SIMULATION MODEL APPROACH ON EFFECT OF MANURE ON GREENHOUSE GAS FLUXES FROM SOIL IN KAPTUMO, KENYA.

By

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ABSTRACT

Agriculture, especially livestock keeping contributes significantly to changes in atmospheric concentrations of greenhouse gases (GHGs). Research quantifying exchange of GHGs between the biosphere and atmosphere are important in developing climate change mitigation plans. However, with limited research methods support to scientists, many research projects have faced major challenges in full implementation and this forms the basis of the research methods course which intends to bridge such a gap. The experiment described herein was undertaken through Mitigation of Climate Change in Agriculture project that facilitates developing countries to contribute to climate change mitigation in agriculture and move smallholder systems towards climate smart agriculture. Cattle urine and dung patches are GHG sources in pasturelands which impacts to the global GHG budget, but specific information about these emissions are still missing for Kenya GHG inventory. Therefore this study conducted a RCBD experiment over a wet month to monitor GHG fluxes from cattle manure treated soils, and further used Monte Carlo simulation of uncertainty analysis that showed cattle urine impact N_2O emission at 68%. The results showed highest N_2O emission (85.72 $\mu g\ m^{-2}\ h^{-1}$) on plot with dung-urine combined treatment. CH_4 highest emission was 0.97 ($mg\ m^{-2}\ h^{-1}$) from plot with dung and CO_2 highest emission (320.00 $mg\ m^{-2}\ h^{-1}$) from dung-urine plot. Multivariate regression analysis showed that urine, dung-urine and dung treatments were statistically significant in explaining the effect of N_2O, CH_4 and CO_2 respectively at ($P \leq 0.05$). This study was successfully accomplished through use of efficient data management and organization plan. Therefore, concluding that all research projects require a data management plan that is well designed by a research methods support, before conducting any research.

CHAPTER ONE

1. INTRODUCTION

Global warming is a major environmental problem, generated by human and natural activities [1]. It causes climate changes that produce significant damage to the human society and biodiversity [2]. The Intergovernmental Panel on climate Change (IPCC) report [3] indicated based on meteorological studies, that in the last 150 years, the earth's global average temperature rose to about 0.8°C mainly due to human activities. Greenhouse gases emission from soils is of great concern since they contribute to global warming and the destruction of the ozone layer [4]. Countries that depend economically to a large extent on agriculture such Kenya, emission from livestock keeping may dominate their greenhouse gas budget. For example, in New Zealand N_2O emissions from urine in pasture fields account for about 52% of the anthropogenic flux [4]. It is therefore important that research projects quantify all GHG emissions sources to promote mitigation of climate change [5].

Most research scientists find that much time is taken in preparing research data for statistical analysis, modeling, interpreting, presenting etc. and as the design and administration of research and surveys grows more complex, researchers get challenged by the logistics in carrying out proper research, therefore there is need to use a well-defined data management system for the success of the research project [6]. A rich literature exists and continues to grow on the topic of research data quality [7]; [8] and its management in national statistical agencies [9]. This paper seeks to use data management plan to quantify GHG emission from pasture field in Kaptumo and provide the impact of cattle urine to N2O emission. This chapter gives a general introduction of this study, statement of the problem and the objectives of the research. It goes further to give a brief description about the host project, MICCA with detailed information on its goals.

1.1 Overview of Mitigation of Climate Change in Agriculture (MICCA) project

The MICCA project, started in 2011, aims to better quantify greenhouse gas emissions to facilitate developing countries to contribute to the climate change mitigation in agriculture and move smallholder systems toward low carbon emission agriculture. The project described in this

document is one of a set of two pilot projects meant to integrate climate-smart agricultural practices into existing agricultural development projects. This project builds upon sites of the East Africa Dairy Development (EADD) project located in Kenya.

The EADD project is a regional industry development program led by Heifer International in partnership with the International Livestock Research Institute (ILRI), TechnoServe, the World Agroforestry Centre (ICRAF) and the African Breeders Service (ABS). The project is being implemented in Kenya, Rwanda and Uganda. The overall goal of EADD in the region is to help one million people – 179,000 families living on small 1-5 acre farms – lift themselves out of poverty through more profitable production and marketing of milk. The EADD focuses on enhancing efforts of the Dairy Farmers Business Associations and seeks to develop sustainable and profitable business development.

Working with the EADD partners at the Kenya site in Kaptumo, MICCA efforts will add value to the dairy development efforts by building capacity for the integration of climate-smart practices that simultaneously increase productivity, income and ecosystem resilience within the farming systems of smallholder farmers and throughout the value chain. This will be accomplished by establishing a baseline and monitoring changes in GHGs and productivity with and without the implementation of climate smart practices agreed upon by the Dairy Farmers Business Associations (DFBA) on farm or within the value chain.

Within the overall context of MICCA, the pilot activities will contribute to the refinement of measurement and modeling methodologies associated with climate change mitigation. Further, the evidence from the MICCA Pilot activity will be used to inform decision makers for shaping policies at multiple levels. The outcomes expected from the pilot effort include: project farmers implementing climate-smart practices in small-holder dairy systems resulting in greener landscapes and greater energy independence; increased crop-livestock productivity; increased ecosystem resilience; and development partners utilizing project evidence.

1.2 Statement of the problem

To achieve proper mitigation of climate change strategies, it is important to quantify all GHGs emission sources. Emissions from livestock form a large percentage of the total global emissions whereas most research that quantify GHG emissions neglect emissions from livestock manure on

pasture land and concentrate on emission from manure heaps and slurry collected and managed by farmers. Furthermore, urine and dung from livestock account for high percentage of global GHG emission however most studies on this topic use artificial urine which may overestimate or underestimate the findings when standardizing emissions across many different livestock groups and regions.

Due to variability and uncertainty in the factors that affect GHG fluxes in the soil, it is a challenge to quantify emissions from a region. Therefore, the use of statistical analysis technique that incorporates the uncertainties will provide accurate information for policy makers to adopt in a region. In addition there has been limited capacity to offer research methods support to research, this limited support and inadequate capacity has weakened the quality of research.

1.3 Objectives of the study

The objective of this study is to provide research support for MICCA project to achieve its main goal of better quantify greenhouse gas emissions and facilitate developing countries to contribute to the climate change mitigation in agriculture and move smallholder systems towards Climate smart agriculture. This project intends to achieve this by quantifying GHG emission from soils with cattle manure during the wet season to bringing out research methods skills for readers to get suitable tools to use in similar research studies.

The specific objectives for the study are;

- To determine the effect of cattle manure (urine and dung) deposition on net soil GHG emission.
- To demonstrate the value of data management and organization process in the study of determining manure GHG emissions from pastureland in Kaptumo.
- To determine impact of cattle urine for Kaptumo farms using Monte Carlo technique.

1.4 Significance of the study

The results of this study will benefit research institutions and scientists looking to quantify GHGs in agricultural fields since it will provide GHG fluxes from cattle manure on pasture fields during the wet season. It will provide research methods skills especially in key areas of data management and organization to adopt while carrying out similar researches. It will further benefit researchers and policy makers who are responsible for mitigation and adaptation to climate change. Moreover, the outcome of this research study will be directly used by ICRAF-MICCA project, since this study will specifically provide feedback to researches being conducted by this project

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Climate change and agriculture

Climate change can be defined as a long-term change in the statistical distribution of weather patterns over periods of time that range from decades to millions of years, or may be a change in the average weather conditions or a change in the distribution of weather events with respect to an average, for example, greater or fewer extreme weather events [10].

Changing climate and weather patterns are predicted to have severe negative impacts on food production, food security and natural resources and this could jeopardize the livelihoods of millions especially in developing countries, particularly where climate impacts are compounded by other factors such as existing poverty and hunger, it makes it difficult to cope with its impacts [11]. The IRI–CS (International research institute for climate & society) summary report indicates that for vulnerable communities, developing flexible and proactive responses to climate change that enhances resilience is crucial step toward achieving the MDGs. Furthermore because climate has confounding influence on many development outcomes, attentions to climate change are essential for measuring progress towards the MDGs [12]. If not well responded to, countries that depend economically on climate sensitive sectors such as agriculture, fisheries and forestry are expected to be the most affected [13].

The role of agriculture in development processes will have to take account of the vulnerabilities and risks posed by climate change. Agricultural land use will be affected by changes in climate and climate variability. Most crop production systems are temperature and water limited, and will therefore, be affected by climate change. Indirect effects on crop production via the changes such as infestations of pests and diseases have the potential to destroy entire harvests[12].

Besides being a victim of climate change, agriculture is also a major contributor to climate change via the emission of greenhouse gases, through land use change, land management, land conversion and livestock husbandry. Response strategies and sustainable development pathways need to take into account the dual focus of adaptation i.e. response to climate change and

mitigation i.e. reducing greenhouse gas emissions. It is important that adaptation and mitigation to climate change be placed in the wider framework of sustainable development [14].

2.2 Agricultural sources and sinks of greenhouse gas emissions

The rise in of GHG concentrations in the atmosphere has become a major environmental concern as revealed in the Kyoto Protocol [15]. Besides contributing to global warming by absorbing infrared radiation, CO_2, CH_4 and N_2O the main agricultural GHGs, have been declared the most harmful gases for ecosystems, apart from ammonia (NH_3) [16]. The impact of each gas varies in terms of its effectiveness in trapping solar radiation and consequently, its contribution to global warming. The variation is indicated by the global warming potential (GWP) of each gas relative to carbon dioxide. The GWP of these gases are; 1, 21 and 298 times, respectively [3].

Agricultural practices account for 10 to 12% of world total GHG emissions; however, it could reach between 17 and 32% when all agriculture-related emission sources are included such as direct and indirect emissions [17]. Direct agricultural GHG emissions are derived from three main sources: a) CH_4 emissions from cattle enteric fermentation; b) CH_4 and N_2O emissions due to manure management practices and c) N_2O emissions from cultivated fields, including direct emissions from cropland and pasture and indirect emissions resulting from the use of nitrogen fertilizer in agriculture [16].

Greenhouse gas accounting is a critical ingredient of efforts to mitigation and adaptation to climate change, with the unique importance of accounting for all agricultural emissions in a country's greenhouse gas profile and in the light of the Kyoto Protocol obligations to develop mitigation strategies, there is need to quantify all emission sources to provide accurate verification of emissions and mitigation measures [18],[5].

2.3 Effect of cattle manure on net soil GHG fluxes

Livestock keeping is a widespread global activity common amongst rural communities with between 77 and 85% of households keeping dairy cattle [19]. CH_4 and CO_2 are produced from the decomposition of livestock manure under anaerobic conditions while N_2O is produced during the nitrification-denitrification of nitrogen contained in livestock waste; N_2O production requires an initial aerobic reaction and then an anaerobic process, therefore dry and aerobic management

systems may provide an environment more conducive for N_2O production[20] however most studies show that farmers use manure slurry (mixture of dung and urine) on their farms thus it is not easy to quantify the emission rate from the separate sources such as those that are found on grazing pasture fields where deposition of urine and dung are sometimes on different spots of the ground.

The principal factors that affect GHGs emission from livestock manure are the amount of manure produced and the portion of the manure that decomposes anaerobically, the total amount of manure produced can be estimated using an average amount of manure produced per animal and the number of animals. The type of manure management system used and the climate (mainly temperature) are the primary factors that determine the amount of GHG produced from the deposited manure [4], thus similar studies should put into account all factor that affect GHG production from the manure to further estimate the emission factor.

Emission factors are estimates of GHG produced in kilograms per animal they help to standardize emissions across many different livestock groups so that relatively correct total emission estimates can be made [20]. The Intergovernmental Panel on Climate Change (IPCC) identified a default urine-N emission factor of 2.0% and for dung the value varied between 0.1 and 0.7% , this emission factors are largely derived from results of long term field studies conducted in northern hemisphere, where N_20 has been measured using soil cover [21]. There is also some concern that most studies that work with artificial urine rather than real urine may overestimate or underestimate the emission factors. Also similar concerns may be formulated for incubation studies vs. field studies [22],[23]. For these reasons this study aims to use real urine on a field study which is the norm in livestock keeping where cattle graze in pasture field during the day and at night they are put in their sheds [24].

Furthermore, most studies with reported emission factors for applied N-urine and N-dung are from the developed countries. Groenigen in their paper [25] summarizes a list of N_2O emission factors for urine patches in pasture soils and their main experimental parameters such as type of urine used and soil characteristics, from 25 published papers that do not show any literature from African countries.

2.4 Value of data management and organization process in research

Data management and organization in research methods includes data planning, handling, analysis, documentation and storage, which are key steps in conducting any research. It involves all activities associated with data other than direct use of data. These activities include; data organization and backups, archiving data for long term preservation, data sharing or publishing, ensuring security for confidential data and data synchronization. However, too often many researchers who lack research methods support neglect or under emphasize on these vital steps [26]. Furthermore, having good data management plan ensures that the variability in the data collected is derived from the phenomena under study and not from the data collection and data entry process. It also ensures accurate, appropriate and defensible analysis and interpretation of due to the use of skilled personnel [27].

Researchers benefit greatly from data management plan because research data are well organized, documented, preserved, accessible, and their accuracy and validity is controlled at all times, the result is high quality data, efficient research findings based on solid evidence and thus saving of time and resources [28]. Therefore there is need to ensure that a proper data management and organization plan is followed in any research however this may be a challenge if a data flow program is not well documented at the beginning of the research.

To ensure that the quality of the data collected is not compromised in any capacity, the following key steps have been suggested by [29] as a measure of complete data management strategies: Planning data management for the project, taking into account the objectives and planned outputs, the resources and skills available. At this stage, a data management plan should be set up to describe what data will be created, what policies will apply to the data, who will own and have access to the data, what data management practices will be used, what facilities and equipment will be required, and who will be responsible for each of these activities. The next step will involve checking of raw data and this will entail finding out if there are any missing values or if the variables are clearly labeled amongst others. Data entry and organization of computer files will follow whereby validation rules are put in place to minimize errors that would be made during the data entry process. Data entry process should be done promptly and simply.

2.5 Statistical modeling of N_2O emission data

Studies have shown that nutrient cycling in a cattle largely affect manure production and consequently produce variability in soil greenhouse gas emission where manure is deposited [30]. Greenhouse gases affect the earth's climate and the earth's climate is too complex to simulate and to make reasonable prediction of greenhouse gases is also a challenge [31]. This is because there are many uncertainties in the parameters that contribute to the emissions. Therefore there is need to use a model that simplify these assumptions by giving the modeler freedom from restriction in generating trial configuration that are flexible in solving a specific problem [32].

Monte Carlo simulation is a computerized statistical technique that allows researchers to account for risk in analysis and decision making. [33]. It performs risk analysis by building models of possible results by substituting a range of values from probability distribution, for any factor that has inherent uncertainty and then calculates results over and over, each time using a different set of random values from the probability functions [34] . Therefore this study will use this model to statistically simulate the N_2O emission and provide the clear picture of the impact of urine to N_2O emission for the cattle in Kaptumo region whereas this information has not been provided for in literatures.

Monte Carlo simulation achieves an approximate solution of a mathematical or physical problem by simulating random quantities. The name "Monte Carlo" comes from the city of the same name in Monaco, famous for gambling. The Monte Carlo algorithm, in general, consists of a process for generating a random event of some kind, then repeating this process in an arbitrarily large number of times and averaging the results [35]. Therefore this study will create random event from uncertain parameters that contribute to cattle urine N_2O emission to predict the significance of the urine to GHG emission.

The Monte Carlo method was first described in a summary by Metropolis and Ulam of the Los Alamos National Laboratory in 1949 as a method for solving large systems in particle physics by means of "statistical mechanics." It represented a departure from the study of classical mechanics of individual particles to the statistical study of sets of particles, thereby combining statistics with the then-new field of set theory. It was used to illustrate particle physics in which a

particle's behavior was described probabilistically for all situations it potentially encountered in its history [36]. Similarly, other recent studies [37], [38], [39],[40] have used this technique to model climatic data, although N_2O emission has not been modelled.

Prudhomme et. al, randomly generated 25,000 climate scenarios for the UK by adopting a Monte Carlo simulation based on different greenhouse gas emissions scenarios [39]. Most scenarios showed an increase in both the magnitude and the frequency of flood events in future. Shackley et. al, Used a global carbon cycle model and historical carbon dioxide emissions levels to generate a large number of possible future carbon dioxide scenarios [40]. Their output showed a greater variability in future carbon dioxide levels than those obtained using deterministic models.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 Data management and organization plan

Before the execution of this research a clear data flow program was set out to ensure quality checks within every process of data collection, data entry, data analysis, presentation and documentation of the research finding. The framework that was used for this study was as below, for each steps guidelines were set to ensure for quality assurance and quality assessment;

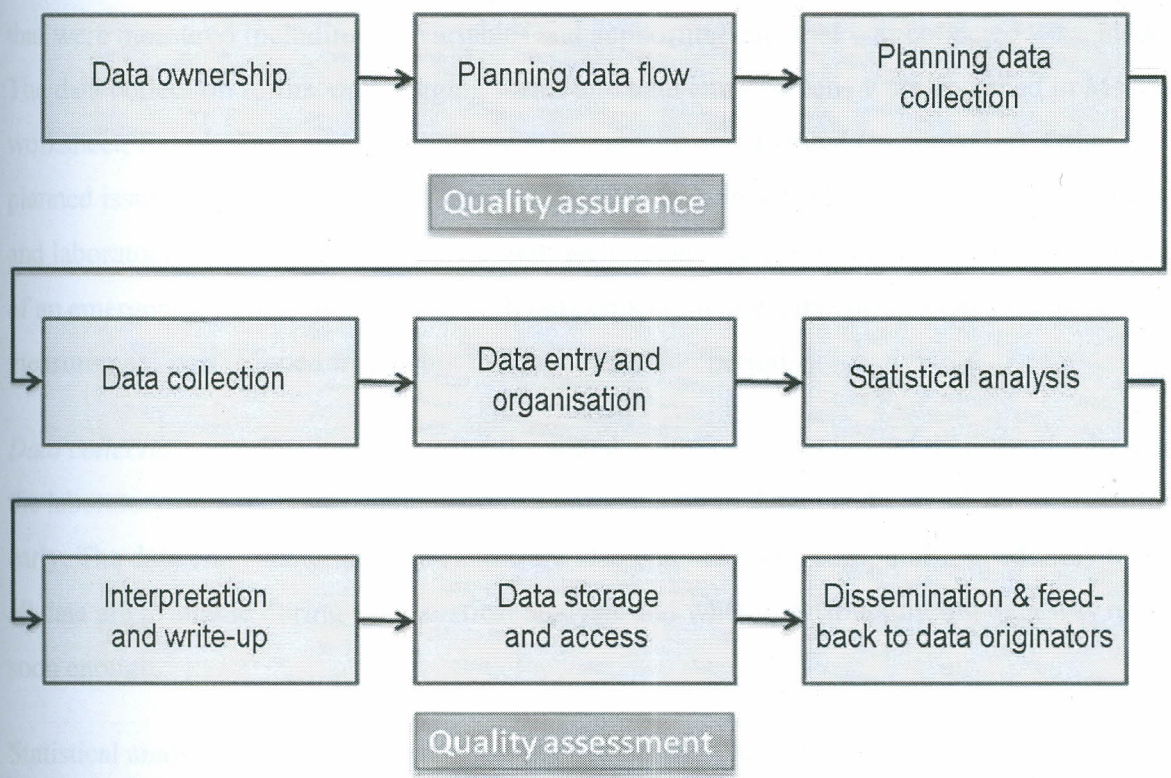


Figure 1: frame work of data management

Author: Gerald W. Chege and Peter K. Muraya (2001).

Data ownership- An authorship guide was required for the sake of sharing and taking responsibility of the research findings. The ICRAF authorship responsibility, financial disclosure, copyright transfer and acknowledgment guide

(http://www.reading.ac.uk/ssc/n/resources/Docs/Authorship.pdf) was used to ensure responsibility is taken when presenting and sharing this document since the research findings will be used by many organizations.

Planning data flow-The study objectives were clearly laid out and explained to the scientists involved in supporting this study. The research design was written down stating where the experiment was set and the availability of all the resources required in the experiment. The farmers involved in the study were also briefed on the measurements to be undertaken in their farms.

Planning for data collection and data entry- At this stage decisions concerning the primary data that were measured including the variables and supporting data that was collected were made. The data collection forms, data logging forms and data entry screens were designed in Ms. excel worksheet; field layouts and the sampling scheme were documented (in appendix). Other planned issues included logistics, costs, timing of collection activities and the planning of field and laboratory technicians involved. Support technician who can stand in for the student in case of an emergency were also trained in both data collection and data entry to ensure that no measurement was skipped trough out the data collection period.

Data collection and data entry –During the actual sampling it was agreed that samples be sent to the laboratory on a daily basis and analyzed immediately to detect and correct errors in sampling early. The data entry material from field were also entered into a computer immediately to ensure all data are available during the statistical analysis and where possible missing data was retrieved soon enough.

Statistical analysis- it was agreed that the initial step was cleaning of the data to ensure no oddities and the data is accurate and valid. Then descriptive and exploratory analysis performed on the data using MS excel and R software packages.

Interpretation and write up- it was agreed that the student interpret the data, use tables and graphs to present the results and summary output and discus the way forward for the research. Then present the work to both the university and MICCA project at ICRAF.

Data storage and access - the data storage and archive system used was Drop box which is an internet cloud system that allows the lead scientist, technicians and the student involved to view files that are stored. The standard operation procedure for sampling, logging forms, and all document involving this study were stored in the folder to allow for free access of the data.

Dissemination and feedback to originator – it was agreed once the study is published then the work will be put online to allow other researchers access the information, also simpler version of the finding translated so that results can be understood by the farmers.

3.2 Study area description

The study was conducted in Nandi south county, Kaptumo Division of Rift Valley Province, Kenya. It is located at an elevation of 1,845-2000 meters above sea level and its coordinates are 0°1'0" N and 35°1'0" E (figure 2). The area is mildly densely populated with 265 people per km^2 about 7,500 inhabitants are farm families. The Location has a humid climate which is classified as a tropical monsoon (short dry season and monsoon rains in other months), with a warm temperate moist forest.

The soil in the area is high in nitosols and andosol, with deep clay-enriched lower horizon with shiny ped surfaces, the soil is classified as high activity clay soil. Precipitation is generally distributed across two seasons. The short rains occur during October and November while the long rains occur from March to June. Despite the two seasons precipitation can occur at most times of the year. The temperature in the region ranges between 16 and 31°C, with a mean annual rainfall of 1500-2200mm. [41].

The land area is cultivated and still has some natural vegetation preserved. Natural vegetation of the region was originally tropical rainforest that parts have been cleared for agriculture. The landscape is mostly covered with mosaic vegetation/croplands. Farming in the area is characterized by large farms under mixed crop-tree-livestock systems. Trees are integrated in cropland, pasture fields, or separately grown in small woodlots while livestock are mainly left to graze in pasture paddocks.

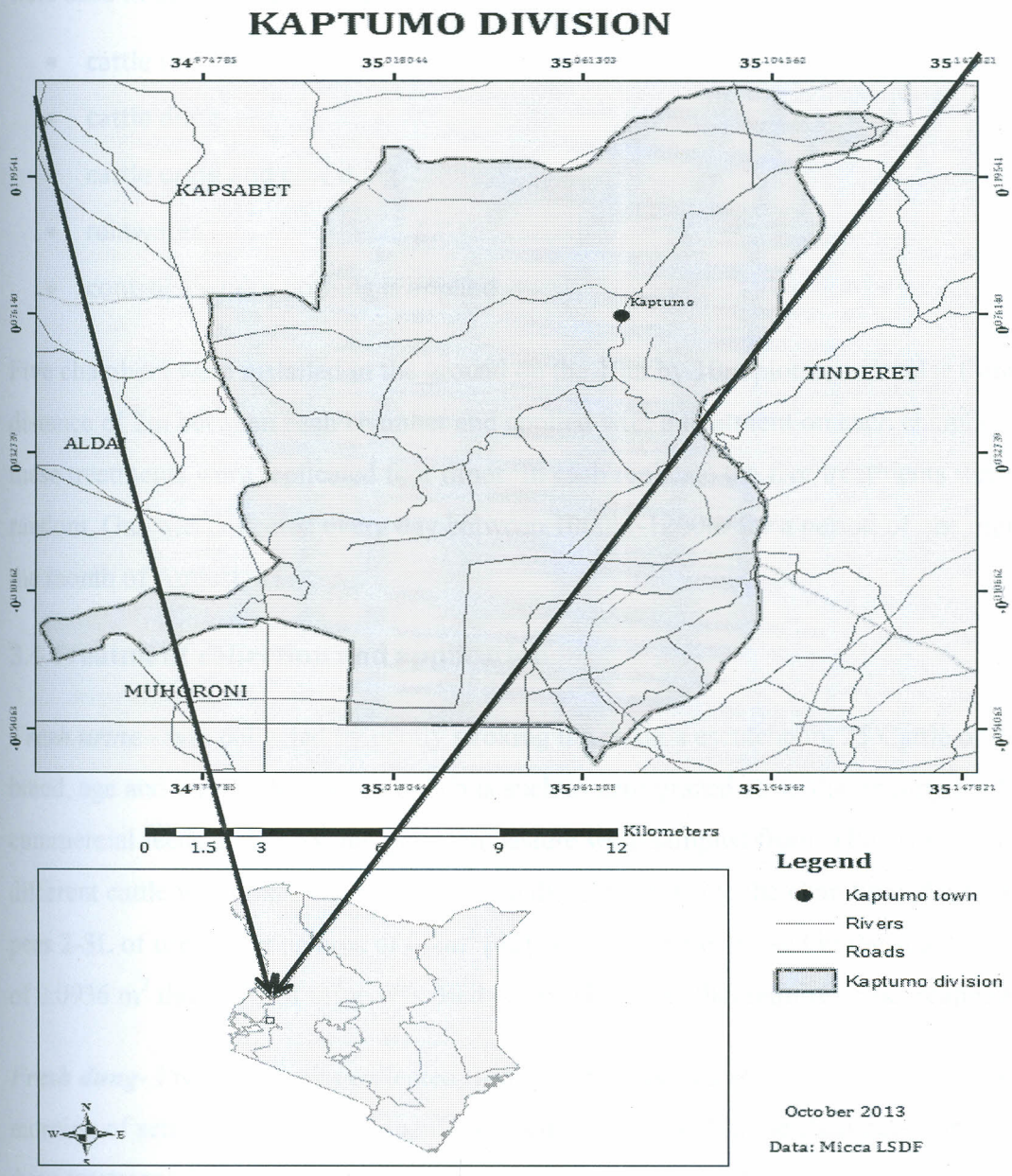


Figure 2: Kaptumo Division in the Nandi South District of the Rift Valley Region in Kenya

3.3 Experimental design and plots establishment

The experiment was laid out in a randomized complete block design (RCBD) on a grassland paddock. Four equal blocks of 10m by 10m plot was set to form the four clusters that were each

randomly applied with the five treatments in the installed chambers. The five treatments that were used in the experiment are;

- cattle urine
- cattle dung
- cattle urine and cow dung
- rainwater
- control – where nothing is applied

Five chambers were installed in the ground on the 10m by 10m plot in a circular form at a distance of 2m between each chamber and applied with a treatment on each chamber, and then these treatments were replicated four times. In each replicate the five treatments were applied at random. Gas was collected every day between 1000hr-1200hr for a period of one month during the month of August.

3.4 Treatment collection and application

Fresh urine - was collected by gently stroking the cattle`s escutcheon. 25 Cattle of different breed, age and with different eating habits such as zero grazed cows that mainly feed on commercial feeds and cows that graze on pasture were sampled from. The urine collected from different cattle was mixed then simulated on the ground inside the chambers. An average cow pees 2-3L of urine over an area of $0.2m^2$ [42] and the chambers used in the study covers an area of 0.0936 m^2 thus 1.2L of urine was used on the chambers that require urine treatment.

Fresh dung- Fresh dung was collected from the cattle pens and the grass paddocks in the morning of setting out the experiment and then 500g applied in the chambers that require the dung treatment. The amount of dung used was observed to be the average of what most cattle in the field produced since there was no standard weight for dung excreted.

Rain water - was collected using buckets from the household reservoir then 1.2L was added on chambers that require rain treatment.

Table 1: Randomized layout of treatment application at the field

Plots	Block 1	Block 2	Block 3	Block 4
1	b	e	d	c
2	a	b	c	e
3	c	d	e	a
4	e	a	b	d
5	d	c	a	b

a- urine, b- dung, c-rainwater, d- dung+urine, e- control

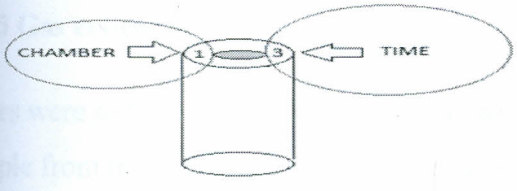
3.5 Gas sampling procedure

Initial gas sampling was done on the 1st of September 2013 immediately after treatment application. The following field supplies were marked available before gas sampling started and the vials labeled before going to the field (as in fig 3);

3.5.1 Field Supplies

- PVC (or plastic) chamber bases
- PVC Chamber lids/tops fitted with an injection, fan and a vent port. With an extra hole to fit in a thermometer to monitor the temp inside the chamber during measurements
- Air temperature sensor
- Soil moisture sensor
- Stop watch timer
- Glass sampling vials
- Digital manometer

- Plastic syringes (60ml) marked **1 to 5** (for each of the five chambers) fitted with a luer-lock stopcock valve for airtight gas sampling (see fig 7).
- Gas sampling needles (0.6x25mm)
- Double ended needles (vacutainer) and silicone tubing for the evacuating assembly
- Measuring Ruler (30cm)
- Vents to fit onto the chamber lids to equilibrate pressure within the chamber with that of the outside atmosphere
- Data sheets for recording the readings
- Zip lock paper bags
- Grabs for chambers/ clamps to hold the base and the top together tightly
- Cables for the battery/fan
- Marker pen
- Pencil
- Rubber bands
- A pair of scissors
- Raincoat and rubber boots



-Label at the top of the vials.

-Left side: chamber's number

-Right side: time

Figure 3: Vials labeling

3.5.2 Fitting gas flux chamber bases onto the soil surface

On the 31st of August 2013 the plots were installed with 20 polyvinyl chloride (PVC) rings that are made from a non-reactive material used in static chamber gas flux measurements [43].

1. Sampling points were identified.
2. Any existing vegetation on the spot to place the chamber bases was clipped.
3. The chambers were pushed into the ground, about 2-3cm deep.
4. Using a ruler, heights of four points inside the chamber from the ground to the top of the rim of the chamber base were recorded.
5. Cables were as (fig 4).

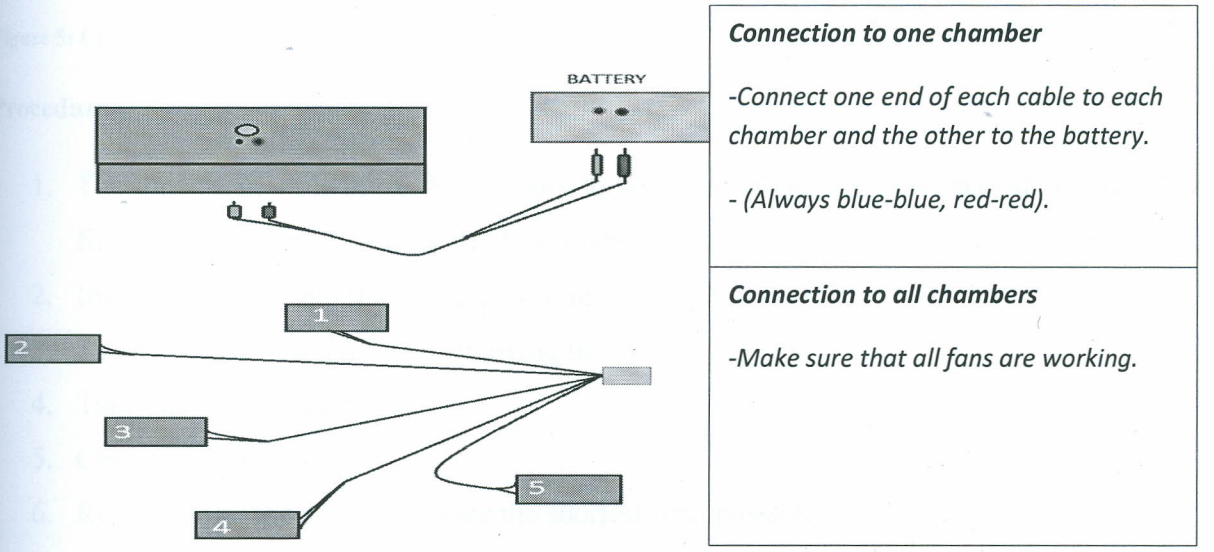
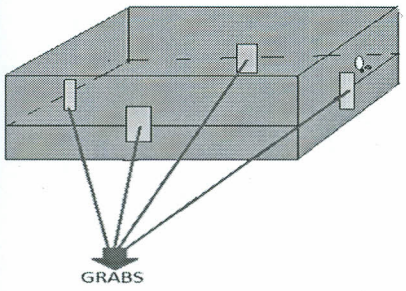


Figure 4: Connecting cables

3.5.3 Gas collection

Gases were sampled using 60ml gas tight syringes fitted with a luer-lock stopcock. A gas sample from the chamber was injected into an evacuated 20 ml vial, resulting in an over-pressurized vial. An air temperature sensor inserted onto each of the chamber tops for the change in temperature recorded at the time of closure of the chamber (T1) then at T2, T3 and at the finish (T4). The temperatures were recorded in the sampling template (in appendix).



-Put the lid on the base.

-Place the 4 grabs.

-Make sure that the system is tight.

-Start timer

-Begin sampling

Figure 5: Closure of chambers

Procedure

1. The timer was set to zero. When ready to begin sampling, the timer was set to start then first chamber tightly closed with the 4 grabs (in fig 5).
2. Insert the needle into the chamber through the septum (see fig 6).
3. Take and expel gas (without removing the syringe).
4. Take gas slowly again.
5. Close the luer-lock.
6. Repeat for all the chambers (take the shortest time possible).
7. Record the time you finish sampling T_1 of the last chamber i.e. [0.30minutes].
8. Insert the needles into the septum of the 5 evacuated vials respectively (1-1) to (5-1) and inject the gas samples into the vials (fig 7).

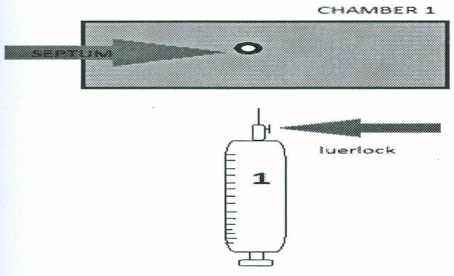


Figure 6: Taking gas from the chamber

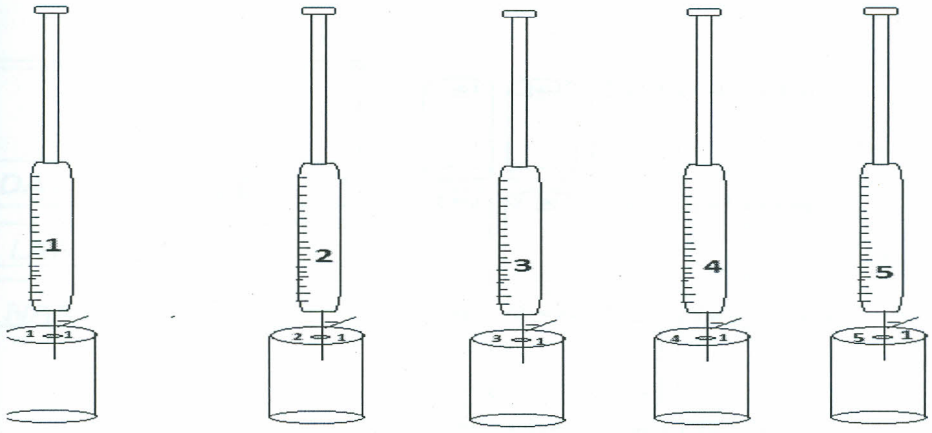


Figure 7: Transfer gas into vials

9. Ten minutes from the time the timer started, start the second round of sampling for T_2 vials in the same sequence sampled for T_1 vials and record the finishing time of the last chamber i.e. [10.25minutes].
10. Twenty minutes after the timer started, sample for T_3 vials in the same sequence as above for all chambers then record the finish time, do this again after exactly 30 minutes on your timer for vial T_4 and ensure you record the finish time.

After each timed sampling, the temperature inside the chambers was recorded. Cables and sensors were picked then all vials (80 in total) and the recording sheet were all packed in a well labelled zip lock plastic bag (Fig 8). Auxiliary measurement such as air and soil temperature, atmospheric pressure, soil characterization, bulk density, soil moisture and relative humidity of the area were recorded of each day.

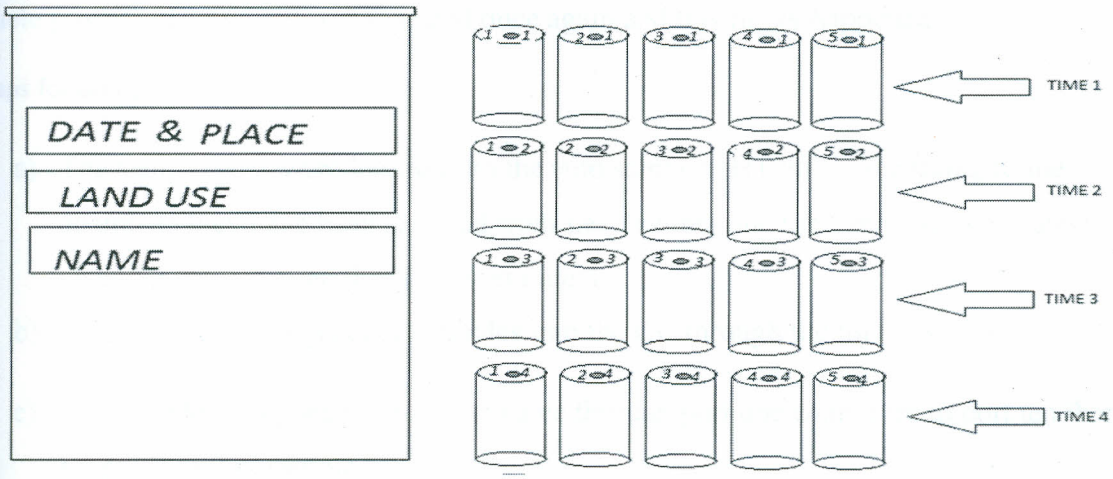


Figure 8: Labelled zip lock bag

3.6 Sample analysis

3.6.1 Gas analysis

Gas chromatography is the separation of a gas mixture by distribution of its components between a mobile (carrier gas) and stationary phase (column packing material) over time. The mobile phase solvent used in the gas chromatograph (GC) was Nitrogen (N_2) and the stationary phase was column packing material that separated the as molecules using the mechanism of selective retardation caused by interactions with bonded phase of stationary phase

The gas samples were analyzed using a gas chromatograph (GC) equiped with; an Electron capture detector (ECD) which has radioactive element that is highly sensitive to molecules containing electronegative functional groups, ideal for N_2O and Flame ionisation detector (FID) best for compounds containing C-C or C-H bonds such as CH_4 and CO_2 .

Immediately the samples arrive at the laboratory from the field their integrity was confirmed through the acceptance/rejection criteria i.e. are they the right ones, are they packaged well and do they have the right documentation. The sampling data sheets were then filed and if they were

missing, the follow up was done from the field. If the documentation misses completely, then the whole process of sampling was repeated once again and this rarely happened.

Steps for analysis

a) The sample vials were loaded onto the auto sampler (HT200H) according to the chambers they have been sampled from i.e. chamber one time zero (zero minutes) to chamber five i.e. time four (thirty minutes).
b) The auto sampler injects the samples into the GC through the injection port.
c) The sample then goes to a ten port valve through port one connected to port ten then proceeds to 2ml sample loop.
d) From the 2ml sample loop it goes to port three connected to port two then to another ten port valve through port one connected to port ten, then to another 2ml sample loop and back again to the valve through port three and excess sample is vented out through port two when the machine is at load position.
e) The valves turn to injection position, and then the sample moves from port ten, goes through the 2ml sample loop to port three as the carrier gas flows through port four and both proceed to a (1m porapak Q) pre-column.
f) In the pre-column moisture/water is removed then the sample proceeds to a (3m Hayesep D) separation column (in appendix).
g) The gases are separated according to their molecular weight, from the lightest to the heaviest, methane, carbon dioxide and nitrous oxide respectively.
h) They then go to the detectors, where the output is in form of peak areas. FID detects (methane and carbon dioxide), and ECD (Nitrous Oxide).
i) Standards of known concentrations are also included in the analysis.

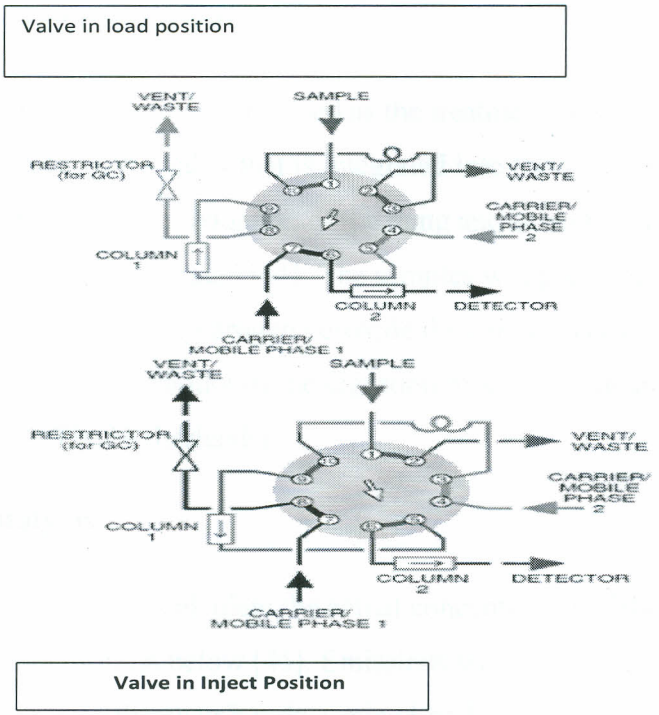
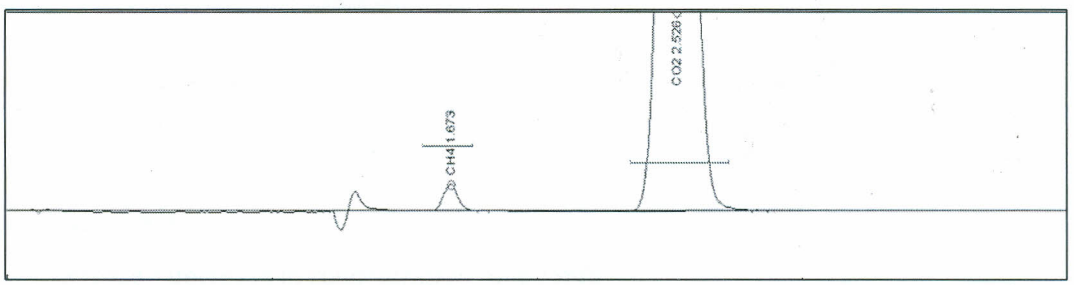


Figure 9: Valve position during analysis

Sample FID chromatogram (output)



Sample ECD chromatogram (output)

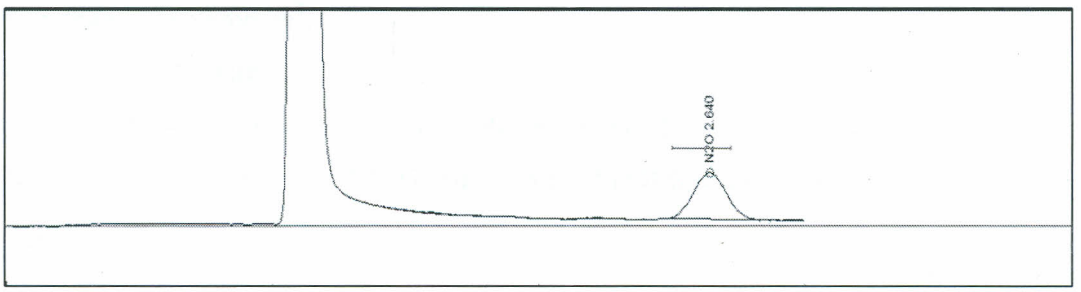


Figure 10: FID and ECD chromatograms

3.6.2 Dung and urine analysis

A sample of fresh urine and dung used as the treatment was carried to the laboratory in a cooler box for the analysis of total N that is integrated into the soil. Total N was analyzed in the laboratory after complete oxidation of the dung and urine by a modified Kjeldahl digestion procedure using sulphuric acid [44]. The samples was pre-treated with sodium salicylate to convert NO_3 to NH_4, and hydrogen peroxide then added as oxidizing agent. Total N applied was determined from 5 mL aliquot of the digestion mixture using an auto analyzer (Sklalar Analytical BV, The Netherlands)

3.7 Data analysis

Peak areas were used to calculate the actual concentration of the samples hence calculating the fluxes using the formula below [45]. Emissions were calculated from the rate of change in concentration inside the chamber determined by linear regression over the time series. Data generated was analyzed using KNIME software (version 2.7.4) platform. This was used to automate the flux calculation therefore increase the rate and efficiency of analysis.

Formula for calculating flux rates for static chambers

$$F = \frac{b * Mw * V_{Ch} * 60 * 10^6}{A_{Ch} * V_m * 10^9}$$

- F = flux rate (μg m^{-2} h^{-1})
- b = slope of increase / decrease in concentration (ppb / min^{-1})
- Mw = molecular weight of component (g mol^{-1})
- V_{Ch} = chamber volume (m^3)
- A_{Ch} = chamber area (m^2)
- V_m = corrected standard gaseous molar volume (m^3 mol^{-1})
- V_m = $22.4*10^{-3}$ m^3 mol^{-1} * ((273.15+Temp)/273.15) * (1013/air pressure)

3.7.1 Determination of treatments effect on GHG emission especially N_2O

Data was analyzed using R statistical software, a multivariate regression model was fitted for each gas (CH_4, N_2O and CO_2) to explain the effect of gas emission of each treatment on the emission of the control, where the emissions from the control was the factor variable and the emission from other treatments (urine, dung, dung + urine and rain water) were the explanatory variables. The formulae used for the calculation was;

$$y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \ldots\ldots + \beta_n X_n$$

Where:

- β_o is the regression constant or intercept,
- β_1 to β_n are Slope or the beta coefficient of the control GHG emission (CH_4, N_2O and CO_2)
- X_1 to X_n are the independent variables that are explaining the variance in GHG emission that is the other treatments GHG emissions (urine, cow dung, dung +urine and rain water) used in the study.

3.7.2 Calculation of urine N_2O emission factor.

The urine treatment N_2O emission and the control treatment N_2O emission from the experiment were integrated overtime for each block, to estimate total emission over the measurement period, an emission factor for each block was then calculated using [31];

EF% = N_2O flux totals (urine) - N_2O flux total (control)/ Urine-N applied.

Where,

- EF is the emission factor (N_2O-N emitted as % of urine-N applied)
- N_2O total (urine) and N_2O total (control) are cumulative N_2O emissions (mg/m^{-2}).

3.7.3 Monte Carlo simulation analysis

To observe the impact of urine in N_2O emission in kaptumo, the relative contribution of all uncertain parameters that affect the transfer of nitrogen (N) were identified. The parameters included the number of cattle producing urine, how much urine they produced, the total N nutrient that is contained in the urine produced and the total N that is emitted (i.e. N_2O emission).

The number of cattle in the region and amount of urine produced were obtained from a socio economic survey conducted by MICCA Project in the region [46]. The total N applied obtained from the laboratory results and total N_2O emission from the experiment set up. For each parameter a probability density function (PDFs) was generated using the means and the standard deviations. Then we ran our model with 227000 iterations which is the number of households in Kaptumo.

Doing this by hand would have been incredibly time consuming and error prone, so the computer was used for this task. Using the global warming potential of N_2O which is 298 mg CO_2 equivalent in 100 year time frame as provided by IPCC we were able to relatively show the impact of cattle urine to N_2O emission.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Data management and organization

The planning and organization of the research enabled accurate and timely analysis of the data, all the required resources where readily and timely available throughout the research process. There were quality checks and assessment during data collection, data entry and analysis and this ensured a smooth run of the experiment and the research conducted, as this was discussed by [29] in their review.

Planning each of the data flow component as explained by [47] before the research was executed was appropriate since we identified the possible problems in the research and action was taken. Specific targets for the project that were set and the appropriate action taken ensured that the targets were met at specified time scale. This was mas made easier through allocation of tasks and responsibilities and ensuring that persons involved are aware of guides and tools to assist in case of problems. The quality of data was assured through accuracy in data entry, use of correct methods of conversion and describing before documenting to ensure that anybody could make sense of the data.

4.2 GHG emission from the experimental plot.

There was large difference in GHG fluxes from every block, with block 3 having the highest average N_2O emission followed by block 4. This difference in emissions from every block is attributed to different soil organic matter in each block because of different locations of the blocks. Introduction of N- nutrient from both cow dung and urine and their combination leads to increased release of N_2O emission from the soil. The cow dung + urine treatment in blocks 2, 3, and 4 had highest average N_2O emission except for block 1 where the urine treatment had the highest N_2O emission. Addition of C- nutrients by cow dung leads to highest emission of CH_4 emission in each block. The addition of urine to the dung dilutes the dung and therefore increases

the rate of decomposition of the dung and therefore the decrease in emission as compared to dung treatment alone. (See Table 2)

Table 2: Mean and standard deviation of daily GHGs emission from each block (n=30).

		CH_4 (mg m^{-2} h^{-1})		N_2O (ug m^{-2} h^{-1})		CO_2 (mg m^{-2} h^{-1})	
Block	**Treatment**	**Average**	**Stdev**	**Average**	**Stdev**	**Average**	**Stdev**
1	Control	0.01	0.29	155.54	132.44	3.44	0.53
	Cow dung	0.28	0.53	161.73	85.33	15.39	21.85
	Dung+urine	0.24	0.55	227.23	243.67	37.8	64.90
	Rain water	0.05	0.46	175.13	124.59	1.28	7.62
	Urine	0.04	0.27	250.27	253.02	53.02	86.75
2	Control	0.04	0.22	147.62	65.63	1.29	2.38
	Cow dung	0.97	2.38	177.47	90.65	0.5	7.76
	Dung+urine	-0.04	0.51	190.14	217.14	22.56	33.21
	Rain water	0.04	0.36	129.38	145.98	4.043	21.00
	Urine	-1.55	3.65	191.91	202.57	21.73	42.72
3	Control	0.17	0.40	214.51	100.32	6.27	0.80
	Cow dung	0.48	0.80	236.6	114.91	14.16	30.09
	Dung+urine	0.35	0.65	316.04	253.24	74.81	119.61
	Rain water	-0.01	0.16	177.32	100.29	7.99	16.90
	Urine	-0.12	0.24	264.36	132.68	54.16	57.41
4	Control	-0.07	0.40	151.58	67.72	12.61	0.50
	Cow dung	0.14	0.50	230.62	149.26	6.87	17.15
	Dung+urine	0.01	0.31	320.49	277.92	85.72	163.45
	Rain water	-0.16	0.45	168.67	116.06	0.55	22.07
	Urine	0.02	0.28	183.81	117.56	39.17	67.57

Application of dung and urine treatment increased the CO_2 and CH_4 emissions on the first day then the emissions reduced, while N_2O emission was low on the first day but increased on the

second after the soil microbes had taken in the treatments. For the control plot and rain treatments was an almost constant emission of all gases because of minimal effect to the soil microbes. (See fig 11). The fluxes for all the gases were dispersed around the mean, with more data on the upper quartile of the mean (see fig 12). There were outliers observed in all urine and dung treatments, this explains the extreme high and low fluxes observed on some days during experiment which do reflect changes in precipitations and temperature (see fig 13).

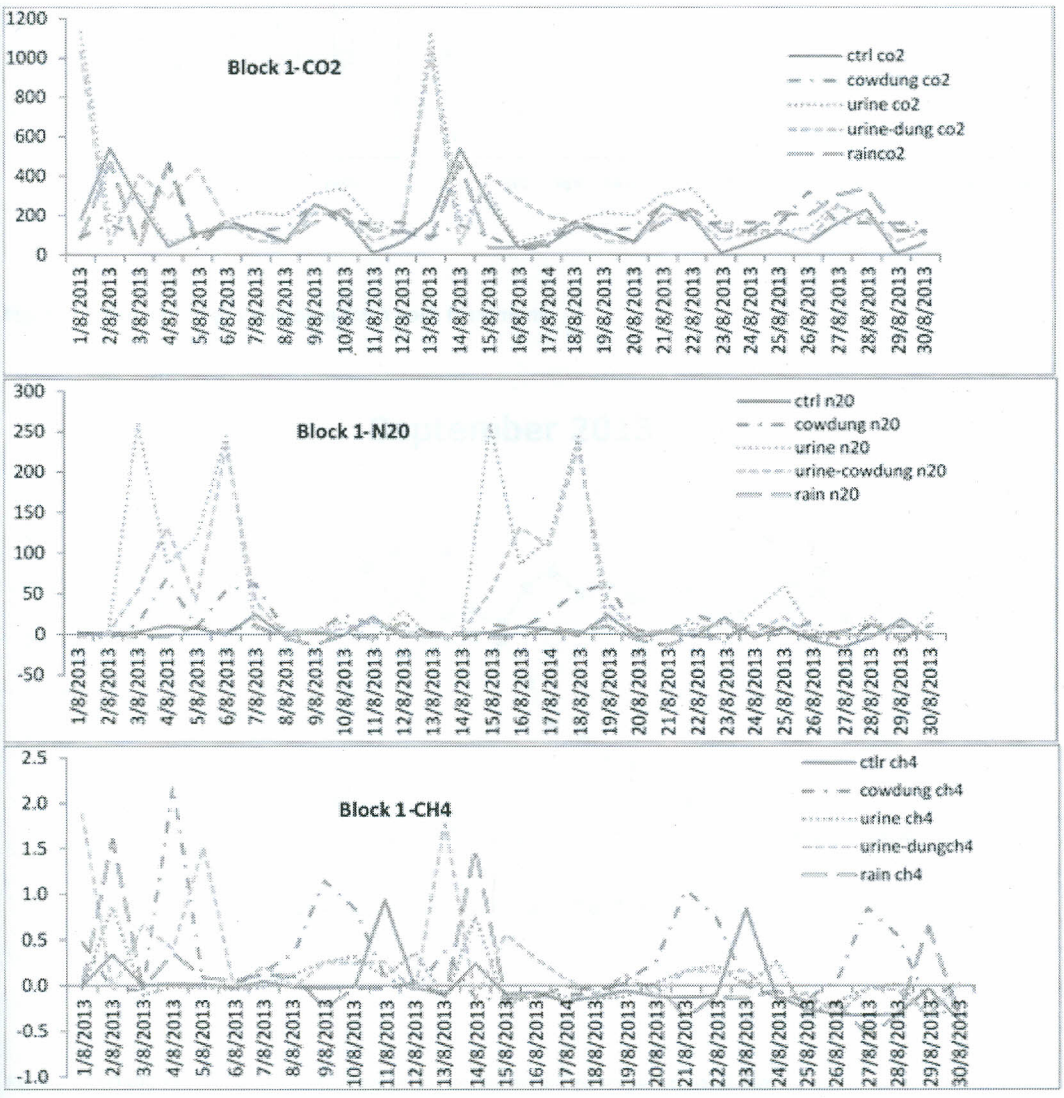


Figure 11: Daily GHG emission from block 1

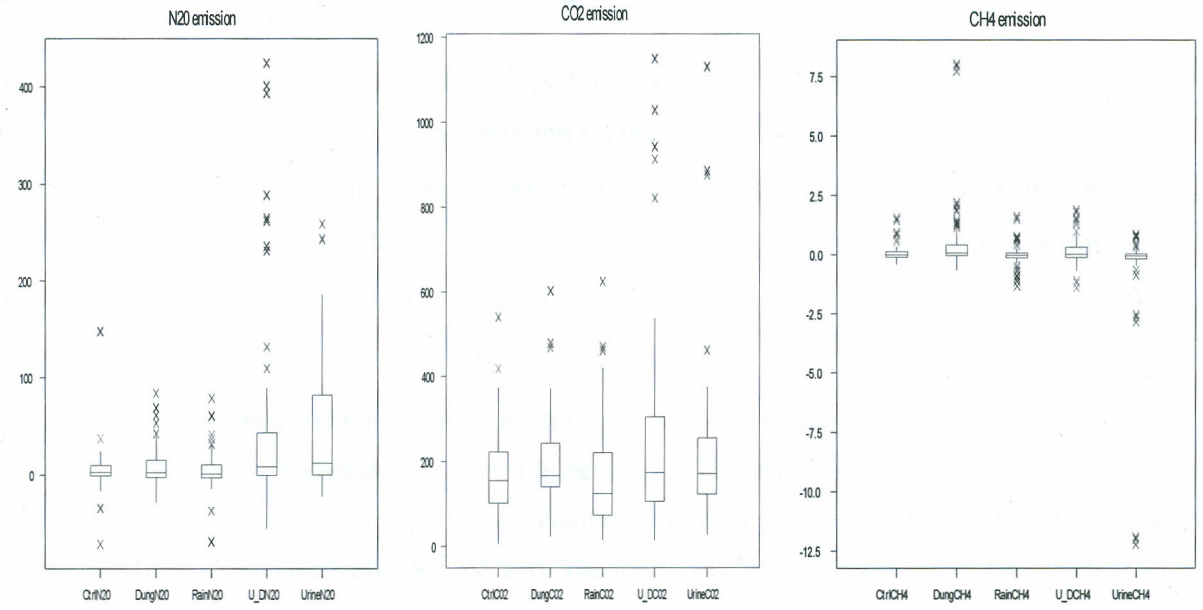


Figure 12: Boxplot of gas emission from each treatment

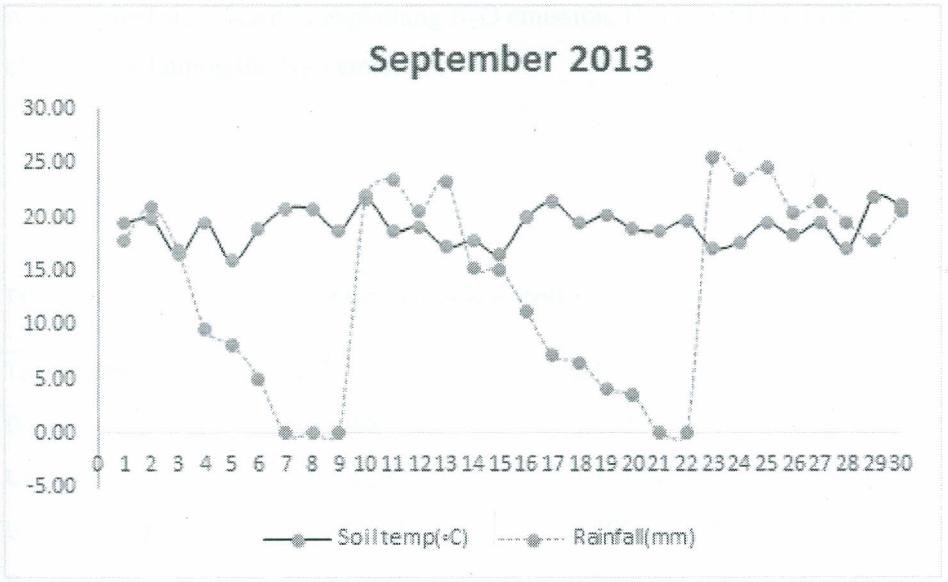


Figure 13: Daily rainfall and soil temperature experienced on experimental plot

4.2 Effect of treatments on GHG emission.

The multivariate regression analysis developed by R program, of each gas indicated a statistically significant effect of each treatment on the GHG emission. Urine, urine combined with dung treatment were statistically significant in explaining the effect of N_2O emission at ($P \leq 0.05$) at 99% and 95% confidence interval respectively, whereas dung alone and rain water treatment had no significant effect in explaining N_2O emission. Urine treatment had the highest effect of all the treatments.

Urine and dung combined and rain water treatment had a significant effect in explaining CH_4 emission at ($P \leq 0.05$) at 99% and 95% confidence interval respectively. This effect is due to adding the N-nutrients to the soil from the urine. Urine, dung and their combination had significant effect on CO_2 emission at ($P \leq 0.05$) and ($P \leq 0.01$) respectively. (See table 4). There was a significant effect due to the blocking effect on N_2O and no effect on CH_4 and CO_2. Similarly in (fig 14) that showed highest emission for CO_2 and N_2O were from dung-urine treatment and urine treatment.

The multiple linear regression is also confirmed with ANOVA (see table 3) that showed urine treatment was the most significant in explaining N_2O emission. Urine combined with dung and also block had an effect in explaining the N_2O emission.

Table 3: P. values from multiple linear regression analysis.

Treatment	N_2O	CH_4	CO_2
Dung	0.15369	0.18302	0.01301*
Urine	0.00000472***	0.17444	0.04998*
Urine + dung	0.00329**	0.00000135***	0.06279.
Rain water	0.4727820	0.00755**	0.11504
Block	0.00491**	0.00491	0.4243

*-significant values

Table 3. ANOVA table

	Degrees of freedom	Sums of Squares	Means of squares	F values	Pr(>F)
DungN20	1	706	106	1.769	0.186187
UrineN20	1	6068	6068	15.213	0.000164***
Urine +DungN20	1	1889	1889	4.735	0.031657*
RainN20	1	184	184	0.462	0.497959
As.factor(Block)	3	3667	1222	3.065	0.30999*
Residuals	112	44672	399		
Significant codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

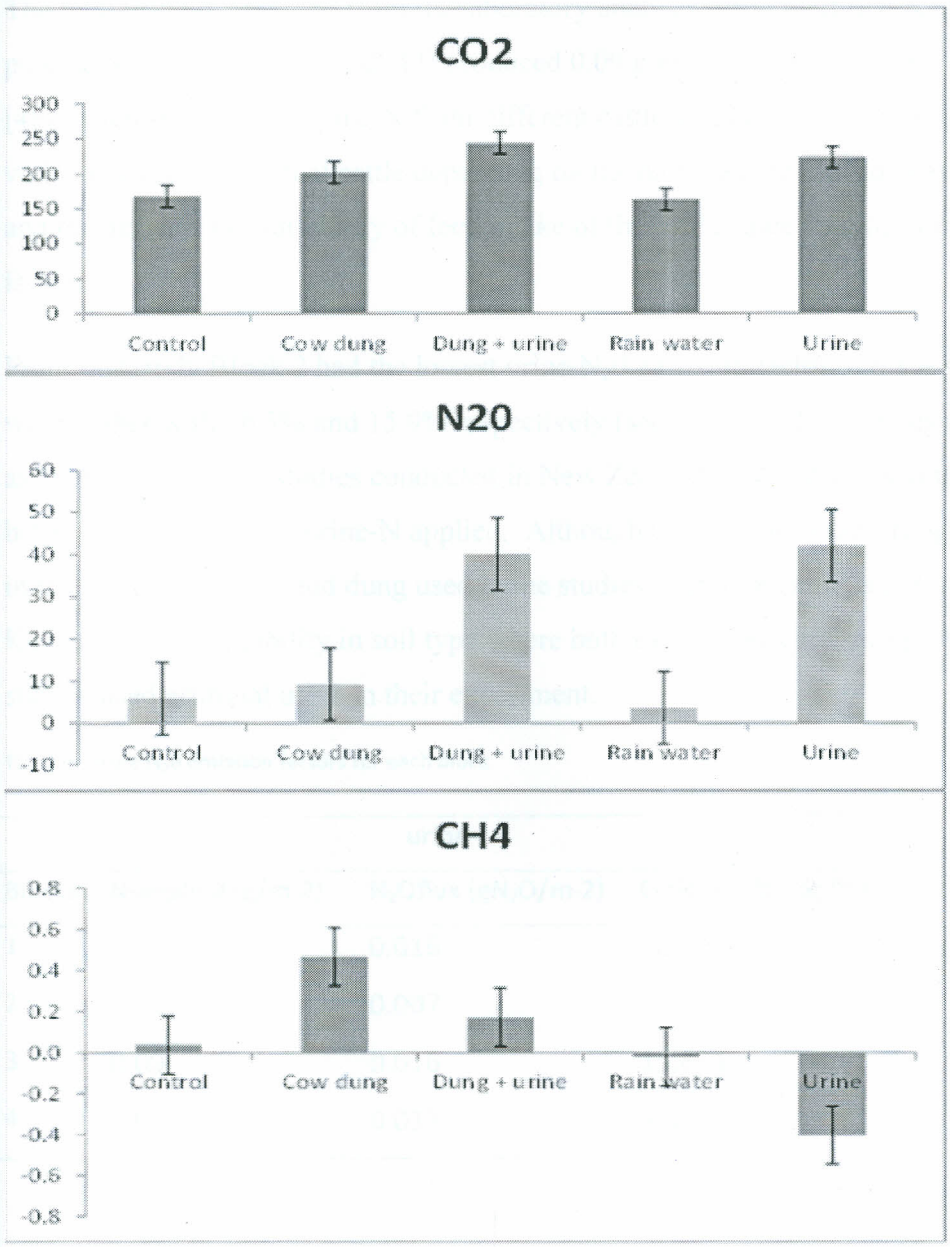


Figure 14: Average emission from each treatment with error bars.

4.3 Urine N_2O emission factor

The total urine-N obtained from the laboratory analysis using modified Kjeldahl digestion procedure with sulphuric acid [44] produced 0.09 g/m-^{2}. This lies between the range obtained by [48] which showed that urine-N from different cattle was between 0.02 to 0.2g/m-^{2}. The value varied between individual cattle depending on the diet feed, time of the day the dung was taken and this reflects the variability of feed intake of the cattle since feeding is managed by different farmers.

From this study Block 2 had the lowest urine-N_20 emission factor of 6.8% while block 1 and 3 were higher with 16.5% and 15.9% respectively (see table 5). This values appear relatively high as compared to other studies conducted in New Zealand [25] that showed urine- N_2O E.F was between 0.1 to 3.8% of urine-N applied. Although the variations are brought about by difference in the volume of urine and dung used in the studies, different cattle breed in New Zealand and Kenya, and the variability in soil type where both experiments are set-up. Also some of the studies used artificial urine in their experiment.

Table 4: Urine N_20 emission factors for each block

	urine		
Blocks	**N-applied (g/m-2)**	**N_2Oflux (gN_2O/m-2)**	**Emission factor (%)**
1	0.09	0.016	16.504
2	0.09	0.007	6.812
3	0.09	0.016	15.854
4	0.09	0.012	9.317

4.4 Simulation analysis

The assessment of impact of urine to N_2O emission in Kaptumo is subject to a range of uncertainties. These uncertainties are interdependent and arise from known or unknown

information that impact N_2O emission in an additive or multiplicative manner (see figure 15). The total uncertainty expands as individual uncertainties are combined.

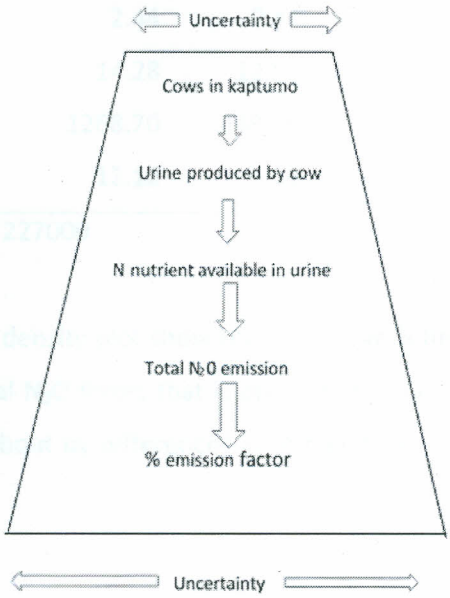


Figure 15: Schematic showing some of the uncertainties that cascade through urine assessment.

The results obtained from the simulation of the key parameters (Table 5) showed that the N_2O-N produced by all the cows in Kaptumo has a mean of 2.27 and the standard deviation of 2.57 (Fig 17). Therefore with the default GWP of N_2O of 298 mg per CO_2 equivalent we see that the urine on pastureland impacts N_2O emission at 67.64% N_2O-N (mg). This is a relatively high as compared to manure spreading on cropland which is 0.2% N_2O-N (mg) and also from manure managed from dairy farming which produces 4.6% CH4 (mg), that is calculated according to IPCC guideline [3]. This results are higher as compared to the study conducted in New Zealand that showed urine contribute 52% of N_2O fluxes [4].

Table 5. Means and standard deviations of key parameters.

Parameters	Mean	Stdev
Cows owned per household*	5.37	1.30
Urine produced per cow (l)	2.44	0.41
N available in urine(g/l)	14.28	12.90
Total N_2O emission (ug m-2 h-1)	1268.70	449.76
% emission factor	12.12	4.80

*Total households in kaptumo is 227000

Our results from the probability density plot show that our curve is heavily skewed on the negative (fig 17) this is brought about by total N_2O fluxes that is presented as uptake by soil are emission from the soil. This variability is brought about by differences in temperature and precipitation during sampling, changes is time of sampling etc.

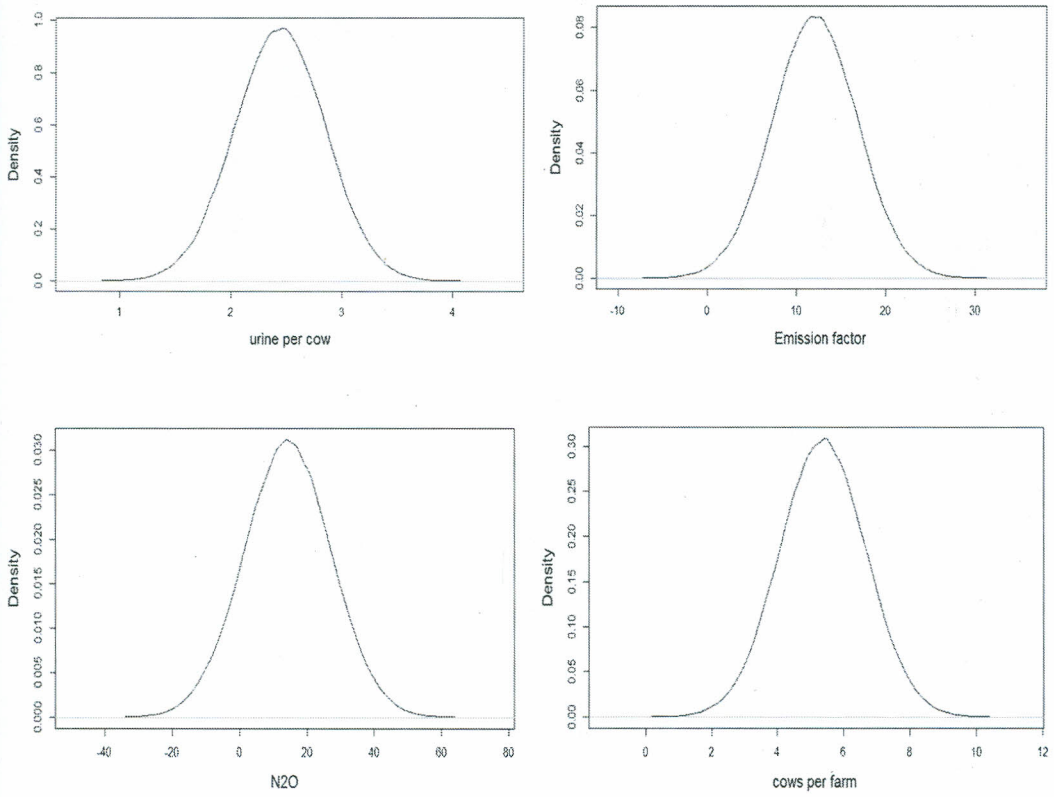


Figure 16: probability density function of each parameter

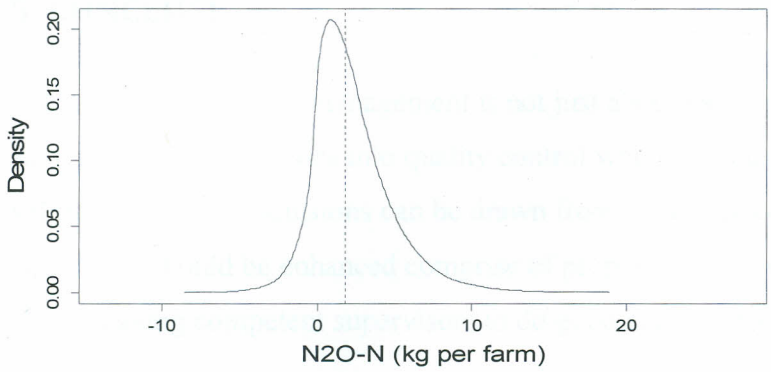


Figure 17 probability density function of N_20-N produced

5. CONCLUSIONS

It was evident that data management is not just about having the data brought from the field and analyzed. A lot more goes into quality control where thorough cleaning must be done so that valid results and conclusions can be drawn from the collected data. Some of the quality control points that should be enhanced comprise of proper training of field technicians and data entry clerks, having competent supervisors to do good supervisory work and make constant follow ups.

The data collection tools and forms should be made simple for ease of understanding by the respondent, short and concise to capture the key variables of interest. Also, validation rules should be set up in the data entry system to limit erroneous entries and double data entry system put in place as a quality control mechanism. Proper choice of the data entry software is of paramount consideration as this will help in checking errors and reduce the time spent on data entry. In the whole process, constant backstopping support should be provided to the entire team by trained personnel, preferably, a research method professional who has better understanding of the area under study and has the technical expertise in data management.

Organizations and research institutions needs for research methods support and capacity building should be set as a major priority. Majority of those who participate in researches that have poor results lack either the technical skills or expertise in designing data collection instruments or management of the data and data analysis.

Urine and dung on pasture fields increased GHG emission in the soil especially for N_2O and CH_4 this difference can be noted in the rain water and control treatments compared to other treatments. Rates of N_2O -urine emission of each block differed. Although in the experiment the weight of dung and volume of urine were constant, difference in the emission of gases in all blocks could only be attributed to difference in soil characteristics of the blocks, since the daily temperature and precipitation remained constant for all the blocks. This is also shown in [49] that variation in GHG emission are brought about by spatial and temporal variability. The

Intergovernmental Panel on Climate Change (IPCC) identified a default urine-N_2O emission factor of 2.0% which was not the case for our study where the urine emission factor in our experiment was higher.

The daily variation in emission was attributed to decomposition and depletion of mineral carbon and nitrogen applied by the dung and urine in the plots. The N substrate applied promotes emission of N_2O depending on the nitrification and denitrification rate of the soil microbes. Although the experiment results could not explain the sudden increase and decrease of GHG emission on some days such as 13^{th} and 14^{th} day, this could be attributed to changes in rainfall and temperature patterns during the experiment (see fig 13). Studies have shown that manure slurry contains easily available substrate for mineral C and N required for N_2O emission [50].

This study has presented a methodology that quantifies a number of uncertainties inherent in the generation of future impact of urine on N_2O emission information for kaptumo. The approach is Bayesian, in that it assumes that key parameters in our model have distributions that are normal (fig 16). The model is then run in a Monte-Carlo simulation that samples the parameter space as defined by the prior probabilities then produces a probability that incorporates all the parameters [34]. From this model we see that cattle urine on pastureland impact on total N_2O fluxes by 67% therefore cattle urine forms a major source of GHG emission in livestock keeping.

5.1 Recommendations and suggestions to other studies

- This study has revealed that pasture lands should not be neglected when quantifying greenhouse gas emissions from agricultural fields since they contribute significantly to total environmental emissions. From this study it is evident that urine and dung have contributed to increased emission of N_2O and CH_4 when compared to the control treatment. Most farmers leave their cattle to graze on fields, therefore we recommend more studies to quantify emission on pasture land when calculating a country`s greenhouse balance. It is also important to promote practices that utilize manure from the pasture fields to minimize emissions and thus promote mitigation of climate change.

- The use of data management plan in conducting research is important for getting reliable and timely results. From this study we therefore recommend that every study be equipped with a data management plan before execution of the research. This is better achieved by having a qualified research methods professional in all researches. The plan used for this study could be suitably adopted by any other research conducted on GHG emission quantification.

- The modelling process was useful in providing the impact of urine to N_2O emission in kaptumo that can be used by stakeholders to come up with more informative policies on climate change mitigation. We therefore recommend that other studies to consider using probabilistic approach in researches that have many uncertain parameters other than a deterministic approach, when statistically modelling research data. Lack of data of N produced from dung posed a challenge for this study to study the impact of dung to N_2O emission. This is an avenue for dung study and a merge of both study would provide answers of livestock keeping with regards to N_2O emission.

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