											Observations
Number of plot	10.Number of the Ploughing (operations per season)	11.Method * of the ploughing (*See options below)	12.Number of the Weeding (Before Harvest)	12.1Method * of the Weeding	12.2Months of the Weeding	13.Fertilizer (Y/N)	14.Type of fertilizer ** (See option below)	15.Time of the Fertilization (before harvest)	16.Method * of fertilization	17. Rates of fertilizer	

(*)Options: A: manual labour/B: tractor /C: oxen plough.(**)Options: Manure (farmyard organic manure)// Urea// Calcium ammonium nitrate (CAN)// Diammonium phosphate (DAP)

Harvest						Observations	
Number of plot	18.Method (A: Manual or B: Machine)	19. Burn at Harvest? (Y/N)	20.Moment of the Burn (before or after harvest)	20.1.Time of the **last** Burn	21.Destination of the Residues (uses: coverage / animal feed / buried, other)	21.1.Other Management	21.3.

Appendix 2: Influence of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 1

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	1.402	1.269	1.077	1.249	-0.256
	Unburned	-0.264	-5.099	0.079	-1.761	
	Mean N. Rates	0.569	-1.915	0.578		
	CV (%)		-2681.57			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-1.161	-3.595	-8.068	-4.275	-5.978
	Unburned	-10.218	-3.776	-9.05	-7.681	
	Mean N. Rates	-5.689	-3.685	-8.559		
	CV (%)		-137.69			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.121	-1.163	-3.495	-1.513	
	Unburned	-5.241	-4.437	-4.485	-4.721	
	Mean N. Rates	-2.560	-2.800	-3.990		
	CV (%)		-240.35			
	LSD, (p≤0.05)		NS		NS	NS

Natural vegetation -0.738; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 3: Contribution of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 2

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-6.804	-7.22	-16.435	-10.153	-7.408
	Unburned	-4.711	-5.366	-3.91	-4.662	
	Mean N. Rates	-5.757	-6.293	-10.172		
	CV (%)		93.57			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	1.549	1.889	-5.354	-0.639	-0.547
	Unburned	2.734	0.249	-4.347	0.455	
	Mean N. Rates	2.142	1.069	-4.851		
	CV (%)		-909.75			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-2.627	-2.666	-10.895	-5.396	
	Unburned	-0.988	-2.559	-4.128	-2.558	
	Mean N. Rates	-1.808	-2.612	-7.511		
	CV (%)		-144.87			
	LSD, (p≤0.05)		NS		NS	3.215

Natural vegetation -3.497**;** *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1})**;** *NS = None Significant (p≤0.05)

Appendix 4: Effect of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 3

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-28.971	-116.855	-217.048		-58.78
	Unburned	27.106	-38.235	21.324	3.398	
	Mean N. Rates	-0.933	-77.545	-97.862		
	CV (%)		-297.02			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-21.414	3.245	1.623	-5.515	0.36
	Unburned	2.509	-15.796	31.992	6.235	
	Mean N. Rates	-9.452	-6.276	16.808		
	CV (%)		-909.75			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-25.192	-56.805	-107.712	-63.237	
	Unburned	14.807	-27.016	26.658	4.817	
	Mean N. Rates	-5.192	-41.910	-40.527		
	CV (%)		-460.49			
	LSD, (p≤0.05)		NS		NS	NS

Natural vegetation 13.641; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 5: Sugarcane Management practices influencing methane fluxes in week 4

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	4.021	4.059	11.747	6.609	-1.809
	Unburned	-29.867	9.239	-10.054	-10.227	
	Mean N. Rates	-12.923	6.649	0.846		
	CV (%)		-1033.87			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	41.203	-9.687	-96.872	-21.785	-38.497
	Unburned	-9.034	-91.915	-64.676	-55.208	
	Mean N. Rates	16.085	-50.801	-80.774		
	CV (%)		-189.64			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	22.612	-2.814	-42.562	-7.588	
	Unburned	-19.451	-41.338	-37.365	-32.718	
	Mean N. Rates	1.581	-22.076	-39.964		
	CV (%)		-317.19			
	LSD, (P≤0.05)		NS		NS	NS

Natural vegetation -6.171; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 6: Drivers of methane fluxes in week 5

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	6.749	2.157	6.438	5.114	10.807
	Unburned	5.074	36.373	8.049	16.499	
	Mean N. Rates	5.911	19.265	7.243		
	CV (%)		231.24			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-8.366	-51.798	-43.287	-34.483	-15.579
	Unburned	45.601	4.814	-40.439	3.325	
	Mean N. Rates	18.618	-23.492	-41.863		
	CV (%)		-415.2			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-0.808	-24.82	-18.424	-14.684	
	Unburned	25.337	20.594	-16.195	9.912	
	Mean N. Rates	12.264	-2.113	-17.310		
	CV (%)		-2009.24			
	LSD, (p≤0.05)		NS		NS	NS

Natural vegetation -5.908; *Figures are CH$_4$ flux rate (µg CH$_4$ – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 7: Factors influencing methane fluxes in week 6

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	18.458	3.523	10.348	10.776	4.325
	Unburned	-1.041	-6.122	0.786	-2.126	
	Mean N. Rates	8.709	-1.3	5.567		
	CV (%)		-415.2			
	LSD, (p≤0.05)		NS		9.465	
>10	Burned	14.836	6.72	-8.992	4.188	0.326
	Unburned	-2.105	-0.989	-7.515	-3.536	
	Mean N. Rates	6.366	2.866	-8.254		
	CV (%)		258.14			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	16.647	5.122	0.678	7.482	
	Unburned	-1.573	-3.555	-3.365	-2.831	
	Mean N. Rates	7.537	0.783	-1.343		
	CV (%)		621.47			
	LSD, (p≤0.05)		NS		NS	NS

Natural vegetation 23.356; *Figures are CH$_4$ flux rate (µg CH$_4$ – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 8: Sugarcane management practices contributing methane fluxes in week 7

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	15.489	1.28	-8.152	2.872	2.949
	Unburned	1.782	5.59	1.707	3.026	
	Mean N. Rates	8.636	3.435	-3.222		
	CV (%)		440.08			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-2.831	18.651	31.803	15.874	6.114
	Unburned	-5.066	0.971	-6.842	-3.645	
	Mean N. Rates	-3.948	9.811	12.481		
	CV (%)		310.83			
	LSD, (P≤0.05)		NS		NS	
Overall mean	Burned	6.329	9.966	11.825	9.373	
	Unburned	-1.642	3.28	-2.567	-0.307	
	Mean N. Rates	2.344	6.623	4.629		
	CV (%)		375.07			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -4.267; *****Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 9: Variation of methane fluxes with sugarcane management practices in week 8

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	10.171	-2.864	2.309	3.205	-1.408
	Unburned	-7.63	-14.592	4.158	-6.021	
	Mean N. Rates	1.27	-8.728	3.234		
	CV (%)		-1024.37			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-3.071	2.775	4.272	1.325	-0.435
	Unburned	-7.035	-0.579	1.025	-2.196	
	Mean N. Rates	-5.053	1.098	2.648		
	CV (%)		-2489.53			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	3.55	-0.044	3.291	2.265	
	Unburned	-7.332	-7.586	2.592	-4.109	
	Mean N. Rates	-1.891	-3.815	2.941		
	CV (%)		-1344.05			
	LSD, (p≤0.05)		NS		NS	NS

Natural vegetation 10.032; *****Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 10: Influence of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 9

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	9.115	2.519	-6.906	1.576	0.474
	Unburned	0.891	-8.134	5.356	-0.629	
	Mean N. Rates	5.003	-2.807	-0.775		
	CV (%)		3477.66			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-1.465	2.195	-3.353	-0.874	-0.599
	Unburned	-1.056	-2.396	2.484	-0.323	
	Mean N. Rates	-1.261	-0.1	-0.435		
	CV (%)		-1728.27			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	3.825	2.357	-5.129	0.351	
	Unburned	-0.083	-5.265	3.92	-0.476	
	Mean N. Rates	1.871	-1.454	-0.605		
	CV (%)		-21056.31			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -3.627; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 11: Contribution of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 10

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-0.999	4.472	-6.51	-1.009	-1.609
	Unburned	0.353	-2.693	-4.284	-2.208	
	Mean N. Rates	-0.318	0.889	-5.397		
	CV (%)		-657.84			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	2.395	-0.605	9.158	3.649	0.657
	Unburned	-5.754	-3.197	1.944	-2.336	
	Mean N. Rates	-1.68	-1.901	5.551		
	CV (%)		1759.11			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.703	1.934	1.324	1.320	
	Unburned	-2.70	-2.945	-1.17	-2.272	
	Mean N. Rates	-0.999	-0.506	0.077		
	CV (%)		-2351.51			
	LSD, (p≤0.05)		NS		NS	NS

Natural vegetation 0.657; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 12: Sugarcane management practices influencing methane fluxes in week 11

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-2.332	-8.024	-11.893	-7.417	-4.15
	Unburned	-1.707	-2.739	1.799	-0.882	
	Mean N. Rates	-2.020	-5.382	-5.047		
	CV (%)		-189.350			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-5.949	15.585	1.951	3.863	-4.52
	Unburned	-8.109	2.258	4.986	-0.288	
	Mean N. Rates	-7.029	8.922	3.467		
	CV (%)		717.510			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-4.140	3.780	-4.971	-1.777	
	Unburned	-4.908	-0.241	3.393	-0.585	
	Mean N. Rates	-4.524	1.770	-0.789		
	CV (%)		-867.08			
	LSD, (p≤0.05)		NS		NS	NS

Natural vegetation -11.11; *****Figures are CH_4 flux rate ($\mu g\ CH_4 - C\ m^{-2}\ hr^{-1}$); *NS = None Significant (p≤0.05)

Appendix 13: Drivers of methane fluxes in week 12

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	1.816	45.620	-0.567	15.623	8.519
	Unburned	-4.113	5.385	2.975	1.416	
	Mean N. Rates	-1.149	25.502	1.204		
	CV (%)		385.17			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-3.312	-0.746	-9.005	-4.354	-4.532
	Unburned	1.954	-12.213	-3.869	-4.709	
	Mean N. Rates	-0.679	-6.48	-6.437		
	CV (%)		-172.77			
	LSD, (P≤0.05)		NS		NS	
Overall mean	Burned	-0.748	22.437	-4.786	5.634	
	Unburned	-1.08	-3.414	-0.447	-1.647	
	Mean N. Rates	-0.914	9.511	-2.616		
	CV (%)		1238.38			
	LSD, (P≤0.05)		NS		NS	NS

Natural vegetation -3.958; *****Figures are CH_4 flux rate ($\mu g\ CH_4 - C\ m^{-2}\ hr^{-1}$); *NS = None Significant (p≤0.05)

Appendix 14: Effect of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 13methane fluxes in week 13

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	3.181	-15.043	-3.075	-4.979	-4.88
	Unburned	4.848	-3.254	-15.934	-4.78	
	Mean N. Rates	4.014	-9.149	-9.505		
	CV (%)		-290.79			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-7.456	-72.798	-5.002	-28.418	-14.204
	Unburned	-4.73	3.358	1.402	0.01	
	Mean N. Rates	-6.093	-34.72	-1.800		
	CV (%)		-335.37			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-2.137	-43.921	-4.039	-16.699	
	Unburned	0.059	0.052	-7.266	-2.385	
	Mean N. Rates	-1.039	-21.934	-5.652		
	CV (%)		-269.40			
	LSD, (P≤0.05)		NS		NS	NS

Natural vegetation -2.908; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 15: Influence of sugarcane management practices on methane fluxes in week 14

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-1.226	11.654	-5.949	1.493	-0.195
	Unburned	-1.116	-1.076	-3.46	-1.884	
	Mean N. Rates	-1.171	5.289	-4.705		
	CV (%)		-6286.660			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-2.637	2.51	-11.280	-3.803	-4.058
	Unburned	-7.519	-3.613	-1.810	-4.314	
	Mean N. Rates	-5.078	-0.552	-6.545		
	CV (%)		-173.800			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-1.931	7.082	-8.615	-1.155	
	Unburned	-4.317	-2.345	-2.635	-3.099	
	Mean N. Rates	-3.124	2.369	-5.625		
	CV (%)		-470.51			
	LSD, (p≤0.05)		NS		NS	NS

Natural vegetation -11.129; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 16: Variation of methane fluxes with sugarcane management practices in week 15

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-8.478	39.761	-5.579	8.568	2.845
	Unburned	-5.279	7.283	-10.637	-2.878	
	Mean N. Rates	-6.878	23.522	-8.108		
	CV (%)		1252.55			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	4.637	-3.07	-1.140	0.152	-5.267
	Unburned	-16.289	-4.619	-11.152	-10.687	
	Mean N. Rates	-5.812	-3.844	-6.146		
	CV (%)		-215.53			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	-1.906	18.346	-3.359	4.360	
	Unburned	-10.784	1.332	-10.895	-6.782	
	Mean N. Rates	-6.345	9.839	-7.127		
	CV (%)		-2123.54			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*Natural vegetation -3.267; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 17: Factors influencing methane fluxes in week 16

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-2.751	-0.346	-2.429	-1.842	-2.898
	Unburned	-4.167	-7.665	-0.032	-3.955	
	Mean N. Rates	-3.459	-4.006	-1.231		
	CV (%)		-621.49			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	-7.841	-2.458	0.265	-3.345	-5.686
	Unburned	-10.884	-10.59	-2.609	-8.028	
	Mean N. Rates	-9.363	-6.524	-1.172		
	CV (%)		-157.59			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	-5.296	-1.402	-1.082	-2.593	
	Unburned	-7.526	-9.128	-1.320	-5.991	
	Mean N. Rates	-6.411	-5.265	-1.201		
	CV (%)		-319.86			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*Natural vegetation 191.729; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 18: Contribution of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 17

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	5.285	1.365	-4.655	0.665	1.625
	Unburned	1.508	0.189	6.058	2.585	
	Mean N. Rates	3.397	0.777	0.701		
	CV (%)		372.100			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-7.958	-1.028	-0.056	-3.014	-3.834
	Unburned	-5.18	-6.556	-2.227	-4.654	
	Mean N. Rates	-6.569	-3.792	-1.141		
	CV (%)		-156.47			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-1.337	0.168	-2.355	-1.174	
	Unburned	-1.836	-3.183	1.915	-1.035	
	Mean N. Rates	-1.59	-1.507	0.220		
	CV (%)		-541.23			
	LSD, (p≤0.05)		NS		NS	NS

*Natural vegetation -2.484; *Figures are CH$_4$ flux rate (µg CH$_4$ – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 19: Sugarcane management practices influencing to methane fluxes in week 18

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-36.094	18.086	-9.346	-9.118	-7.284
	Unburned	-0.517	-10.354	-5.48	-5.450	
	Mean N. Rates	-18.305	3.866	-7.413		
	CV (%)		-365.9			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-3.749	-6.891	-8.801	-6.480	-0.894
	Unburned	24.202	-1.765	-8.362	4.692	
	Mean N. Rates	10.227	-4.328	-8.581		
	CV (%)		-2072.47			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-19.921	5.598	-9.073	-7.799	
	Unburned	11.843	-6.059	-6.921	-0.379	
	Mean N. Rates	-4.039	-0.231	-7.997		
	CV (%)		-537.57			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -3.444; *Figures are CH$_4$ flux rate (µg CH$_4$ – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 20: Effect of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 19

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-7.456	-8.632	-21.997	-12.695	
	Unburned	-12.664	-13.14	-12.731	-12.845	
	Mean N. Rates	-10.06	-10.886	-17.364		-12.770
	CV (%)		-86.54			
	LSD, (P≤0.05)		NS		NS	
>10	Burned	-19.309	-2.574	-5.128	-9.004	
	Unburned	-11.152	-12.400	5.802	-5.916	-7.460
	Mean N. Rates	-15.130	-7.487	0.337		
	CV (%)		-191.61			
	LSD, (P≤0.05)		NS		NS	
Overall mean	Burned	-13.383	-5.603	-13.562	-10.849	
	Unburned	-11.908	-12.77	-3.464	-9.381	
	Mean N. Rates	-12.645	-9.186	-8.513		
	CV (%)		-150.66			
	LSD, (P≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.051; *****Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (P ≤ 0.05)

Appendix 21: Drivers of methane fluxes in week 20

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-2.872	-7.774	-13.453	-8.033	
	Unburned	-3.875	-3.193	-14.449	-7.172	
	Mean N. Rates	-3.373	-5.483	-13.951		-7.603
	CV (%)		-112.74			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-6.954	-0.864	-8.168	-5.329	
	Unburned	-4.914	-5.877	-7.133	-5.974	-5.652
	Mean N. Rates	-5.934	-3.370	-7.650		
	CV (%)		-103.11			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-4.913	-4.319	-10.811	-6.681	
	Unburned	-4.394	-4.535	-10.791	-6.573	
	Mean N. Rates	-4.654	-4.427	-10.801		
	CV (%)		-127.67			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -4.407; *****Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 22: Sugarcane management practices influencing methane fluxes in week 21

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-15.333	-15.056	1.13	-9.753	2.337
	Unburned	-19.062	65.229	-2.886	14.427	
	Mean N. Rates	-17.198	25.087	-0.878		
	CV (%)		2159.73			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-8.14	2.216	-77.969	-27.964	-15.979
	Unburned	-4.858	-5.866	-1.254	-3.993	
	Mean N. Rates	-6.499	-1.825	-39.612		
	CV (%)		-308.53			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-11.737	-6.420	-38.420	-18.859	
	Unburned	-11.960	29.682	-2.070	5.217	
	Mean N. Rates	-11.848	11.631	-20.245		
	CV (%)		-720.75			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -3.416; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 23: Contribution of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 22

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-5.638	-10.304	-135.989	-50.644	-27.878
	Unburned	-0.514	-6.066	-8.759	-5.113	
	Mean N. Rates	-3.076	-8.185	-72.374		
	CV (%)		-318.23			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	2.953	-17.239	3.785	-3.500	-39.958
	Unburned	-12.963	-2.125	1.841	-4.416	
	Mean N. Rates	-5.005	-9.682	2.813		
	CV (%)		-369.12			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-1.342	-13.772	-66.102	-27.072	
	Unburned	-6.739	-4.095	-3.459	-4.765	
	Mean N. Rates	-4.041	-8.934	-34.781		
	CV (%)		-397.76			
	LSD, (P≤0.05)		NS		NS	NS

*NV = Natural vegetation -3.227; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 24: Effect of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 23

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-13.634	-4.016	-5.922	-7.857	-5.123
	Unburned	2.037	19.14	-28.345	-2.389	
	Mean N. Rates	-5.799	7.562	-17.133		
	CV (%)		-703.18			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	-4.874	-15.806	0.496	-6.728	-6.425
	Unburned	-6.067	-5.749	-6.552	-6.123	
	Mean N. Rates	-5.471	-10.777	-3.028		
	CV (%)		-85.21			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	-9.254	-9.911	-2.713	-7.293	
	Unburned	-2.015	6.696	-17.449	-4.256	
	Mean N. Rates	-5.635	-1.608	-10.081		
	CV (%)		-429.60			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation -6.303; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 25: Influence of sugarcane management practices on methane fluxes in week 24

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-61.701	-71.188	-76.939	-69.943	-73.476
	Unburned	-86.701	-68.572	-76.223	-77.009	
	Mean N. Rates	-73.966	-69.88	-76.581		
	CV (%)		-8.97			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	-3.77	-2.146	-7.996	-4.637	-8.205
	Unburned	-12.677	5.14	-27.778	-11.772	
	Mean N. Rates	-8.224	1.497	-17.887		
	CV (%)		-200.41			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	-32.736	-36.667	-42.467	-37.290	
	Unburned	-49.454	-31.716	-52.0	-44.390	
	Mean N. Rates	-41.095	-34.192	-47.234		
	CV (%)		-148.59			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation -13.106; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 26: Variation of methane fluxes with sugarcane management practices in week 25

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-15.488	-6.813	-12.813	-8.581	-11.436
	Unburned	-12.07	-10.502	-10.931	-8.207	
	Mean N. Rates	-13.779	-8.657	-11.872		
	CV (%)		-79.56			
	LSD, ($p \le 0.05$)		NS		NS	
>10	Burned	-9.219	-9.027	1.875	-11.704	-5.351
	Unburned	-4.578	-2.227	-8.932	-11.168	
	Mean N. Rates	-6.899	-5.627	-3.528		
	CV (%)		-114.24			
	LSD, ($p \le 0.05$)		NS		NS	
Overall mean	Burned	-12.354	-7.92	-5.469	-8.581	
	Unburned	-8.324	-6.365	-9.932	-8.207	
	Mean N. Rates	-10.339	-7.142	-7.700		
	CV (%)		-113.27			
	LSD, ($p \le 0.05$)		NS		NS	NS

*NV = Natural vegetation -7.350; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant ($p \le 0.05$)

Appendix 27: Factors influencing methane fluxes in week 26

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-8.735	-67.867	-17.182	-31.261	-40.863
	Unburned	-67.502	-67.696	-16.196	-50.464	
	Mean N. Rates	-38.119	-67.781	-16.689		
	CV (%)		-144.06			
	LSD, ($p \le 0.05$)		NS		NS	
>10	Burned	-12.976	-0.165	-5.420	-6.187	-4.613
	Unburned	0.889	-0.524	-9.485	-3.040	
	Mean N. Rates	-6.043	-0.345	-7.452		
	CV (%)		-390.60			
	LSD, ($p \le 0.05$)		NS		NS	
Overall mean	Burned	-10.855	-34.016	-11.301	-18.724	
	Unburned	-33.306	-34.110	-12.840	-26.752	
	Mean N. Rates	-22.081	-34.063	-12.070		
	CV (%)		-205.12			
	LSD, ($p \le 0.05$)		NS		NS	NS

*NV = Natural vegetation -13.953; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant ($p \le 0.05$)

Appendix 28: Sugarcane management practices influencing methane fluxes in week 27

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-10.587	-13.201	-4.399	-9.396	-7.831
	Unburned	-12.518	-3.315	-2.966	-6.266	
	Mean N. Rates	-11.552	-8.258	-3.682		
	CV (%)		-112.12			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-5.461	-5.021	-5.986	-5.489	-18.492
	Unburned	-25.662	-5.155	-63.668	-31.495	
	Mean N. Rates	-15.561	-5.088	-34.827		
	CV (%)		-249.61			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-8.024	-9.111	-5.192	-7.442	
	Unburned	-19.09	-4.235	-33.317	-18.881	
	Mean N. Rates	-13.557	-6.673	-19.255		
	CV (%)		-242.60			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -8.878; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (P ≤ 0.05)

Appendix 29: Drivers of methane fluxes in week 28

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-19.201	-16.421	-12.827	-16.149	-13.460
	Unburned	-11.377	-8.156	-12.780	-10.771	
	Mean N. Rates	-15.289	-12.288	-12.803		
	CV (%)		-87.28			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-60.518	-18.047	54.826	-7.913	-29.627
	Unburned	-72.465	-75.731	-5.828	-51.341	
	Mean N. Rates	-66.491	-46.889	24.499		
	CV (%)		-313.59			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-39.859	-17.234	20.999	-12.031	
	Unburned	-41.921	-41.944	-9.304	-31.056	
	Mean N. Rates	-40.890	-29.589	5.848		
	CV (%)		-298.53			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -20.854**; ***Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}**;** *NS = None Significant (p≤0.05

Appendix 30: Sugarcane management practices contributing to methane fluxes in week 29

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-9.758	-8.604	-12.647	-10.336	-11.124
	Unburned	-11.647	-10.951	-13.137	-11.912	
	Mean N. Rates	-10.702	-9.777	-12.892		
	CV (%)		-53.20			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-6.789	-21.551	-9.826	-12.721	-12.237
	Unburned	-5.786	-10.749	-18.915	-11.753	
	Mean N. Rates	-6.19	-16.15	-14.371		
	CV (%)		-100.71			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-8.272	-15.077	-11.237	-11.529	
	Unburned	-8.620	-10.850	-16.026	-11.832	
	Mean N. Rates	-8.446	-12.964	-13.631		
	CV (%)		-95.99			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -2.085; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 31: Contribution of conversion period, trash management and nitrogen fertilizer application on methane fluxes week 30

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-5.59	0.833	-10.101	-4.953	-5.341
	Unburned	-4.388	-12.21	-0.587	-5.728	
	Mean N. Rates	-4.989	-5.689	-5.344		
	CV (%)		-222.28			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-2.698	-0.197	-3.598	-2.164	-3.146
	Unburned	-11.146	-6.789	5.550	-4.129	
	Mean N. Rates	-6.922	-3.493	0.976		
	CV (%)		-385.50			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-4.144	0.318	-6.849	-3.559	
	Unburned	-7.767	-9.500	2.482	-4.928	
	Mean N. Rates	-5.956	-4.591	-2.184		
	CV (%)		-289.56			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -16.585; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 32: Effect of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 31

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-16.023	-22.822	-9.119	-15.988	-14.420
	Unburned	-6.897	-12.741	-18.918	-12.852	
	Mean N. Rates	-11.460	-17.781	-14.081		
	CV (%)		-68.38			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-6.823	-4.949	-19.055	10.276	-11.357
	Unburned	-18.129	-17.210	-1.975	-12.438	
	Mean N. Rates	-12.476	-11.079	-10.515		
	CV (%)		-56.32			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-11.423	-13.885	-14.087	-13.132	
	Unburned	-12.513	-14.975	-10.446	-12.645	
	Mean N. Rates	-11.968	-14.430	-12.267		
	CV (%)		-70.22			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -6.014; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 33: Influence of sugarcane management practices on methane fluxes on CH4 fluxes in week 32

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	3.438	-8.691	-11.394	-5.549	-5.635
	Unburned	-9.521	-2.954	-4.689	-5.721	
	Mean N. Rates	-3.041	-5.822	-8.041		
	CV (%)		-191.62			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.023	1.064	-7.183	-2.032	-8.094
	Unburned	-11.629	-10.491	-20.351	-14.157	
	Mean N. Rates	-5.803	-4.713	-13.767		
	CV (%)		-113.95			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	1.730	-3.813	-9.288	-3.790	
	Unburned	-10.575	-6.722	-12.520	-9.939	
	Mean N. Rates	-4.422	-5.268	-10.904		
	CV (%)		-142.95			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 5.922; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 34: Factors contributing to methane fluxes in week 33

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-9.145	8.416	-3.043	-1.257	-3.652
	Unburned	-6.747	2.109	-13.501	-6.046	
	Mean N. Rates	-7.946	5.263	-8.277		
	CV (%)		-341.18			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-2.614	-10.506	-9.205	-7.442	-8.216
	Unburned	-10.865	-12.210	-3.898	-8.991	
	Mean N. Rates	-6.740	-11.358	-6.551		
	CV (%)		-174.46			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-5.880	-1.045	-6.124	-4.349	
	Unburned	-8.806	-5.050	-8.700	-7.519	
	Mean N. Rates	-7.343	-3.048	-7.412		
	CV (%)		-222.14			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -1.062; *Figures are CH$_4$ flux rate (µg CH$_4$ – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 35: Variation of methane fluxes with sugarcane management practices in week 34

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	5.149	-3.932	7.186	2.801	3.159
	Unburned	1.906	4.279	4.369	3.518	
	Mean N. Rates	3.527	0.174	5.777		
	CV (%)		-483.07			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	1.110	-7.870	-3.207	-3.322	-4.518
	Unburned	-2.986	6.349	-20.503	-5.713	
	Mean N. Rates	-0.938	-0.760	-11.855		
	CV (%)		-207.57			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	3.130	-5.901	1.990	-0.261	
	Unburned	-0.540	5.314	-8.067	-1.098	
	Mean N. Rates	1.295	-0.293	-3.039		
	CV (%)		-1841.29			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -15.630; *Figures are CH$_4$ flux rate (µg CH$_4$ – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 36: Sugarcane management practices influencing methane fluxes in week 35

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-2.681	6.848	-3.855	0.104	-3.165
	Unburned	-10.984	-6.620	-1.699	-6.434	
	Mean N. Rates	-6.832	0.144	-2.777		
	CV (%)		-377.68			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	2.737	-5.340	7.592	1.663	-1.662
	Unburned	-7.075	-14.045	6.159	-4.987	
	Mean N. Rates	-2.169	-9.692	6.876		
	CV (%)		-941.86			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.028	0.754	1.869	0.884	
	Unburned	-9.030	-10.332	2.230	-5.711	
	Mean N. Rates	-4.501	-4.789	2.049		
	CV (%)		-579.68			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -7.512; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 37: Drivers of methane fluxes in week 36

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-0.0672	12.397	13.712	8.479	0.951
	Unburned	-9.908	-10.262	0.438	-6.577	
	Mean N. Rates	-5.290	1.068	7.075		
	CV (%)		1075.25			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-1.900	0.553	-1.914	-1.087	-6.689
	Unburned	-1.495	-11.992	-23.383	-12.290	
	Mean N. Rates	-1.698	-5.720	-12.648		
	CV (%)		-144.41			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-1.286	6.475	5.899	3.696	
	Unburned	-5.701	-11.127	-11.472	-9.434	
	Mean N. Rates	-3.494	-2.326	-2.787		
	CV (%)		-360.40			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 4.335; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 38: Effect of conversion period, trash management and nitrogen fertilizer application on methane fluxes in week 37

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-3.082	0.762	-12.881	-5.067	-5.564
	Unburned	-10.560	11.501	3.879	-6.061	
	Mean N. Rates	-6.821	-5.370	-4.501		
	CV (%)		-136.96			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-10.294	-3.976	-3.217	-5.829	-6.118
	Unburned	2.874	-9.362	-12.731	-6.406	
	Mean N. Rates	-3.710	-6.669	-7.974		
	CV (%)		-335.64			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-6.688	-1.607	-8.049	-5.448	
	Unburned	-3.843	-10.432	-4.426	-6.234	
	Mean N. Rates	-5.266	-6.019	-6.238		
	CV (%)		-253.74			
	LSD, (P≤0.05)		NS		NS	NS

*NV = Natural vegetation -0.067; *Figures are CH_4 flux rate (µg CH_4 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 39: Cumulativefluxes of methane due to conversion period, trash management and nitrogen fertilizer

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-0.589	-0.379	-0.547	-0.505	-0.545
	Unburned	-0.858	-0.319	-0.581	-0.586	
	Mean N. Rates	-0.723	-0.349	-0.564		
	CV (%)		-98.05			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-0.567	-0.596	-0.431	-0.531	-0.606
	Unburned	-0.414	-0.715	-0.911	-0.680	
	Mean N. Rates	-0.491	-0.656	-0.671		
	CV (%)		-86.01			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-0.578	-0.487	-0.489	-0.518	
	Unburned	-0.636	-0.517	-0.746	-0.633	
	Mean N. Rates	-0.607	-0.502	-0.617		
	CV (%)		-89.26			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.277; *Figures are CH_4 flux rate (kg / ha / yr); *NS = None Significant *(*p≤0.05)

Appendix 40: Influence of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 1

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.006	0.017	0.022	0.015	0.014
	Unburned	0.014	0.023	0.004	0.014	
	Mean N. Rates	0.010	0.020	0.013		
	CV (%)		65.40			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.028	0.022	0.022	0.024	0.020
	Unburned	0.01	0.017	0.019	0.015	
	Mean N. Rates	0.019	0.019	0.020		
	CV (%)		66.65			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.017	0.019	0.022	0.019	
	Unburned	0.012	0.020	0.011	0.014	
	Mean N. Rates	0.014	0.020	0.017		
	CV (%)		64.80			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.019; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant *(*$p \leq 0.05$*)*

Appendix 41: Contribution of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 2

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.050	0.026	0.034	0.037	0.029
	Unburned	0.019	0.011	0.035	0.022	
	Mean N. Rates	0.035	0.019	0.035		
	CV (%)		63.41			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.016	-0.002	0.003	0.006	0.009
	Unburned	0.004	0.029	0.004	0.012	
	Mean N. Rates	0.010	0.013	0.004		
	CV (%)		242.83			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.033	0.012	0.018	0.021	
	Unburned	0.011	0.020	0.020	0.017	
	Mean N. Rates	0.022	0.016	0.019		
	CV (%)		139.66			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.024; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant *(*$p \leq 0.05$)

Appendix 42: Effect of conversion period, trash management and nitrogen fertilizer application on flu carbon dioxide fluxes in week 3

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.108	0.119	0.101	0.109	0.078
	Unburned	0.006	0.080	0.057	0.047	
	Mean N. Rates	0.057	0.100	0.079		
	CV (%)		77.61			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.078	0.096	0.082	0.085	0.072
	Unburned	0.048	0.052	0.074	0.058	
	Mean N. Rates	0.063	0.074	0.078		
	CV (%)		62.59			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.093	0.108	0.092	0.097	
	Unburned	0.027	0.066	0.065	0.053	
	Mean N. Rates	0.060	0.087	0.078		
	CV (%)		78.04			
	LSD, (p≤0.05)		NS		0.033	NS

*NV = Natural vegetation 0.143; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 43: Sugarcane Management practices influencing carbon dioxide fluxes in week 4

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.099	0.088	0.089	0.092	0.077
	Unburned	0.043	0.079	0.065	0.062	
	Mean N. Rates	0.071	0.084	0.077		
	CV (%)		45.77			
	LSD, (p≤0.05)		NS		NS	
	Burned	0.066	0.066	0.091	0.074	0.070
	Unburned	0.090	0.047	0.064	0.067	
	Mean N. Rates	0.078	0.056	0.077		
	CV (%)		57.63			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.083	0.077	0.090	0.083	
	Unburned	0.066	0.063	0.065	0.065	
	Mean N. Rates	0.074	0.070	0.077		
	CV (%)		51.78			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.612; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 44: Drivers of carbon dioxide fluxes in week 5

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.161	0.146	0.150	0.153	0.116
	Unburned	0.090	0.068	0.079	0.079	
	Mean N. Rates	0.125	0.107	0.115		
	CV (%)		49.59			
	LSD, ($p \leq 0.05$)		NS		0.043	
>10	Burned	0.093	0.088	0.066	0.082	0.071
	Unburned	0.057	0.070	0.055	0.061	
	Mean N. Rates	0.075	0.079	0.061		
	CV (%)		44.54			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.127	0.117	0.108	0.117	
	Unburned	0.074	0.069	0.067	0.070	
	Mean N. Rates	0.100	0.093	0.088		
	CV (%)		52.34			
	LSD, ($p \leq 0.05$)		NS		0.027	NS

*NV = Natural vegetation 0.373; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant *(*$p \leq 0.05$)

Appendix 45: Factors influencing carbon dioxide fluxes in week 6

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.152	0.137	0.143	0.144	0.114
	Unburned	0.096	0.088	0.070	0.085	
	Mean N. Rates	0.124	0.113	0.107		
	CV (%)		27.57			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.133	0.180	0.164	0.152	0.133
	Unburned	0.102	0.128	0.111	0.114	
	Mean N. Rates	0.108	0.154	0.137		
	CV (%)		43.5			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.133	0.159	0.153	0.148	
	Unburned	0.099	0.108	0.090	0.099	
	Mean N. Rates	0.116	0.133	0.122		
	CV (%)		52.46			
	LSD, ($p \leq 0.05$)		NS		0.036	NS

*NV = Natural vegetation 0.181; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 46: Sugarcane management practices contributing to carbon dioxide fluxes in week 7

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.141	0.116	0.097	0.118	0.095
	Unburned	0.066	0.094	0.053	0.071	
	Mean N. Rates	0.104	0.105	0.075		
	CV (%)		41.39			
	LSD, ($p \leq 0.05$)		NS		0.033	
>10	Burned	0.064	0.066	0.046	0.059	0.079
	Unburned	0.109	0.106	0.081	0.099	
	Mean N. Rates	0.087	0.086	0.063		
	CV (%)		37.15			
	LSD, ($p \leq 0.05$)		NS		0.025	
Overall mean	Burned	0.103	0.091	0.071	0.088	
	Unburned	0.088	0.100	0.067	0.085	
	Mean N. Rates	0.095	0.096	0.069		
	CV (%)		40.34			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.128; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 47: Sugarcane management practices influencing carbon dioxide fluxes in Week 8

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.123	0.144	0.127	0.131	0.102
	Unburned	0.076	0.093	0.050	0.073	
	Mean N. Rates	0.099	0.119	0.088		
	CV (%)		45.44			
	LSD, ($p \leq 0.05$)		NS		0.039	
>10	Burned	0.165	0.121	0.122	0.136	0.123
	Unburned	0.138	0.092	0.097	0.109	
	Mean N. Rates	0.152	0.107	0.11		
	CV (%)		41.85			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.144	0.133	0.124	0.134	
	Unburned	0.107	0.093	0.074	0.091	
	Mean N. Rates	0.126	0.113	0.099		
	CV (%)		47.96			
	LSD, ($p \leq 0.05$)		NS		0.030	NS

*NV = Natural vegetation 0.149; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 48: Influence of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 9

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.156	0.169	0.121	0.149	0.123
	Unburned	0.102	0.096	0.094	0.097	
	Mean N. Rates	0.129	0.133	0.107		
	CV (%)		36.54			
	LSD, (p≤0.05)		NS		0.038	
>10	Burned	0.117	0.089	0.108	0.105	0.064
	Unburned	0.008	0.037	0.024	0.023	
	Mean N. Rates	0.063	0.063	0.066		
	CV (%)		91.91			
	LSD, (p≤0.05)		NS		0.05	
Overall mean	Burned	0.137	0.129	0.115	0.127	
	Unburned	0.055	0.067	0.059	0.060	
	Mean N. Rates	0.096	0.098	0.087		
	CV (%)		92.88			
	LSD, (p≤0.05)		NS		0.049	

*NV = Natural vegetation 0.143; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 49: Contribution of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 10

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.113	0.108	0.109	0.110	0.095
	Unburned	0.076	0.086	0.081	0.081	
	Mean N. Rates	0.094	0.097	0.095		
	CV (%)		16.16			
	LSD, (≤0.05)		NS		0.013	
>10	Burned	0.177	0.107	0.094	0.106	0.094
	Unburned	0.088	0.094	0.062	0.081	
	Mean N. Rates	0.103	0.1	0.078		
	CV (%)		33.21			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.115	0.108	0.101	0.108	
	Unburned	0.082	0.090	0.072	0.081	
	Mean N. Rates	0.098	0.099	0.087		
	CV (%)		40.22			
	LSD, (p≤0.05)		NS		0.021	NS

*NV = Natural vegetation 0.114; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($P \leq 0.05$)

Appendix 50: Management practices influencing carbon dioxide fluxes in week 11

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.102	0.111	0.066	0.093	0.076
	Unburned	0.057	0.075	0.047	0.060	
	Mean N. Rates	0.08	0.093	0.057		
	CV (%)		51.38			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.112	0.111	0.118	0.114	0.096
	Unburned	0.113	0.080	0.040	0.077	
	Mean N. Rates	0.112	0.096	0.079		
	CV (%)		61.99			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.107	0.111	0.092	0.103	
	Unburned	0.085	0.077	0.044	0.069	
	Mean N. Rates	0.096	0.094	0.068		
	CV (%)		70.57			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.136; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}) ;*NS = None Significant ($p \leq 0.05$)

Appendix 51: Sugarcane management practices contributing to f carbon dioxide fluxes in week 12

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.105	0.120	0.125	0.117	0.103
	Unburned	0.074	0.106	0.086	0.089	
	Mean N. Rates	0.090	0.113	0.105		
	CV (%)		55.93			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.043	0.085	0.100	0.076	0.069
	Unburned	0.041	0.095	0.052	0.063	
	Mean N. Rates	0.042	0.09	0.076		
	CV (%)		48.38			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.074	0.102	0.113	0.096	
	Unburned	0.058	0.100	0.069	0.076	
	Mean N. Rates	0.066	0.101	0.091		
	CV (%)		77.41			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.083; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 52: Drivers of carbon dioxide fluxes in week 13

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.116	0.203	0.100	0.139	0.121
	Unburned	0.125	0.093	0.091	0.103	
	Mean N. Rates	0.120	0.148	0.095		
	CV (%)		55.74			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.097	0.138	0.132	0.122	0.119
	Unburned	0.097	0.137	0.111	0.115	
	Mean N. Rates	0.097	0.137	0.122		
	CV (%)		47.37			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.106	0.170	0.116	0.131	
	Unburned	0.111	0.115	0.101	0.109	
	Mean N. Rates	0.109	0.143	0.108		
	CV (%)		54.12			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.107; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 53: Effect of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 14

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.128	0.159	0.115	0.134	0.114
	Unburned	0.079	0.100	0.106	0.095	
	Mean N. Rates	0.103	0.130	0.110		
	CV (%)		43.24			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.085	0.082	0.150	0.106	0.106
	Unburned	0.095	0.135	0.091	0.107	
	Mean N. Rates	0.090	0.109	0.120		
	CV (%)		59.37			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.106	0.120	0.132	0.120	
	Unburned	0.087	0.118	0.098	0.101	
	Mean N. Rates	0.097	0.119	0.115		
	CV (%)		68.72			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.067; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 54: Management practices influencing carbon dioxide fluxes in week 15

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.076	0.109	0.086	0.811	0.086
	Unburned	0.083	0.105	0.060	0.744	
	Mean N. Rates	0.079	0.107	0.073		
	CV (%)		58.25			
	LSD, ($p \leq 0.05$)		NS		0.043	
>10	Burned	0.057	0.099	0.166	0.966	0.098
	Unburned	0.047	0.160	0.057	0.792	
	Mean N. Rates	0.052	0.130	0.111		
	CV (%)		87.05			
	LSD, ($p \leq 0.05$)		NS		0.072	
Overall mean	Burned	0.067	0.104	0.126	0.099	
	Unburned	0.065	0.133	0.059	0.085	
	Mean N. Rates	0.066	0.118	0.092		
	CV (%)		87.47			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.124; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant *(*$p \leq 0.05$)

Appendix 55: Variation of carbon dioxide fluxes with sugarcane management practices in week 16

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.074	0.082	0.047	0.068	0.071
	Unburned	0.067	0.096	0.057	0.073	
	Mean N. Rates	0.071	0.089	0.052		
	CV (%)		30.66			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.049	0.113	0.048	0.070	0.059
	Unburned	0.051	0.055	0.041	0.049	
	Mean N. Rates	0.050	0.084	0.044		
	CV (%)		54.12			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.061	0.098	0.047	0.069	
	Unburned	0.059	0.075	0.049	0.061	
	Mean N. Rates	0.060	0.086	0.048		
	CV (%)		40.98			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation -0.041; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant *(*$p \leq 0.05$)

Appendix 56: Factors influencing carbon dioxide fluxes in week 17

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.125	0.096	0.057	0.093	0.085
	Unburned	0.066	0.071	0.097	0.078	
	Mean N. Rates	0.096	0.084	0.077		
	CV (%)		50.72			
	LSD, $(p \leq 0.05)$		NS		NS	
>10	Burned	0.061	0.068	0.062	0.064	0.074
	Unburned	0.072	0.088	0.092	0.084	
	Mean N. Rates	0.067	0.078	0.077		
	CV (%)		55.78			
	LSD, $(p \leq 0.05)$		NS		NS	
Overall mean	Burned	0.093	0.082	0.059	0.078	
	Unburned	0.069	0.080	0.095	0.081	
	Mean N. Rates	0.081	0.081	0.077		
	CV (%)		69.49			
	LSD, $(p \leq 0.05)$		NS		NS	NS

*NV = Natural vegetation 0.058; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant $(p \leq 0.05)$

Appendix 57: Management practices influencing carbon dioxide fluxes in week 18

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.026	0.086	0.065	0.059	0.055
	Unburned	0.054	0.042	0.058	0.051	
	Mean N. Rates	0.040	0.064	0.062		
	CV (%)		53.52			
	LSD, $(p \leq 0.05)$		NS		NS	
>10	Burned	0.035	0.045	0.055	0.045	0.041
	Unburned	0.033	0.021	0.056	0.036	
	Mean N. Rates	0.034	0.033	0.055		
	CV (%)		44.14			
	LSD, $(p \leq 0.05)$		NS		NS	
Overall mean	Burned	0.031	0.066	0.060	0.052	
	Unburned	0.043	0.031	0.057	0.044	
	Mean N. Rates	0.037	0.048	0.058		
	CV (%)		66.16			
	LSD, $(p \leq 0.05)$		NS		NS	NS

*NV = Natural vegetation 0.050; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant $(p \leq 0.05)$

Appendix 58: Effect of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 19

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.075	0.068	0.076	0.073	0.068
	Unburned	0.076	0.062	0.054	0.064	
	Mean N. Rates	0.076	0.065	0.065		
	CV (%)		21.24			
	LSD, ($p\leq0.05$)		NS		NS	
>10	Burned	0.046	0.067	0.022	0.045	0.050
	Unburned	0.063	0.052	0.047	0.054	
	Mean N. Rates	0.055	0.060	0.035		
	CV (%)		77.74			
	LSD, ($p\leq0.05$)		NS		NS	
Overall mean	Burned	0.061	0.068	0.049	0.059	
	Unburned	0.069	0.057	0.050	0.059	
	Mean N. Rates	0.065	0.062	0.050		
	CV (%)		70.61			
	LSD, ($p\leq0.05$)		NS		NS	NS

*NV = Natural vegetation 0.036; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p\leq0.05$)

Appendix 59: Drivers of carbon dioxide fluxes in week 20

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.064	0.092	0.084	0.080	0.077
	Unburned	0.081	0.057	0.086	0.075	
	Mean N. Rates	0.072	0.075	0.085		
	CV (%)		40.12			
	LSD, ($p\leq0.05$)		NS		NS	
>10	Burned	0.107	0.082	0.086	0.092	0.087
	Unburned	0.067	0.102	0.078	0.082	
	Mean N. Rates	0.087	0.092	0.082		
	CV (%)		38.82			
	LSD, ($p\leq0.05$)		NS		NS	
Overall mean	Burned	0.086	0.087	0.085	0.086	
	Unburned	0.074	0.080	0.082	0.079	
	Mean N. Rates	0.080	0.083	0.084		
	CV (%)		69.65			
	LSD, ($p\leq0.05$)		NS		NS	NS

*NV = Natural vegetation 0.058; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p\leq0.05$)

Appendix 60: Sugarcane management practices influencing carbon dioxide fluxes in week 21

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.019	0.025	0.047	0.031	0.029
	Unburned	0.039	0.011	0.033	0.027	
	Mean N. Rates	0.029	0.018	0.04		
	CV (%)		77.92			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.028	0.032	0.014	0.025	0.419
	Unburned	0.003	0.032	0.031	0.022	
	Mean N. Rates	0.015	0.032	0.023		
	CV (%)		144.17			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.023	0.029	0.031	0.028	
	Unburned	0.021	0.021	0.032	0.025	
	Mean N. Rates	0.022	0.025	0.031		
	CV (%)		150.71			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.031; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant *(*p≤0.05)

Appendix 61: Contribution of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes week 22

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.035	0.048	0.035	0.039	0.044
	Unburned	0.054	0.042	0.050	0.049	
	Mean N. Rates	0.045	0.045	0.042		
	CV (%)		27.51			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.079	0.036	0.056	0.057	0.049
	Unburned	0.041	0.042	0.041	0.041	
	Mean N. Rates	0.060	0.039	0.049		
	CV (%)		33.49			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.057	0.042	0.045	0.048	
	Unburned	0.048	0.042	0.045	0.045	
	Mean N. Rates	0.052	0.042	0.045		
	CV (%)		62.15			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.023; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant *(*p≤0.05)

Appendix 62: Effect of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 23

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.011	0.029	0.037	0.026	0.027
	Unburned	0.031	0.031	0.024	0.029	
	Mean N. Rates	0.021	0.030	0.031		
	CV (%)		36.41			
	LSD, (P≤0.05)		NS		NS	
>10	Burned	0.028	0.027	0.048	0.034	0.035
	Unburned	0.011	0.041	0.054	0.036	
	Mean N. Rates	0.020	0.034	0.051		
	CV (%)		83.2			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.020	0.028	0.043	0.030	
	Unburned	0.021	0.036	0.039	0.032	
	Mean N. Rates	0.021	0.032	0.041		
	CV (%)		86.63			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.019; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 63: Influence of sugarcane management practices on carbon dioxide fluxes in week 24

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.052	0.044	0.054	0.050	0.046
	Unburned	0.040	0.039	0.045	0.041	
	Mean N. Rates	0.046	0.042	0.050		
	CV (%)		21.46			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.046	0.042	0.049	0.046	0.048
	Unburned	0.054	0.060	0.039	0.051	
	Mean N. Rates	0.050	0.051	0.044		
	CV (%)		91.00			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.049	0.043	0.051	0.048	
	Unburned	0.047	0.050	0.042	0.046	
	Mean N. Rates	0.048	0.046	0.047		
	CV (%)		64.59			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.051; *Figures are CH_4 flux rate (g CO_2 – C M^{-2} hr^{-1}); *NS = None Significant (P ≤ 0.05)

Appendix 64: Variation of carbon dioxide fluxes with sugarcane management practices in week 25

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.065	0.065	0.066	0.065	0.059
	Unburned	0.064	0.050	0.043	0.052	
	Mean N. Rates	0.064	0.058	0.055		
	CV (%)		23.58			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.054	0.076	0.082	0.071	0.069
	Unburned	0.066	0.057	0.080	0.068	
	Mean N. Rates	0.060	0.067	0.081		
	CV (%)		30.64			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.059	0.071	0.074	0.068	
	Unburned	0.065	0.054	0.062	0.060	
	Mean N. Rates	0.062	0.062	0.068		
	CV (%)		64.65			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.066; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 65: Factors influencing carbon dioxide fluxes in week 26

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.103	0.101	0.091	0.098	0.100
	Unburned	0.091	0.112	0.101	0.101	
	Mean N. Rates	0.097	0.106	0.096		
	CV (%)		30.24			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.059	0.068	0.073	0.067	0.072
	Unburned	0.030	0.112	0.092	0.078	
	Mean N. Rates	0.045	0.090	0.083		
	CV (%)		53.92			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.081	0.084	0.082	0.083	
	Unburned	0.061	0.112	0.096	0.090	
	Mean N. Rates	0.071	0.098	0.089		
	CV (%)		51.21			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.115; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 66: Sugarcane management practices influencing carbon dioxide fluxes in week 27

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.080	0.101	0.074	0.085	0.074
	Unburned	0.062	0.057	0.072	0.064	
	Mean N. Rates	0.071	0.079	0.073		
	CV (%)		35.81			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.072	0.050	0.045	0.056	0.056
	Unburned	0.059	0.059	0.053	0.057	
	Mean N. Rates	0.065	0.055	0.049		
	CV (%)		50.83			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.076	0.075	0.060	0.070	
	Unburned	0.060	0.058	0.062	0.060	
	Mean N. Rates	0.068	0.067	0.061		
	CV (%)		45.10			
	LSD, (≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.042; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 67: Drivers of carbon dioxide fluxes in week 28

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.070	0.057	0.073	0.067	0.060
	Unburned	0.054	0.046	0.061	0.054	
	Mean N. Rates	0.062	0.052	0.067		
	CV (%)		28.64			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.051	0.037	0.026	0.038	0.048
	Unburned	0.054	0.058	0.064	0.059	
	Mean N. Rates	0.052	0.047	0.045		
	CV (%)		47.65			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.060	0.047	0.050	0.052	
	Unburned	0.054	0.052	0.062	0.056	
	Mean N. Rates	0.057	0.049	0.056		
	CV (%)		41.01			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.045; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 68: Influence of sugarcane management practices on carbon dioxide fluxes fluxes in week 29

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.060	0.071	0.042	0.058	0.058
	Unburned	0.063	0.045	0.064	0.057	
	Mean N. Rates	0.062	0.058	0.053		
	CV (%)		44.82			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.041	0.052	0.054	0.049	0.052
	Unburned	0.047	0.066	0.054	0.056	
	Mean N. Rates	0.044	0.059	0.054		
	CV (%)		40.71			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.050	0.062	0.048	0.053	
	Unburned	0.055	0.055	0.059	0.056	
	Mean N. Rates	0.053	0.058	0.053		
	CV (%)		49.16			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.014; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}) ;*NS = None Significant (p≤0.05)

Appendix 69: Contribution of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 30

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.026	0.066	0.059	0.050	0.049
	Unburned	0.063	0.035	0.044	0.047	
	Mean N. Rates	0.044	0.051	0.052		
	CV (%)		56.96			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.035	0.034	0.053	0.041	0.043
	Unburned	0.038	0.046	0.054	0.046	
	Mean N. Rates	0.036	0.04	0.054		
	CV (%)		33.53			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.030	0.050	0.056	0.045	
	Unburned	0.050	0.040	0.049	0.047	
	Mean N. Rates	0.040	0.045	0.053		
	CV (%)		43.68			
	LSD, (≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.023; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 70: Effect of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 31

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.045	0.067	0.065	0.059	0.060
	Unburned	0.063	0.057	0.062	0.061	
	Mean N. Rates	0.054	0.062	0.063		
	CV (%)		35.82			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.036	0.037	0.061	0.044	0.049
	Unburned	0.043	0.075	0.042	0.053	
	Mean N. Rates	0.040	0.056	0.052		
	CV (%)		39.11			
	LSD, (≤0.05)		NS		NS	
Overall mean	Burned	0.040	0.052	0.063	0.052	
	Unburned	0.053	0.066	0.052	0.057	
	Mean N. Rates	0.047	0.059	0.057		
	CV (%)		37.09			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.052; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant *(*p≤0.05)

Appendix 71: Influence of sugarcane management practices on carbon dioxide fluxes fluxes in week 32

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.032	0.073	0.049	0.051	0.048
	Unburned	0.034	0.070	0.030	0.045	
	Mean N. Rates	0.033	0.071	0.039		
	CV (%)		NS			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.033	0.015	0.029	0.025	0.029
	Unburned	0.036	0.033	0.029	0.033	
	Mean N. Rates	0.034	0.024	0.029		
	CV (%)		31.1			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.032	0.044	0.039	0.038	
	Unburned	0.035	0.051	0.030	0.039	
	Mean N. Rates	0.034	0.048	0.034		
	CV (%)		66.65			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.051; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant *(*p≤0.05)

Appendix 72: Factors contributing to carbon dioxide fluxes in week 33

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.057	0.035	0.059	0.050	0.048
	Unburned	0.048	0.044	0.046	0.046	
	Mean N. Rates	0.053	0.039	0.052		
	CV (%)		56.59			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.045	0.061	0.054	0.053	0.055
	Unburned	0.054	0.063	0.053	0.057	
	Mean N. Rates	0.050	0.062	0.053		
	CV (%)		33.64			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.051	0.048	0.056	0.052	
	Unburned	0.051	0.053	0.049	0.051	
	Mean N. Rates	0.051	0.051	0.053		
	CV (%)		43.19			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.079; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1});
*NS = None Significant ($p \leq 0.05$)

Appendix 73: Variation of carbon dioxide fluxes with sugarcane management practices in week 34

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.051	0.056	0.054	0.054	0.062
	Unburned	0.072	0.062	0.080	0.071	
	Mean N. Rates	0.061	0.059	0.067		
	CV (%)		34.07			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.030	0.036	0.048	0.038	0.049
	Unburned	0.048	0.068	0.062	0.059	
	Mean N. Rates	0.039	0.052	0.055		
	CV (%)		39.34			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.040	0.046	0.051	0.046	
	Unburned	0.060	0.065	0.071	0.065	
	Mean N. Rates	0.050	0.055	0.061		
	CV (%)		39.69			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.089; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}) ;*NS= None Significant ($p \leq 0.05$)

Appendix 74: Sugarcane management practices contributing to GHGs fluxes in week 35

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.068	0.067	0.047	0.061	0.056
	Unburned	0.059	0.033	0.063	0.052	
	Mean N. Rates	0.064	0.050	0.055		
	CV (%)		55.35			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.028	0.036	0.033	0.032	0.027
	Unburned	0.022	0.029	0.015	0.022	
	Mean N. Rates	0.025	0.032	0.024		
	CV (%)		45.38			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.048	0.052	0.040	0.047	
	Unburned	0.040	0.031	0.039	0.037	
	Mean N. Rates	0.044	0.041	0.040		
	CV (%)		69.39			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.061; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 75: Contribution of conversion period, trash management and nitrogen fertilizer application on carbon dioxide fluxes in week 36

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.098	0.095	0.052	0.082	0.076
	Unburned	0.088	0.054	0.071	0.071	
	Mean N. Rates	0.093	0.074	0.061		
	CV (%)		67.91			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	0.063	0.068	0.089	0.073	0.068
	Unburned	0.065	0.071	0.050	0.062	
	Mean N. Rates	0.064	0.069	0.069		
	CV (%)		18.98			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.080	0.081	0.070	0.077	
	Unburned	0.076	0.062	0.061	0.066	
	Mean N. Rates	0.078	0.072	0.065		
	CV (%)		54.35			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 0.068; *Figures are CH_4 flux rate (g CO_2 – C m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 76: Factors influencing nitrous oxide fluxes in week 37

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.092	0.098	0.074	0.088	0.079
	Unburned	0.087	0.065	0.057	0.070	
	Mean N. Rates	0.089	0.082	0.065		
	CV (%)		43.87			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.074	0.074	0.065	0.071	0.060
	Unburned	0.034	0.049	0.066	0.050	
	Mean N. Rates	0.054	0.062	0.065		
	CV (%)		45.26			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.083	0.086	0.069	0.080	
	Unburned	0.060	0.057	0.061	0.060	
	Mean N. Rates	0.072	0.072	0.065		
	CV (%)		57.49			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.051; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 77: Cumulativecarbon dioxide emission due to conversion period, trash management and nitrogen fertilizer application

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	7.237	8.220	6.895	7.451	6.646
	Unburned	5.954	5.840	5.732	5.842	
	Mean N. Rates	6.595	7.030	6.313		
	CV (%)		25.03			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	5.852	6.265	6.478	6.198	5.928
	Unburned	5.115	6.418	5.442	5.658	
	Mean N. Rates	5.484	6.342	5.960		
	CV (%)		23.54			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	6.545	7.242	6.687	6.825	
	Unburned	5.534	6.129	5.587	5.750	
	Mean N. Rates	6.040	6.686	6.137		
	CV (%)		37.07			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 15.465; *Figures are CH_4 flux rate (Mg / ha / hr); *NS = None Significant ($p \leq 0.05$)

Appendix 78: Influence of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 1

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.193	-1.657	0.934	-0.177	-0.140
	Unburned	-0.661	0.069	0.284	-0.103	
	Mean N. Rates	-0.234	-0.794	0.609		
	CV (%)		-1145.31			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	4.550	-1.299	2.081	1.778	0.809
	Unburned	-1.200	0.443	0.278	-0.160	
	Mean N. Rates	1.675	-0.428	1.18		
	CV (%)		393.96			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	2.371	-1.478	1.508	0.800	
	Unburned	-0.931	0.256	0.281	-0.131	
	Mean N. Rates	0.720	-0.611	0.894		
	CV (%)		729.41			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation -0.697; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 79: Contribution of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 2

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	8.445	7.282	-3.848	3.960	3.059
	Unburned	-1.909	3.298	5.084	2.158	
	Mean N. Rates	3.268	5.290	0.618		
	CV (%)		289.15			
	LSD, ($P \leq 0.05$)		NS		NS	
>10	Burned	1.149	-0.091	-0.184	0.291	0.319
	Unburned	0.688	0.801	-0.449	0.346	
	Mean N. Rates	0.918	0.355	-0.317		
	CV (%)		211.27			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	4.797	3.595	-2.016	2.125	
	Unburned	-0.611	2.049	2.317	1.252	
	Mean N. Rates	2.093	2.822	0.151		
	CV (%)		424.49			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 1.756; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 80: Effect of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 3

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	8.379	5.492	16.847	10.239	7.640
	Unburned	4.492	2.898	7.735	5.042	
	Mean N. Rates	6.435	4.195	12.291		
	CV (%)		53.67			
	LSD, ($p\leq0.05$)		NS		NS	
>10	Burned	8.187	18.860	10.065	12.371	10.315
	Unburned	-2.761	23.205	4.336	8.260	
	Mean N. Rates	2.713	21.032	7.201		
	CV (%)		151.43			
	LSD, ($p\leq0.05$)		NS		NS	
Overall mean	Burned	8.283	12.176	13.455	11.305	
	Unburned	0.866	13.051	6.036	6.651	
	Mean N. Rates	4.574	12.614	9.746		
	CV (%)		142.23			
	LSD, ($p\leq0.05$)		NS		NS	NS

*NV = Natural vegetation 7.113; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p\leq0.05$)

Appendix 81: Sugarcane Management practices influencing nitrous oxide fluxes in week 4

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	18.367	14.434	28.325	20.375	10.442
	Unburned	-14.927	12.364	4.090	0.509	
	Mean N. Rates	1.72	13.399	16.207		
	CV (%)		173.78			
	LSD, ($p\leq0.05$)		NS		NS	
>10	Burned	36.532	5.698	-6.793	11.812	7.601
	Unburned	8.502	-2.600	4.268	3.390	
	Mean N. Rates	22.517	1.549	-1.263		
	CV (%)		355.49			
	LSD, ($p\leq0.05$)		NS		NS	
Overall mean	Burned	27.449	10.066	10.766	16.094	
	Unburned	-3.213	4.882	4.179	1.950	
	Mean N. Rates	12.118	7.474	7.472		
	CV (%)		258.73			
	LSD, ($p\leq0.05$)		NS		NS	NS

*NV = Natural vegetation 3.897; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p\leq0.05$)

Appendix 82: Drivers of nitrous oxide fluxes in week 5

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	13.916	10.449	15.112	13.159	10.474
	Unburned	4.861	12.697	5.805	7.788	
	Mean N. Rates	9.389	11.573	10.459		
	CV (%)		63.58			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	16.986	5.332	2.567	8.295	7.099
	Unburned	14.019	16.863	-13.174	5.903	
	Mean N. Rates	15.502	11.097	-5.303		
	CV (%)		311.48			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	15.451	7.891	8.840	10.727	
	Unburned	9.440	14.780	-3.684	6.845	
	Mean N. Rates	12.446	11.335	2.578		
	CV (%)		207.69			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*Figures are CH_4 flux rate (μg N_2O –N m^{-2} hr^{-1}); *NV = Natural vegetation; *NS = None Significant *(*$p \leq 0.05$)

Appendix 83: Factors influencing nitrous oxide fluxes in week 6

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	8.000	3.141	4.332	5.158	5.773
	Unburned	5.531	8.772	4.864	6.389	
	Mean N. Rates	6.765	5.957	4.598		
	CV (%)		58.69			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	23.315	16.320	21.328	20.321	16.292
	Unburned	22.674	6.722	7.394	12.263	
	Mean N. Rates	22.995	11.521	14.361		
	CV (%)		81.75			
	LSD, (($p \leq 0.05$)		NS		NS	
Overall mean	Burned	15.658	9.731	12.830	12.739	
	Unburned	14.102	7.747	6.129	9.326	
	Mean N. Rates	14.880	8.739	9.479		
	CV (%)		103.72			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 14.175; *Figures are CH_4 flux rate (μg N_2O –N m^{-2} hr^{-1}); *NS = None Significant *(*$p \leq 0.05$)

Appendix 84: Sugarcane management practices contributing nitrous oxide fluxes in week 7

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	31.123	13.102	23.330	22.518	14.566
	Unburned	4.431	10.752	4.657	6.613	
	Mean N. Rates	17.777	11.927	13.994		
	CV (%)		101.96			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	66.753	14.850	11.430	31.011	25.519
	Unburned	30.289	12.895	16.899	20.028	
	Mean N. Rates	48.521	13.873	14.164		
	CV (%)		152.58			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	48.938	13.976	17.380	26.765	
	Unburned	17.360	11.824	10.778	13.321	
	Mean N. Rates	33.149	12.900	14.079		
	CV (%)		158.75			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 5.565; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}) ;*NS = None Significant ($p \leq 0.05$)

Appendix 85: Variation of nitrous oxide fluxes with sugarcane management practices in week 8

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	15.720	12.764	10.908	13.131	9.975
	Unburned	5.687	11.081	3.689	6.819	
	Mean N. Rates	10.704	11.923	7.298		
	CV (%)		90.59			
	LSD, ($P \leq 0.05$)		NS		NS	
>10	Burned	56.468	51.626	87.472	65.189	64.759
	Unburned	94.392	30.071	68.528	64.330	
	Mean N. Rates	75.430	40.848	78.000		
	CV (%)		69.45			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	36.094	32.195	49.190	39.160	
	Unburned	50.040	20.576	36.109	35.575	
	Mean N. Rates	43.067	26.386	42.649		
	CV (%)		142.08			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 4.395; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 86: Influence of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 9

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	7.624	9.172	6.476	7.757	10.781
	Unburned	6.858	15.611	18.946	13.805	
	Mean N. Rates	7.241	12.391	12.711		
	CV (%)		68.00			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.441	9.389	16.922	8.917	5.907
	Unburned	1.720	5.314	1.655	2.896	
	Mean N. Rates	1.081	7.352	9.288		
	CV (%)		185.91			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	4.032	9.280	11.699	8.337	
	Unburned	4.289	10.462	10.300	8.351	
	Mean N. Rates	4.161	9.871	11.000		
	CV (%)		135.80			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 7.111 ;*Figures are CH_4 flux rate (μg N_2O –N m^{-2} hr^{-1}) ; *NS = None Significant ($p \leq 0.05$)

Appendix 87: Contribution of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 10

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	6.134	9.363	12.378	9.292	15.213
	Unburned	7.588	23.980	31.836	21.135	
	Mean N. Rates	6.861	16.672	22.107		
	CV (%)		79.45			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	4.706	5.971	4.699	5.125	6.881
	Unburned	3.635	16.368	5.906	8.636	
	Mean N. Rates	4.171	11.169	5.303		
	CV (%)		64.99			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	5.420	7.667	8.539	7.209	
	Unburned	5.611	20.174	18.871	14.886	
	Mean N. Rates	5.516	13.920	13.795		
	CV (%)		92.49			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 24.408; *Figures are CH_4 flux rate (μg N_2O –N m^{-2} hr^{-1}) ;*NS = None Significant ($p \leq 0.05$)

Appendix 88: Management practices influencing nitrous oxide fluxes in week 11

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	53.613	65.448	67.190	62.084	66.330
	Unburned	66.497	87.666	57.565	70.576	
	Mean N. Rates	60.055	76.557	62.377		
	CV (%)		57.17			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	10.025	15.906	23.815	16.582	13.703
	Unburned	11.682	14.028	6.761	10.824	
	Mean N. Rates	10.853	14.967	15.288		
	CV (%)		115.79			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	31.819	40.677	45.502	39.333	
	Unburned	39.090	50.847	32.163	40.700	
	Mean N. Rates	35.454	45.762	38.832		
	CV (%)		111.72			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 1.538 ;*Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant *(*$p \leq 0.05$)

Appendix 89: Sugarcane management practices contributing to nitrous oxide fluxes in week 12

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	11.919	23.399	44.835	26.718	54.475
	Unburned	0.943	131.041	114.716	82.233	
	Mean N. Rates	6.431	77.220	79.776		
	CV (%)		73.94			
	LSD, ($p \leq 0.05$)		41.82		34.15	
>10	Burned	8.983	35.443	77.714	40.713	39.473
	Unburned	2.079	85.542	27.075	38.232	
	Mean N. Rates	5.531	60.493	52.395		
	CV (%)		124.77			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	10.451	29.421	61.275	33.716	
	Unburned	1.511	108.291	70.896	60.233	
	Mean N. Rates	5.981	68.856	66.085		
	CV (%)		126.55			
	LSD, ($p \leq 0.05$)		40.63		NS	NS

*NV = Natural vegetation 5.209; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}) ;*NS = None Significant *(*$p \leq 0.05$)

Appendix 90: Drivers of nitrous oxide fluxes in week 13

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	4.986	61.338	13.298	26.541	53.758
	Unburned	27.366	41.769	173.793	80.976	
	Mean N. Rates	16.176	51.553	93.545		
	CV (%)		198.29			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	3.130	9.590	74.093	28.938	58.356
	Unburned	0.631	89.628	173.063	87.774	
	Mean N. Rates	1.880	49.609	123.578		
	CV (%)		79.37			
	LSD, (p≤0.05)		48.090		39.26	
Overall mean	Burned	4.058	35.464	43.696	27.739	
	Unburned	13.998	65.698	173.428	84.375	
	Mean N. Rates	9.028	50.581	108.562		
	CV (%)		149.44			
	LSD, (p≤0.05)		57.25		46.740	NS

*NV = Natural vegetation -1.455; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}) ;*NS = None Significant *(*p≤0.05)

Appendix 91: Effect of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 14

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	2.383	7.697	7.765	5.948	29.101
	Unburned	11.483	13.365	131.917	52.255	
	Mean N. Rates	6.933	10.531	69.841		
	CV (%)		278.54			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	5.249	8.979	119.088	44.438	48.842
	Unburned	2.725	57.603	99.409	53.246	
	Mean N. Rates	3.987	33.291	109.248		
	CV (%)		154.59			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	3.816	8.338	63.426	25.193	
	Unburned	7.104	35.484	115.663	52.750	
	Mean N. Rates	5.460	21.911	89.545		
	CV (%)		222.43			
	LSD, (p≤0.05)		59.24		NS	NS

*NV = Natural vegetation 2.694; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1})*;* *NS = None Significant *(*p≤0.05)

Appendix 92: Influence of sugarcane management practices on nitrous oxide fluxes in week 15

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	7.637	3.518	4.878	5.344	16.014
	Unburned	7.915	3.684	68.452	26.683	
	Mean N. Rates	7.776	3.601	36.665		
	CV (%)		244.00			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.650	9.223	55.206	21.693	19.387
	Unburned	-0.047	16.901	34.387	17.080	
	Mean N. Rates	0.301	13.062	44.796		
	CV (%)		190.75			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	4.143	6.370	30.042	13.519	
	Unburned	3.934	10.293	51.420	21.882	
	Mean N. Rates	4.039	8.332	40.731		
	CV (%)		222.97			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.648; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant($p \leq 0.05$)

Appendix 93: Variation of nitrous oxide fluxes with sugarcane management practices in week 16

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	2.999	2.451	3.048	2.833	5.433
	Unburned	15.594	5.156	3.349	8.033	
	Mean N. Rates	9.296	3.803	3.198		
	CV (%)		164.51			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.297	8.489	6.479	5.088	5.563
	Unburned	0.406	3.647	14.057	6.037	
	Mean N. Rates	0.352	6.068	10.268		
	CV (%)		108.45			
	LSD, ($p \leq 0.05$)		6.260		NS	
Overall mean	Burned	1.648	5.470	4.763	3.960	
	Unburned	8.000	4.401	8.703	7.035	
	Mean N. Rates	4.824	4.936	6.733		
	CV (%)		147.84			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 32.545; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant($p \leq 0.05$)

Appendix 94: Factors influencing nitrous oxide fluxes in week 17

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	2.584	0.601	0.324	1.170	1.225
	Unburned	0.500	0.624	2.717	1.281	
	Mean N. Rates	1.542	0.613	1.521		
	CV (%)		161.95			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.001	4.027	6.061	3.364	7.322
	Unburned	0.639	4.742	28.460	11.281	
	Mean N. Rates	0.320	4.385	17.261		
	CV (%)		227.72			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	1.293	2.314	3.192	2.266	
	Unburned	0.570	2.683	15.589	6.281	
	Mean N. Rates	0.931	2.499	9.391		
	CV (%)		293.98			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.319; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}) ;*NS = None Significant ($p \leq 0.05$)

Appendix 95: Contribution of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 18

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-14.862	17.445	1.207	1.263	1.692
	Unburned	1.522	3.256	1.586	2.121	
	Mean N. Rates	-6.67	10.351	1.397		
	CV (%)		1064.92			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.599	1.059	0.602	0.753	3.630
	Unburned	16.530	0.564	2.425	6.506	
	Mean N. Rates	8.564	0.812	1.513		
	CV (%)		284.9			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	-7.132	9.252	0.905	1.008	
	Unburned	9.026	1.910	2.005	4.314	
	Mean N. Rates	0.947	5.581	1.455		
	CV (%)		536.08			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.545; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant($p \leq 0.05$)

Appendix 96: Sugarcane management practices influencing to nitrous oxide fluxes in week 19

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	3.448	9.248	4.250	5.649	5.167
	Unburned	3.788	4.991	5.277	4.685	
	Mean N. Rates	3.618	7.120	4.764		
	CV (%)		122.53			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	4.955	1.696	10.915	5.855	15.517
	Unburned	53.729	-9.646	31.453	25.178	
	Mean N. Rates	29.342	-3.975	21.184		
	CV (%)		272.75			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	4.202	5.472	7.582	5.752	
	Unburned	28.758	-2.328	18.365	14.932	
	Mean N. Rates	16.480	1.572	12.974		
	CV (%)		306.75			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant($p \leq 0.05$)

Appendix 97: Effect of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 20

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	2.170	0.994	3.513	2.226	2.675
	Unburned	2.766	2.715	3.890	3.124	
	Mean N. Rates	2.468	1.855	3.702		
	CV (%)		105.23			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	4.059	14.680	0.619	6.453	4.652
	Unburned	-0.192	4.383	4.365	2.852	
	Mean N. Rates	1.934	9.531	2.492		
	CV (%)		218.56			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	3.114	7.837	2.066	4.339	
	Unburned	1.287	3.549	4.128	2.988	
	Mean N. Rates	2.201	5.693	3.097		
	CV (%)		221.22			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation -0.243; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant($p \leq 0.05$)

Appendix 98: Drivers of nitrous oxide fluxes in week 21

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.116	0.466	1.345	0.642	2.487
	Unburned	0.648	12.403	-0.056	4.331	
	Mean N. Rates	0.382	6.434	0.645		
	CV (%)		343.94			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	1.184	1.120	-47.629	-15.108	-8.118
	Unburned	-1.129	-2.753	0.500	-1.127	
	Mean N. Rates	0.027	-0.816	-23.564		
	CV (%)		-414.69			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	0.650	0.793	-23.142	-7.233	
	Unburned	-0.240	4.825	0.222	1.602	
	Mean N. Rates	0.205	2.809	-11.460		
	CV (%)		-869.01			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -0.061; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant(p≤0.05)

Appendix 99: Management practices influencing nitrous oxide fluxes in week 22

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-10.502	-10.391	-44.919	-21.937	-15.352
	Unburned	-9.748	-8.471	-8.083	-8.768	
	Mean N. Rates	-10.125	-9.431	-26.501		
	CV (%)		-158.23			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	84.209	0.630	-0.644	28.065	11.389
	Unburned	-0.408	-16.897	1.444	-5.287	
	Mean N. Rates	41.900	-8.134	0.4		
	CV (%)		537.98			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	36.853	-4.881	-22.781	3.064	
	Unburned	-5.078	-12.684	-3.320	-7.027	
	Mean N. Rates	15.888	-8.782	-13.050		
	CV (%)		-2567.63			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 12.522; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant(p≤0.05)

Appendix 100: Contribution of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 23

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-2.083	-0.610	0.972	-0.558	3.168
	Unburned	0.410	15.990	4.281	6.894	
	Mean N. Rates	-0.814	7.690	2.627		
	CV (%)		341.27			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.281	0.041	-0.167	0.054	-0.048
	Unburned	-0.121	0.028	-0.359	-0.150	
	Mean N. Rates	0.084	0.035	-0.263		
	CV (%)		-778.35			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	-0.874	-0.284	0.402	-0.252	
	Unburned	0.144	8.009	1.961	3.372	
	Mean N. Rates	-0.365	3.862	1.182		
	CV (%)		471.70			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.884; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 101: Effect of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 24

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-0.464	1.475	-19.642	-30.210	-17.271
	Unburned	-7.800	1.488	-6.684	-4.332	
	Mean N. Rates	-4.132	1.481	-49.163		
	CV (%)		-193.82			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	2.613	3.780	2.614	3.002	1.636
	Unburned	-0.584	1.902	-0.510	0.269	
	Mean N. Rates	1.014	2.841	1.052		
	CV (%)		196.89			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	1.075	2.627	-44.514	-13.604	
	Unburned	-4.192	1.695	-3.597	-2.031	
	Mean N. Rates	-1.559	2.161	-24.056		
	CV (%)		-605.34			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.382; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS =None Significant ($p \leq 0.05$)

Appendix 102: Influence of sugarcane management practices on nitrous oxide fluxes in week 25

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	12.177	19.360	18.936	16.824	22.351
	Unburned	22.564	33.733	27.334	27.877	
	Mean N. Rates	17.371	26.547	23.135		
	CV (%)		61.65			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	1.400	2.694	3.700	2.598	2.705
	Unburned	0.516	4.871	3.048	2.812	
	Mean N. Rates	0.958	3.783	3.374		
	CV (%)		116.38			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	6.789	11.027	11.318	9.711	
	Unburned	11.540	19.302	15.191	15.344	
	Mean N. Rates	9.164	15.165	13.254		
	CV (%)		162.57			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.212; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 103: Variation of nitrous oxide fluxes with sugarcane management practices in week 26

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-0.856	-9.632	-0.615	-3.701	-3.823
	Unburned	-9.549	-5.200	2.913	-3.945	
	Mean N. Rates	-5.203	-7.416	1.149		
	CV (%)		-283.87			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	1.896	5.887	2.446	3.410	2.091
	Unburned	-0.696	3.092	-0.076	0.773	
	Mean N. Rates	0.600	4.489	1.185		
	CV (%)		202.81			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.520	-1.873	0.916	-0.146	
	Unburned	-5.122	-1.054	1.418	-1.586	
	Mean N. Rates	-2.301	-1.463	1.167		
	CV (%)		-1095.84			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 1.647; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 104: Factors influencing nitrous oxide fluxes in week 27

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	1.520	2.161	1.064	1.582	1.542
	Unburned	0.413	1.322	2.772	1.502	
	Mean N. Rates	0.966	1.742	1.918		
	CV (%)		137.36			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	2.032	0.991	-0.265	0.919	-0.532
	Unburned	-2.733	0.716	-3.935	-1.984	
	Mean N. Rates	-0.350	0.853	-2.100		
	CV (%)		-872.82			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	1.776	1.576	0.399	1.250	
	Unburned	-1.160	1.019	-0.581	-0.241	
	Mean N. Rates	0.308	1.297	-0.091		
	CV (%)		740.87			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -0.200; *Figures are CH_4 flux rate (μg N_2O –N m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 105: Sugarcane management practices influencing nitrous oxide fluxes in week 28

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	1.260	0.083	0.711	0.684	0.527
	Unburned	0.601	0.368	0.140	0.370	
	Mean N. Rates	0.931	0.225	0.425		
	CV (%)		125.59			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	-4.288	-0.417	5.553	0.283	-1.425
	Unburned	-4.115	-5.330	0.046	-3.113	
	Mean N. Rates	-4.201	-2.873	2.800		
	CV (%)		-656.26			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	-1.514	-0.167	3.132	0.484	
	Unburned	-1.757	-2.481	0.093	-1.382	
	Mean N. Rates	-1.635	-1.324	1.612		
	CV (%)		-1392.29			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation -0.985; *Figures are CH_4 flux rate (μg N_2O –N m^{-2} hr^{-1}); *NS = None Significant (p≤0.05)

Appendix 106: Drivers of nitrous oxide fluxes in week 29

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.587	0.160	-0.299	0.149	0.620
	Unburned	2.521	-1.275	2.024	1.090	
	Mean N. Rates	1.554	-0.557	0.863		
	CV (%)		336.26			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	-0.265	-0.315	0.207	-0.125	-0.031
	Unburned	1.252	0.861	-1.927	0.062	
	Mean N. Rates	0.493	0.273	-0.86		
	CV (%)		-11897.3			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	0.161	-0.078	-0.046	0.012	
	Unburned	1.886	-0.207	0.049	0.576	
	Mean N. Rates	1.023	-0.142	0.001		
	CV (%)		1016.06			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.194; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant *(*$p \leq 0.05$)

Appendix 107: Sugarcane management practices contributing to nitrous oxide fluxes in week 30.

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-1.108	1.494	4.121	1.502	1.400
	Unburned	2.591	-2.148	3.451	1.298	
	Mean N. Rates	0.742	-0.327	3.786		
	CV (%)		220.36			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.582	1.305	1.203	1.030	0.089
	Unburned	-4.781	0.452	1.774	-0.852	
	Mean N. Rates	-2.100	0.879	1.488		
	CV (%)		4900.21			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	-0.263	1.400	2.662	2.266	
	Unburned	-1.095	-0.848	2.612	0.223	
	Mean N. Rates	-0.679	0.276	2.637		
	CV (%)		494.20			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation -0.601;*Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant *(*$p \leq 0.05$)

Appendix 108: Contribution of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes week 31

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-0.423	0.859	1.336	0.590	0.538
	Unburned	0.687	0.627	0.142	0.485	
	Mean N. Rates	0.132	0.743	0.739		
	CV (%)		350.35			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	0.087	0.114	-0.093	0.036	0.215
	Unburned	0.065	1.193	-0.078	0.393	
	Mean N. Rates	0.076	0.653	-0.086		
	CV (%)		231.57			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	-0.168	0.486	0.621	0.313	
	Unburned	0.376	0.910	0.032	0.439	
	Mean N. Rates	0.104	0.698	0.327		
	CV (%)		388.43			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 1.413;*Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant ($p \leq 0.05$)

Appendix 109: Effect of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 32

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	4.005	0.452	-8.121	-1.221	0.432
	Unburned	1.133	-0.168	5.290	2.085	
	Mean N. Rates	2.569	0.142	-1.416		
	CV (%)		1439.76			
	LSD, ($p \leq 0.05$)		NS		NS	
	Burned	0.314	5.434	0.483	2.077	1.171
	Unburned	0.213	1.256	-0.674	0.265	
	Mean N. Rates	0.264	3.345	-0.095		
	CV (%)		330.91			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	2.159	2.943	-3.819	0.428	
	Unburned	0.673	0.544	2.308	1.175	
	Mean N. Rates	1.416	1.744	-0.756		
	CV (%)		621.46			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation 0.906; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1});*NS = None Significant ($p \leq 0.05$)

Appendix 110: Influence of sugarcane management practices on nitrous oxide fluxes in week 33

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	1.693	1.127	1.732	1.517	1.904
	Unburned	1.763	4.424	0.684	2.291	
	Mean N. Rates	1.728	2.776	1.208		
	CV (%)		89.49			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	1.344	0.831	1.584	1.253	0.107
	Unburned	-5.424	1.539	0.769	-1.039	
	Mean N. Rates	-2.040	1.185	1.177		
	CV (%)		3340.05			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	1.519	0.979	1.658	1.385	
	Unburned	-1.831	2.982	0.727	0.626	
	Mean N. Rates	-0.156	1.980	1.192		
	CV (%)		268.03			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation -1.168; *Figures are CH_4 flux rate ($\mu g\ N_2O$ –N $m^{-2}\ hr^{-1}$); *NS = None Significant ($p \leq 0.05$)

Appendix 111: Factors contributing to nitrous oxide fluxes in week 34

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	4.065	-0.121	2.818	2.254	2.152
	Unburned	2.125	2.347	1.677	2.050	
	Mean N. Rates	3.095	1.113	2.248		
	CV (%)		121.87			
	LSD, ($p \leq 0.05$)		NS		NS	
>10	Burned	2.282	-1.153	0.576	0.568	0.984
	Unburned	0.203	4.459	-0.461	1.400	
	Mean N. Rates	1.242	1.653	0.058		
	CV (%)		273.01			
	LSD, ($p \leq 0.05$)		NS		NS	
Overall mean	Burned	3.173	-0.637	1.697	1.411	
	Unburned	1.164	3.403	0.608	1.725	
	Mean N. Rates	2.169	1.383	1.153		
	CV (%)		163.84			
	LSD, ($p \leq 0.05$)		NS		NS	NS

*NV = Natural vegetation -3.274; *Figures are CH_4 flux rate ($\mu g\ N_2O$ –N $m^{-2}\ hr^{-1}$) ;*NS = None Significant ($p \leq 0.05$)

Appendix 112: Variation of nitrous oxide fluxes with sugarcane management practices in week 35

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	3.617	2.398	7.760	4.592	3.683
	Unburned	6.087	1.766	0.472	2.775	
	Mean N. Rates	4.852	2.082	4.116		
	CV (%)		113.71			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	3.096	2.450	-2.360	1.062	0.628
	Unburned	-4.635	2.797	2.420	0.194	
	Mean N. Rates	-0.770	2.624	0.030		
	CV (%)		661.08			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	3.356	2.424	2.700	2.827	
	Unburned	0.726	2.282	1.446	1.485	
	Mean N. Rates	2.041	2.353	2.073		
	CV (%)		187.19			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 1.647; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant *(*p≤0.05)

Appendix 113: Sugarcane management practices influencing nitrous oxide fluxes in week 36

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	5.364	8.322	1.010	4.899	3.902
	Unburned	0.522	2.519	5.672	2.905	
	Mean N. Rates	2.943	5.421	3.341		
	CV (%)		150.14			
	LSD, (p≤0.05)		NS		NS	
>10	Burned	2.855	7.659	0.689	3.734	-0.191
	Unburned	-2.519	2.868	-12.699	-4.117	
	Mean N. Rates	0.168	5.264	-6.005		
	CV (%)		-5148.61			
	LSD, (p≤0.05)		NS		NS	
Overall mean	Burned	4.110	7.990	0.849	4.316	
	Unburned	-0.998	2.694	-3.513	-0.606	
	Mean N. Rates	1.556	5.342	-1.332		
	CV (%)		418.42			
	LSD, (p≤0.05)		NS		NS	NS

*NV = Natural vegetation 3.595; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant *(*p≤0.05)

Appendix 114: Contribution of conversion period, trash management and nitrogen fertilizer application on nitrous oxide fluxes in week 37

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	-0.280	0.871	3.670	1.421	0.294
	Unburned	1.190	1.480	-5.168	-0.833	
	Mean N. Rates	0.455	1.175	-0.749		
	CV (%)		2132.01			
	LSD, ($p\leq0.05$)		NS		NS	
>10	Burned	2.485	-0.766	16.249	5.989	4.114
	Unburned	-4.567	4.928	6.355	2.239	
	Mean N. Rates	-1.041	2.081	11.302		
	CV (%)		304.00			
	LSD, ($p\leq0.05$)		NS		NS	
Overall mean	Burned	1.103	0.052	9.960	3.705	
	Unburned	-1.689	3.204	0.593	0.703	
	Mean N. Rates	-0.293	1.628	5.277		
	CV (%)		516.23			
	LSD, ($p\leq0.05$)		NS		NS	NS

*NV = Natural vegetation -0.276; *Figures are CH_4 flux rate (µg N_2O –N m^{-2} hr^{-1}); *NS = None Significant *(*$p\leq0.05$)

Appendix 115: Cumulativenitrous oxide emission due to conversion period, trash management and nitrogen fertilize

Time(yrs)	Trash management	Nitrogen rates			Mean Trash management	Mean time
		0	50	100		
<10	Burned	0.540	0.655	0.653	0.616	0.794
	Unburned	0.371	0.977	1.568	0.972	
	Mean N. Rates	0.455	0.816	1.110		
	CV (%)		80.89			
	LSD, ($p\leq0.05$)		NS		NS	
>10	Burned	1.007	0.972	1.451	1.144	1.088
	Unburned	0.745	0.965	1.384	1.032	
	Mean N. Rates	0.876	0.969	1.418		
	CV (%)		NS	NS		
	LSD, ($p\leq0.05$)		62.740			
Overall mean	Burned	0.774	0.813	1.052	0.880	
	Unburned	0.558	0.971	1.476	1.002	
	Mean N. Rates	0.650	1.422	0.750		
	CV (%)		92.48			
	LSD, ($p\leq0.05$)		NS		NS	NS

*NV = Natural vegetation 0.626; *Figures are CH_4 flux rate (kg / ha / yr); *NS = None Significant *(*$p\leq0.05$)