TAMK UNIVERSITY OF APPLIED SCIENCES
Environmental Engineering

Final thesis

Antti Hannila

EVALUATION OF URINE AS FERTILIZER FOR MAIZE AND CABBAGE PRODUCTION IN KALOKO VILLAGE, ZAMBIA

Supervisor Senior Lecturer Eeva-Liisa Viskari
Commissioned by The Global Dry Toilet Association of Finland (Käymäläseura Huussi Ry), Project Coordinator Sari Huuhtanen

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ABSTRACT

Inadequate sanitation is a major problem in the developing countries, Zambia being one of them. In 2006, the Global Dry Toilet Association of Finland (GDTF) and Kaloko Trust Zambia (KTZ) started the Dry Sanitation Improvement Programme for Zambia (ZASP) in Masaiti District on the Copperbelt Province of Zambia. The aim of the three-year project is to build dry toilets on the area, improve sanitation and to educate the local people on the benefits and opportunities offered by dry toilets. Not just being more hygienic than conventional pit latrines, commonly used throughout Africa, the dry toilets also offer the chance to utilize human excreta as fertilizer instead of classifying it as waste. The ever-increasing food demand and increasing fertilizer prices in the world are a problem as the population grows rapidly. The urine obtained from dry toilets can be used to increase the crop in the areas where people can not afford to purchase commercial fertilizers. The concept of ecological sanitation offers a solution to fight two major problems - hunger and poor hygiene. The objective of this study was to assess the effect of using human urine on maize and cabbage production and show its use in practice to locals, as a part of the ZASP project. The study was conducted in Luansobe school garden, in Kaloko on four 3 m x 10 m trial plots with the following treatments to control. One plot was treated with commercial fertilizer, one with human urine, one with cow dung and in one plot no crop nutrients were applied. Harvest determination was carried out by determining the average mass of cabbage heads and maize cobs from each trial plot and measuring the dimensions of maize cobs, after which comparisons were done. The study showed that human urine is a good potential fertilizer instead of artificial fertilizers. The growth of cabbage and maize was equally good with urine-fertilized crops than artificially fertilized crops. It is therefore recommended that urine would be utilized also in larger scale in the target area.

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TIIVISTELMÄ

Puutteellinen sanitaatio on vakava ongelma kehitysmaissa, joihin Sambia voidaan lukea. Vuonna 2006, Käymäläseura Huussi Ry sekä Kaloko Trust Zambia aloittivat yhdessä Sambian Kuivasanitaation Kehittämishankkeen (ZASP) Masaitin alueella, Copperbeltin maakunnassa, Sambian keskiosassa. Kolmivuotisen hankkeen tavoitteena on rakennuttaa projektialueelle kuivakäymälöitä, parantaa sanitaatiotilannetta ja valistaa paikallisia kuivakäymälöiden tarjoamista mahdollisuuksista ja hyödyistä. Sen lisäksi, että kuivakäymälät ovat hygieenisempiä kuin tavanomaiset kuoppakäymälät joita käytetään laajalti Afrikassa, tarjoavat ne myös mahdollisuuden hyödyntää ihmisjätöksiä sen sijaan, että ne luokiteltaisiin jätteeksi. Jatkuvasti kasvava ruoantarve, sekä kohoavat lannoitteiden hinnat muodostuvat ongelmaksi väestön kasvaessa kovaa vauhtia. Kuivakäymälöistä kerättyä virtsaa voidaan hyödyntää lannoitteena alueilla, joissa paikallisella väestöllä ei ole varaa kaupallisiin lannoitteisiin. Ekologinen sanitaatio tarjoaa ratkaisua kahteen vakavaan ongelmaan – nälänhätään sekä puutteelliseen sanitaatioon. Tämän tutkimuksen tavoitteena oli arvioida virtsan käyttöä lannoitteena maissin ja kaalin tuotannossa, sekä näyttää sen toimivuus käytännössä paikallisille ihmisille, osana ZASP-projektia. Tutkimus tehtiin Kalokon kylässä, Luansoben peruskoulun puutarhassa, neljällä testiviljelmällä. Viljelmillä käytettiin seuraavia kontrolleja: Yhdelle viljelmistä lisättiin keinolannoitetta, toiselle kuivakäymälöistä kerättyä virtsaa ja kolmannelle lehmänlantaa. Yhdelle viljelmistä ei lisätty lainkaan lannoitteita. Sadonmääritys tehtiin punnitsemalla kaalinpäiden ja maissintähkien keskimääräinen paino jokaiselta viljelmältä, sekä mittaamalla maissintähkien pituus ja leveys. Tämän jälkeen tuloksia eri viljelmiltä verrattiin keskenään. Tutkimus osoitti, että ihmisvirtsa on varteenotettava vaihtoehto keinolannoitteelle. Kaalin ja maissin kasvu havaittiin lähes yhtä tehokkaaksi sekä virtsalla, että keinolannoitteella käsiteltynä. Virtsan hyödyntämistä lannoitteena voidaan näin ollen suositella kohdealueella myös laajemmassa mittakaavassa.

FOREWORD

I am grateful to all the students, teachers and staff members at Luansobe school who aided me in preparing, fertilizing and watering the trial plots. I would especially like to thank the headmaster of the school, Mr. Hanyama Habanyama, for giving me lots of agricultural information in local conditions and helping me at field work.

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I am thankful for my thesis supervisor Mrs. Eeva-Liisa Viskari for giving me valuable information regarding the work and for Ms. Sari Huuhtanen for entrusting me the responsibility to undertake this project. I am indebted to Tampereen Ammattikorkeakoulu and Maa- ja Vesitekniikan tuki Ry for financial aid - and last but not least I would like to thank Toni-Petteri Paju for keeping me company during my whole stay in Zambia and my family and friends for supporting me with my studies since the beginning.

Tampere, June 2008

Antti Hannila

LIST OF ABBREVIATIONS

ZASP	Dry Sanitation Improvement Programme for Zambia
GDTF	Global Dry Toilet Association of Finland
KTZ	Kaloko Trust Zambia
NGO	Non Governmental Organization
WHO	World Health Organization
VIP	Ventilated Improved Latrine
ANOVA	Analysis of Variance
LSD	Least Significant Difference

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1 INTRODUCTION

According to different estimations, there are approximately 2.6-3 billion people without proper sanitation throughout the world. These people have to think on daily basis, how and where to relieve themselves in a safe and decent way. They have to be afraid of violence and direct health problems that the inadequate sanitation brings. If the people do not have proper sanitation, they are forced to make decisions that have an effect, not only on their personal life, but also to the society and environment. Insufficient sanitation is often connected to insufficient water supply, sewerage and poverty in general. By improving sanitation, welfare as a whole can be affected directly and indirectly. Annually, millions of people die because of inadequate sanitation. In the developed world, one toilet flush can consume equal amount of water that some inhabitants in the developing countries have in their disposal during the whole day. The question is not whether the people in the developing countries want to improve their sanitation or not, but they lack the information and means how to do something about it. Cultural beliefs and prejudices act an important role in sanitation and it is sometimes problematic to make things happen through ordinary hygiene and sanitation education. It is important that people understand the benefits of good hygiene and new methods are needed to deliver the message. Culturally acceptable, easily constructed and maintained toilets are needed. /1,4/

As the population grows more and more rapidly, so does the food demand. Many rural families in Africa cannot afford the increasing market price of commercial fertilizers, and thus they are continuously cropping with insufficient fertilization and depleting the soil of its natural mineral and organic constituents. This leads to low yields and poor food security. Correctly constructed and managed dry toilets enable us to separate the urine from faeces, offering a safe and affordable fertilizer throughout the world. Briefly put, ecological sanitation offers one solution for two major problems in developing countries. /9/

2 SANITATION IN DEVELOPING COUNTRIES

The availability of clean water should be considered as one of basic human needs and rights as clean water is the basis for human health. For people coming from developed countries, it is hard to understand the state of sanitation in third world countries and its extent without experiencing it personally. Clean, running water is often taken for granted and it is considered as an abundant resource. Warm showers and flushing toilets are part of everyday life for many, but for more than a half of the world's population, they are a luxury or something they might have heard of. At present, many people get their drinking water from open wells, often carrying it for several kilometres to their home. Some people use the bush, not far from the wells, to do their businesses. When the next rainfall comes, it flushes the pathogens from the excreta to the open wells spreading the diseases and parasites to a new host. Many of the people living in these conditions are not even aware of the risks that insufficient sanitation yields and the ones that have the knowledge, may not have the possibility to do anything to improve the situation. Cultural beliefs, religion and traditions are highly valued in many developing countries, where also the access to new innovations or information is usually quite restricted. People tend to continue using the same practices they have used before, unless they are told about and even more importantly, shown the use of better alternatives. According to an estimate by WHO, providing clean water and sufficient sanitation to everybody between 2005 – 2015, would cost annually 9 billion US dollars. It is a big sum, but when compared for example to annual alcohol and tobacco consumption only in Europe (155 billion USD), it does not sound so big after all. /1/

2.1 Present situation and different latrines in use

There is a vast variety of different types of latrines, but the most common solution around the world is still a pit latrine. It is basically a hole dug in the ground, but there are multiple variations of this latrine. The simplest ones are just plain open pits, but some of the improved versions are actually quite developed. Many households in the developing world cannot afford to build their own private latrine, so communities might have shared, better pit latrines with brick or concrete walls. Private household latrines are usually just surrounded with vegetation or plastic to offer some privacy. Ventilated improved pit latrines (VIP's) are, as the name implies, improved versions of pit latrines. The ventilation makes them more pleasant to use and if built properly, they should be odourless. The problem with pit latrines in general is the possibility of pathogens spreading to groundwater in case the water table is high. Neither is pit latrine a sustainable solution as it is removed once the pit is full.

Other types of solutions are pour-flush latrines and composting latrines, though these are not so commonly in use. In a pour-flush latrine, the excreta are flushed away from a U-shaped water lock to a pit with a small amount of water after use. This is also an odourless solution and works well in case there is enough water in disposal and climatic conditions are suitable, preventing the water in the pipe from freezing. Composting latrines are a step to a direction where the human excreta are utilized. In simplest versions, once a meter-deep pit is full of excreta, it is covered with some soil and couple of months later, a fruit tree can be planted in the pit. This is so called Arborloo. Another option is digging out the composed matter after approximately one year, and mix it with soil to improve its fertility in cultivation. After emptying the pit, it can be used again. /1/

2.2 Composting dry toilets

In principle a dry toilet means a latrine that is built on top of the ground. This makes it possible for them to be utilized in the areas where the water table is high or where there are runoffs to surface waters. Because the soil does not have to be dug when building a dry toilet, they are also useful in the areas where the soil is hard or difficult to dig in some other way. Conventional pit latrines have to be moved when the pit is full, but composting dry toilets have the advantage of being stationary, located close to the user. The main advantage of composting dry toilets lies in the utilization of the excreta though. Because of these properties, composting dry toilet is the ultimate solution when thinking in a sustainable manner. Nevertheless, the safe and efficient use of composting dry toilets requires training for the users and commitment to the utilization of excreta and is therefore not always the best solution in some areas where these can not be provided. /1/

In Figure 1 on page 11 a model of one type of composting dry toilet is presented. The base of the toilet is built on top of the ground from bricks, concrete or some other water impermeable material. The base should have two separate chambers, so that the excreta in one can be left to decompose for a minimum of one year as the other is in use. The composted faecal matter can be used to improve soil fertility by mixing it into the soil. In case that urine is separated, which is highly recommended, a bowl made from local materials can be used for the purpose. Anyway, the urine should be collected and stored in a sealed container if possible, to minimize the evaporation of nitrogen that acts as the main nutrient in fertilization. In case that the urine is planned to be utilized, the type of the urine collection vessel should be given some thought. The urine can be directed to the container via a channel or a hose. A separate urinal can also be built for men, leading the urine to the same collection vessel. A hole is made for the ventilation pipe on the floor of the toilet and hatches are installed on the back wall of the chambers for emptying purposes. Imagination and local materials can be used in building the toilets. Recommended colour for the interior is blue as it repels flies. /1/

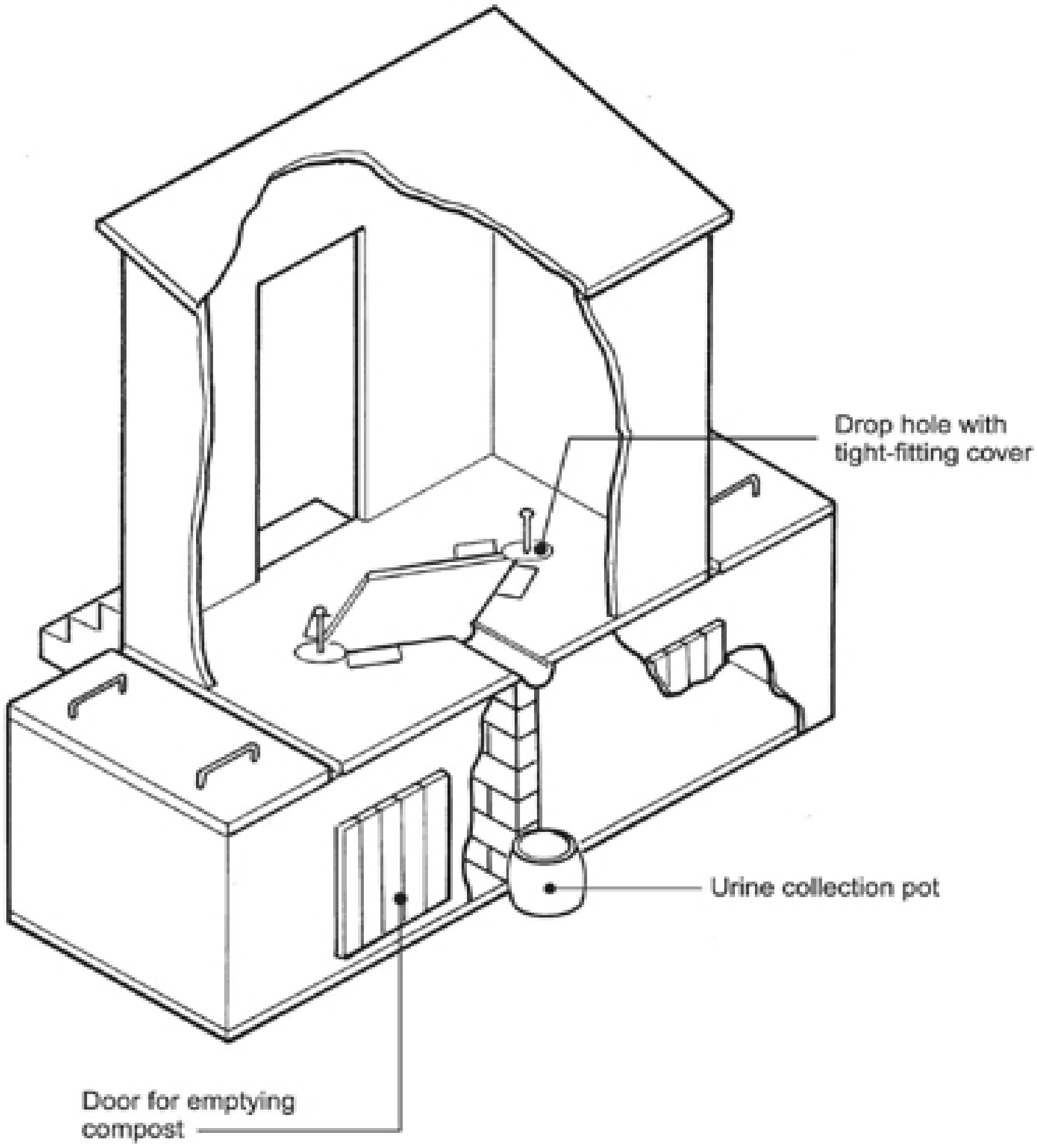

Figure 1. A model of one type of composting dry toilet. /7/

There are many factors favouring the separation of urine from faeces and utilizing it. This separation makes handling the excreta easier and it reduces the load created by it. The separation reduces the volume of material handled, the odour problems and the runoffs of nutrients and pathogens to soil, ground water and surface waters. The excrement is also easier and more comfortable to handle when it is dry and contains less pathogens than the wet mixture of urine and faeces. Most importantly, urine is an excellent and free nutrient solution. When separating the urine from faeces, the nutritional value of urine is recovered and can be utilized. If the separation is not done, its nutritional value is wasted due to evaporation and runoffs and the nutrients may eventually end up in water bodies causing problems like eutrophication. /1/

2.3 Utilisation of latrine waste

The annual amount of excrement (urine and faecal matter) from a single person contains approximately same amount of nutrients that are required to grow grain for single person's annual need. Basically, this means that we all produce enough fertilizer to cover our own food requirements. The figures can be seen in Table 1. /1/

Table 1. The amount of nutrients in human excrement (person/year) in western diet. /1/

The most important nutrients	Urine (500L)	Solid excrement (50 L)	Total	Nutrients required to produce 250kg of grain
Nitrogen (N)	5.6 kg	0.09kg	5.7kg	5.6kg
Phosphorus (P)	0.4 kg	0.19kg	0.6kg	0.7kg
Potassium (K)	1.0 kg	0.17kg	1.2kg	1.2kg
Total	7.0kg	0.45kg	7.5kg	7.5kg

As can be seen from the table above, most of the nutrients in human excrement are in urine, which makes it an excellent fertilizer. It is most beneficial for soil fertility to use both, urine and faeces, but not necessarily during the same year in the same area. As urine contains most of the nutrients in human excrement and it is safer to use than faeces, the following chapter concentrates on urine and its properties as a fertilizer. /2/

2.3.1 Urine as a fertilizer

Even though composting dry toilets have been in use in Finland for decades or even centuries at summer cottages, traditionally the urine has not been separated. In Finland, the utilization of urine is still quite small scale, but for example in China, it has been used for centuries also in larger scale. In Europe, the effectiveness of urine as a fertilizer has been studied during recent years in Sweden, and it is used commercially.

In many ways, urine is an excellent fertilizer if stored and applied properly. The most important nutrient in fertilizing - nitrogen is mostly in form of urea in urine. Phosphorus is as superphosphate and potassium in ionic form, easily available for the plants. Urine also contains micronutrients in a balanced way. From 60 to 70% of the plant nutrients produced for human consumption in agriculture end up in human excreta. Actually 70-90% of nutrients in human excrement are in urine and it contains hardly any microbes, whereas faecal matter contains the rest of the nutrients, but also a lot of bacteria and pathogens. This is the reason why urine should be separated from faecal matter at the point of collection. It should be noticed though, that for example cystitis, typhoid fever, schistosomiasis or leptospirosis infected people can have pathogens in their urine. The following bacteria have been found in urine: *Leptospira interrogans*, *Salmonella typhi*, *Salmonella paratyphi* and *Schistosoma haematobium*. Even if bacteria are found from urine they usually die quite fast and do not pose a threat in further utilisation of urine. Nevertheless, the urine should be stored before application especially if it is known that diseased people have been using the latrine where the urine was collected from. More importantly, the urine should be stored because there is a substantial risk of cross contamination with faeces. There are different guidelines on the storing period before applying it on the crop, but in general the recommendations are from 3 to 6 months which is enough for the pH of urine to increase and cause the pathogens to die. /1,2/

It can be estimated that one liter of urine contains 3-7 grams of nitrogen (N). In fresh urine, 85-92% of nitrogen is in the form of urea ($CO(NH_2)_2$). A reaction takes place in the stored urine, converting the urea to an ammonium-form, which is easily soluble and usable by the plants. The portion of this type of ammoniumnitrogen is large in urine compared to other organic fertilizers. However, studies have shown that the nitrogen in urine is not as efficient as the nitrogen in artificial fertilizers. This is due to fact that the efficiency of ammoniumnitrogen-fertilizers (e.g urine) is somewhat weaker compared to artificial nitrate-fertilizers. More importantly, the artificial fertilizer’s placement next to the seed improves the fertilizing effect when comparing to urine that is spread on the soil surface. The placement of fertilizer within the reach of the root system affects the availability of the nutrients especially in the beginning of the plant growth. Human urine also contains more salt than animal urine, so it should not be used constantly or in large doses for chlorine-sensitive plants. Nevertheless, urine is an excellent fertilizer for most plants in conditions where artificial fertilizer is not available or affordable as it is in small scale use in private gardens. /2,12/

2.3.2 Application of urine

To take full advantage of the fertilizing capability of urine, there are some things to take into consideration in storing and applying it. As urine should be stored before the application, the container where it is collected and stored should be properly chosen for the purpose. Careless handling and storing of the urine can cause even 90% loss in the nitrogen as it tends to evaporate in the form of ammonia. If the nitrogen evaporates, the fertilizing value of urine is lost. This is why the container where the urine is stored, should be sealed. In the container, a layer of low nitrogen content is formed on the surface, slowing down the evaporation of ammonia. Therefore the container should be moved or shaken only when needed. Some of the nutrients form sediment on the bottom though, so the container can and should be shaken just before applying the urine. /12/

Amount of urine applied depends on the plants in question and local conditions. If no local recommendations are available, a rule of thumb is to apply the urine produced during one day (24 hours) by a single person to one square meter of land per growing season. Urine can be applied neat or diluted. In case the urine is diluted, separate irrigation after spreading is not needed. Used dilutions are for example 3:1 (one liter of urine to three liters of water) and 10:1 (one liter of urine to ten liters of water). To avoid smells, evaporation of nitrogen and foliar burns, urine should be applied close or into the soil and incorporated as quickly as possible (see figure 4 on page 18). If possible, the application should be timed so that the plant can take advantage of all the available nitrogen before it evaporates or washes away. The best time to apply the urine is before sowing takes place, so that the urine is covered with soil and ready to be used by plants in the beginning of their growth. The weather should be cool, calm and moist to minimize the evaporation of nitrogen. Different application rates are also in use. The urine can be applied only once prior to sowing or in several portions from prior to sowing up until two thirds of the period between sowing and harvest. /1,2,12/

Figure 2. Applying the urine to maize. After the urine is poured, it is covered with soil to minimize evaporation. (Photo by Teemu Toivola)

3 DRY SANITATION IMPROVEMENT PROGRAMME FOR ZAMBIA (ZASP)

The three-year ZASP project was initiated in 2006 by the Global Dry Toilet Association of Finland in partnership with a local NGO, Kaloko Trust Zambia in order to create a programme that develops ecological sanitation in Africa and Asia. The Global Dry Toilet Association of Finland (GDTF) aims to improve global hygiene by promoting dry toilets and ecological sanitation. It contributes to global efforts towards reaching one part of the Millennium development goal No. 7: *To halve the population of people suffering from lack of water and sanitation by the year 2015*. The local partner, Kaloko Trust Zambia (KTZ) is an organization concentrating on rural development projects, receiving funding through charity in the United Kingdom. The organization is based in Masaiti district on the Copperbelt province of Zambia. KTZ is working with 11 local communities, covering an area of 26 000 hectares. /1,4/

3.1 Objectives

In most parts of Zambian countryside, the sanitation is insufficient. Pit latrines and open pits are in common use while parts of the population do not use any kind of toilets, performing their business in the bushes. The ZASP project aims to improve the state of sanitation in Luansobe-Luankuni environmental programme area, having altogether approximately 10 000 inhabitants. The main objective is to affect the awareness of the people about the importance of sanitation and hygiene and to increase their interest in the subject. In practice, building dry toilets to schools, medical clinics and communities and educating people on their use plays an important part in the project. It is hoped that the inhabitants of the area are inspired by the project, leading to the spreading of functional sanitation throughout the villages around the project area. One of the main goals is also to encourage people to use the toilet waste as a fertilizer, improving the cultivation conditions in the area. Many of the people in the area have prejudices towards dry toilets and human excreta and it is desirable to get rid of these. The project also serves as a pilot to other projects of GDTF and its sanitation programme in developing countries. /4/

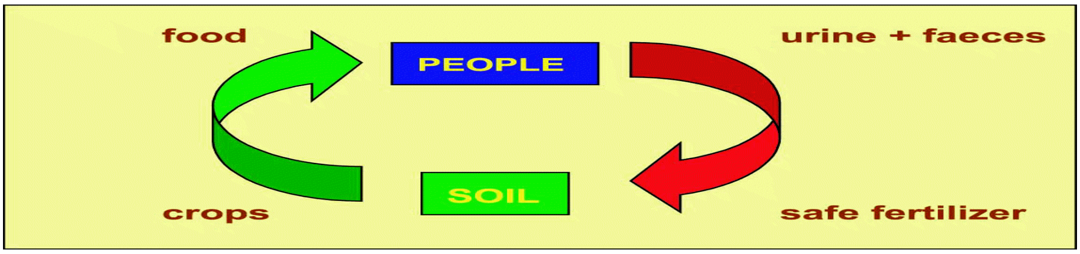

Figure 3. Closing the loop on sanitation. /8/

3.2 Project area

Luansobe-Luankuni environmental programme area is located in Masaiti district on the Copperbelt province of Zambia. Copperbelt is a densely populated industrial province sharing a border with The Democratic Republic of Congo and having most of Zambia’s numerous copper mines. ZASP project is centred in the village of Kaloko, having Luansobe-basic school of 970 students, a church and a health clinic. The 11 communities surrounding Kaloko that are involved in the project, have approximately 10 000 inhabitants. The location of the project area in Zambia can be seen in Figure 2. /4/

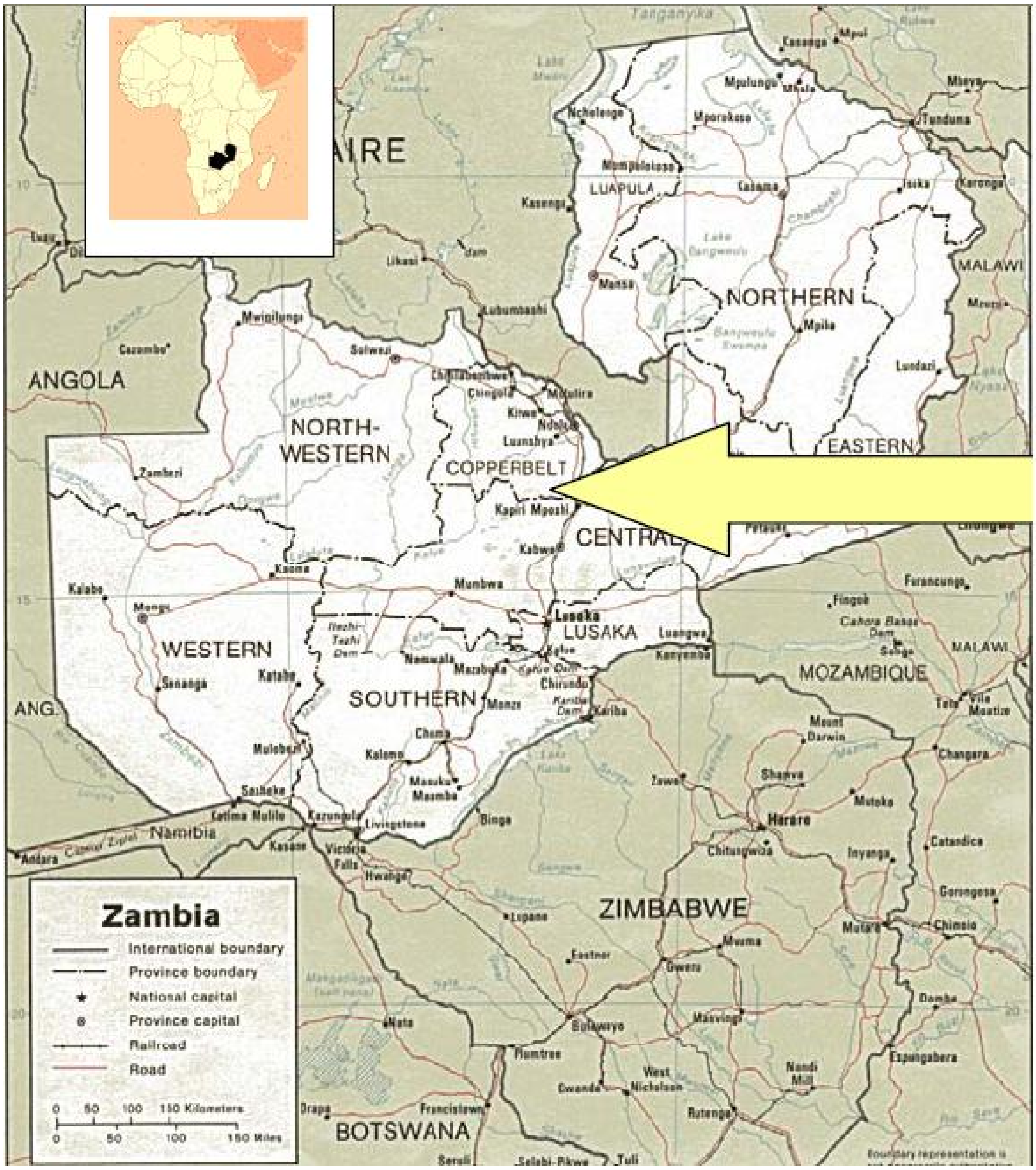

Figure 4. Map of Zambia and the location of ZASP project area /4/

3.3 Aim of the study

This study was done as a part of the ZASP project to test and demonstrate the value of urine as fertilizer. The urine used in the study was collected from the dry toilets built in the ZASP project. Studies of urine as a fertilizer have been done before with positive outcome, but the local conditions like climate and soil characteristics always affect the results, so the efficiency in these conditions was to be clarified. More importantly, the aim was to convince the local people that urine is a safe and efficient fertilizer by showing its use in practice. Local people's attitudes towards dry toilets and dealing with human excreta before the project were mostly negative or indifferent because of stigmatic status of handling human waste. One of the main objectives was to shift this trend. Showing previous studies on the subject to the people does not deliver the message the same way than performing the actual study amidst the people, allowing the people to see the results with their own eyes. This also teaches the people on how to utilize the urine better than giving lectures or literature on it. In the long run, it is desired that the local people would implement the lessons learned from this study and spread the knowledge forward.

4 CASE ZASP: KALOKO, ZAMBIA

4.1 Methodology

The study was carried out during a three-month period in February-May 2008. The beginning of the study was conducted during the wet season, the plants being rainfed, but towards the end of the growing season, the plants had to be watered frequently. The two species used in the experiment were flour maize (*Zea mays amylacea)* and riana-variety cabbage (*Brassica oleracea capitata*), both having the suggestive growing period of 90 days. These species were chosen because they are both widely used and play important roles in people's diet in the part of Africa where the study took place. The area used for the experiment was a fenced garden of Luansobe basic school. Originally, a different - larger test area was meant to be used in the experiment, but because it had no fence around it and one could not be obtained, the experiment had to be done in a smaller area.

Figure 5. Pupils from Luansobe-school preparing the garden for the study.

Even though the main objective of the experiment was to test only urine as a fertilizer and more importantly, show its use in practice to the local people, a comparison was done with other fertilizers to get a better idea of its effectiveness. The resources available in the study were rather limited, as I conducted the study alone with small budget and basic tools in ascetic circumstances. This served the objective well though as the local people for whose benefit this study was conducted do not have sophisticated tools in use either. It was not possible to measure the nutrient contents in different fertilizers, so nitrogen was chosen to be the one to be used in the comparison as its quantity could be best estimated in urine and artificial fertilizer. The comparison was done mainly between urine and artificial fertilizer as in the other two plots with cow dung and no applied crop nutrients, no measurements of nitrogen content were made.

4.1.1 Control plots

Four similar plots with different controls were used in the experiment. The controls used in the plots were urine, cow dung and artificial fertilizer respectively. In one of the plots, no crop nutrients were added. Each test plot had the size of 30m^2 (3m x 10m) consisting of 3 separate beds (see Figure 6). In one bed, two rows of maize were planted with intervals of 30 centimeters and in two of the beds, the cabbages were planted with same intervals. The cabbages were planted as young seedlings, but the maize was sown as seeds. Some of the maize seeds were already rotten at the time of purchase, so the ones to be planted were handpicked. There were also other difficulties with the garden and seedlings later on in the study, affecting the development of the crops. These are presented in more detail in chapter 5.

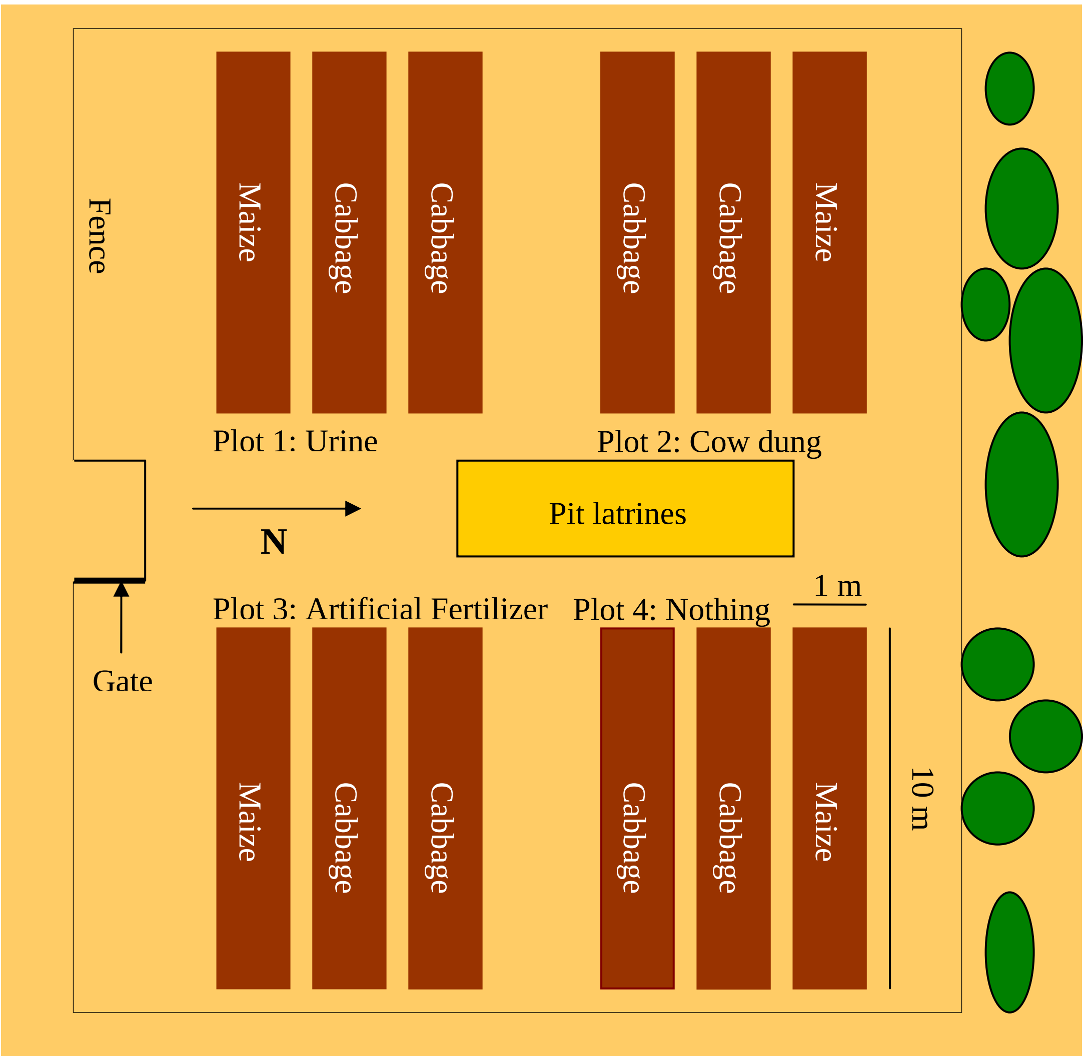

Figure 6. A drawing of Luansobe-school garden where the experiment took place.

Figure 7. Luansobe-school garden. Maize on plot 3, fertilized with artificial fertilizer in the foreground of the picture. Plot 1, fertilized with urine on the background.

4.1.1.1 Plot 1: Urine

The urine used in the experiment was collected initially from a single dry toilet built in ZASP-project, but later on during the study another one was finished and it was used for collection as well. Since the beginning, there were difficulties getting enough urine for the experiment. It was estimated that the urine used in the experiment had 3 grams of nitrogen per litre. The estimation was based on the low amount of protein on local people's diet. The original plan was to use a reference value of 175 kilograms of nitrogen per hectare, but because of difficulties getting enough urine, eventually 100 kg/ha was used. In relation to the size of the test plot, this meant 100 litres of urine or 300 grams of nitrogen. The urine was applied in five separate portions during the first two months of the growing season. It was supposed to be applied in five equal portions of 20 litres, but because not enough urine was always in store at the time of application, the size of the portions were not always the same. Nevertheless, the total amount of urine added to the plot eventually was 100 liters. The urine was diluted with a ratio of 3:1 (three liters of water to one liter of urine). The diluted solution was applied evenly to the base of all plants in the bed with a watering can, after which it was covered with soil to minimize evaporation. /6/

4.1.1.2 Plot 2: Cow dung

On the second test plot, cow dung was used as a crop nutrient. Six wheelbarrows (180 kilograms) of cow dung were mixed with the soil in the three beds just before sowing. Because of our hasty schedule, composted dry dung could not be obtained. Fresh dung with a relatively large organic content had to be used. It was not possible to measure the nitrogen content in the dung, so this plot was used mainly to see if it had any kind of fertilizing effect. Later on it was found out, that cow dung normally used for fertilization contains approximately 0.25-0.4% nitrogen. If 0.25% reference value was used, the nitrogen applied would have been 450 grams, which equals 150kg/ha. It has to be noticed though, that the dung was not composted and the nitrogen may not have been in the form usable by plants. /10/

4.1.1.3 Plot 3: Artifical fertilizer

Compound D (10% Nitrogen, 20% Phosphorus, 10% Potassium and 6% Sulphur) was chosen as the artificial fertilizer to be used in the experiment. It is widely used in Africa as a basal fertilizer. Originally, ammonium nitrate was planned to be used as a top dressing, but because the compound D had already been applied and there was no more urine left to be applied, ammonium nitrate was not added to keep the comparison balanced. Compound D was applied in two portions during the growing season. In the first portion (one week after the sowing) 1.6 kilograms of compound D was applied, having 160 grams of nitrogen. The second portion of 1.4 kilograms (140g N) was applied in the middle of the growing season. The total amount of 300 grams of nitrogen applied was therefore estimated to be equal to the plot with urine. The amount of 300 grams in the test plot is relative to 100kg/ha. The compound D granules were evenly applied to the base of the plants.

4.1.1.4 Plot 4: No added crop nutrients

In this control plot, maize and cabbage were planted and allowed to grow without any crop nutrients applied. Otherwise, the plot was weeded, watered and looked after as the other plots.

4.2 Growth monitoring

The growth of the crops was monitored during the growing season and it was measured twice. The first measurement was done 30 days after the sowing, at the end of first trimester of growing season. The second measurement was done at the midpoint of growing season, after 45 days. The measurements were done with a tape measure, giving suggestive results that could be used in comparison of different test plots. As we could not afford to remove the plants at this stage, because of not having enough of them, we did not measure the weight of the plants. The weight was only measured in the end of the study. The cabbage growth was monitored by measuring the width of the largest leaf in ten cabbage heads. The maize growth was monitored by measuring the length of the plant from ground to the tip of the longest leaf in ten maize plants. With both, maize and cabbage, the average was calculated. The tables with growth monitoring measurements can be found in appendix 1.

4.3 Measuring the final results

In the final measurements, five randomly chosen cabbages and maize cobs were removed from each plot and their mass weighed. From these results, the mean values were calculated. Because of multiple problems that occurred during the study, we did not get a lot of mature plants, resulting in low sample size (n=5). Furthermore, from plot 2 (cow dung), we managed to get only two maize cobs, giving even lower sample size in that specific plot. From maize cobs, also length and width were measured. A simple manual balance was used in the weight measurements, whereas the dimensions of maize cobs were measured with a tape measure.

The results were supposed to be measured 90 days after sowing, but because we managed to launch the study later than originally expected and I had to leave the project area, they had to be measured 12 days ahead of schedule.

Figure 8. Weighing the cabbages.

5 RESULTS

Cutting approximately two weeks from the growing period meant that the size of cabbage and maize remained somewhat smaller than after a full growing season, making it hard to compare the results with previous similar studies. Nevertheless, as the main objective of the study was to demonstrate the fertilizing effect of urine and compare it to the other forms of fertilizers, the shorter growing season had minor effect on it.

5.1 Cabbage

Cabbage did quite well in all of the test plots, even though difference could be seen between different controls in use. When the cabbage was harvested, it was noticeable that the growing season was still ongoing. Cabbages are supposed to form a round head and even though most of the cabbage had started forming a ball in the middle, most of the outer leaves were still open. There was a lot variation in the size of cabbages not only between the different plots, but also within the plots. From the results, it can be seen that artificial fertilizer gave the best results with an average mass of 801.7 grams, but the results obtained with urine were good as well with an average mass of 673.2 grams. There was no statistical difference between these treatments, therefore the results from urine can be considered as good as from artificial fertilizer. The results can be seen below in Table 2. A graphical presentation of the results can be seen in Figure 9, giving a better idea of the differences between the different controls.

Table 2. Cabbage head mass in grams with different fertilizers. Results with different letters are significantly different. (ANOVA, LSD, $p<0.05$)

Cabbage mass in grams							
Plant number:	**1**	**2**	**3**	**4**	**5**	**Average**	**Standard deviation**
Plot 1: Urine	776,50	730,00	587,50	313,00	959,00	673,20 **ab**	241,18
Plot 2: Cow dung	168,00	646,00	370,00	850,50	380,50	483,00 **ab**	266,52
Plot 3: Artificial Fertilizer	511,50	224,50	1483,00	951,00	838,50	801,70 **a**	475,71
Plot 4: N/A	221,00	467,00	226,00	169,50	639,50	344,60 **b**	201,22

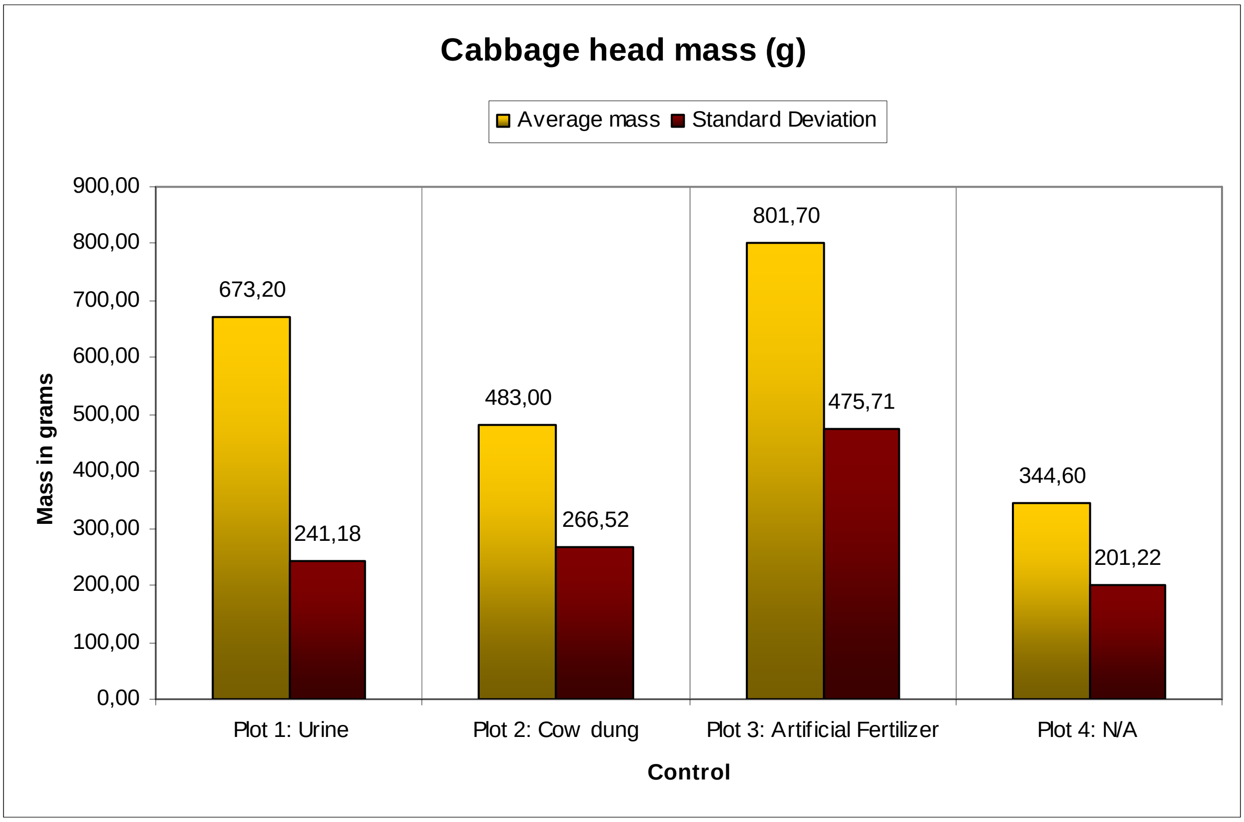

Figure 9. Cabbage mass (g) in different fertilizer treatments.

5.2 Maize

With maize, the yield remained relatively low in all the test plots and a proper comparison was harder to establish. There are various reasons that might have had an effect on the crops, leading to lower yield. As the soil was not studied before the experiment, it is hard to tell if the characteristics of the soil were unsuitable for maize production. Clear signs of nutrient deficiencies were found though, suggesting the soil was not fertile enough. Many of the leaves of the plants on all test plots had yellow stripes indicating magnesium deficiency (see figure 10).

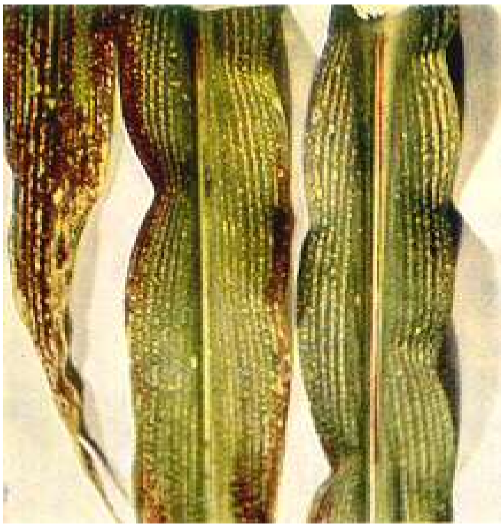

Figure 10. Maize suffering from magnesium deficiency. /11/

Compound D and urine gave somewhat equal results, whereas the results from the other two controls stayed far behind. The margin between different controls was far more distinctive than with cabbage, but no matter what fertilizer was used, the size of the maize cobs remained surprisingly small, most likely because of too short growing season. Different properties were studied and measured from maize cobs, namely weight, length and width. This has hoped to give a wider perspective to the comparison and possibly shed some light on why the yield remained so low with all the different controls. The results of maize cob measurements can be found in the following tables 3,4 and 5 and graphical presentations in the figures 4,5 and 6.

Table 3. Maize cob mass in grams with different fertilizers. Results with different letters are significantly different. (ANOVA, LSD, p<0.05)

Maize cob mass in grams							
Plant number:	**1**	**2**	**3**	**4**	**5**	**Average**	**Standard deviation**
Plot 1: Urine	99,00	72,50	119,50	130,00	41,50	92,50 **a**	35,98
Plot 2: Cow dung	11,50	10,00				10,75 **b**	1,06
Plot 3: Artificial Fertilizer	204,50	62,00	58,00	178,00	119,00	124,30 **a**	66,37
Plot 4: N/A	10,50	13,00	25,00	13,50	8,50	14,10 **b**	6,42

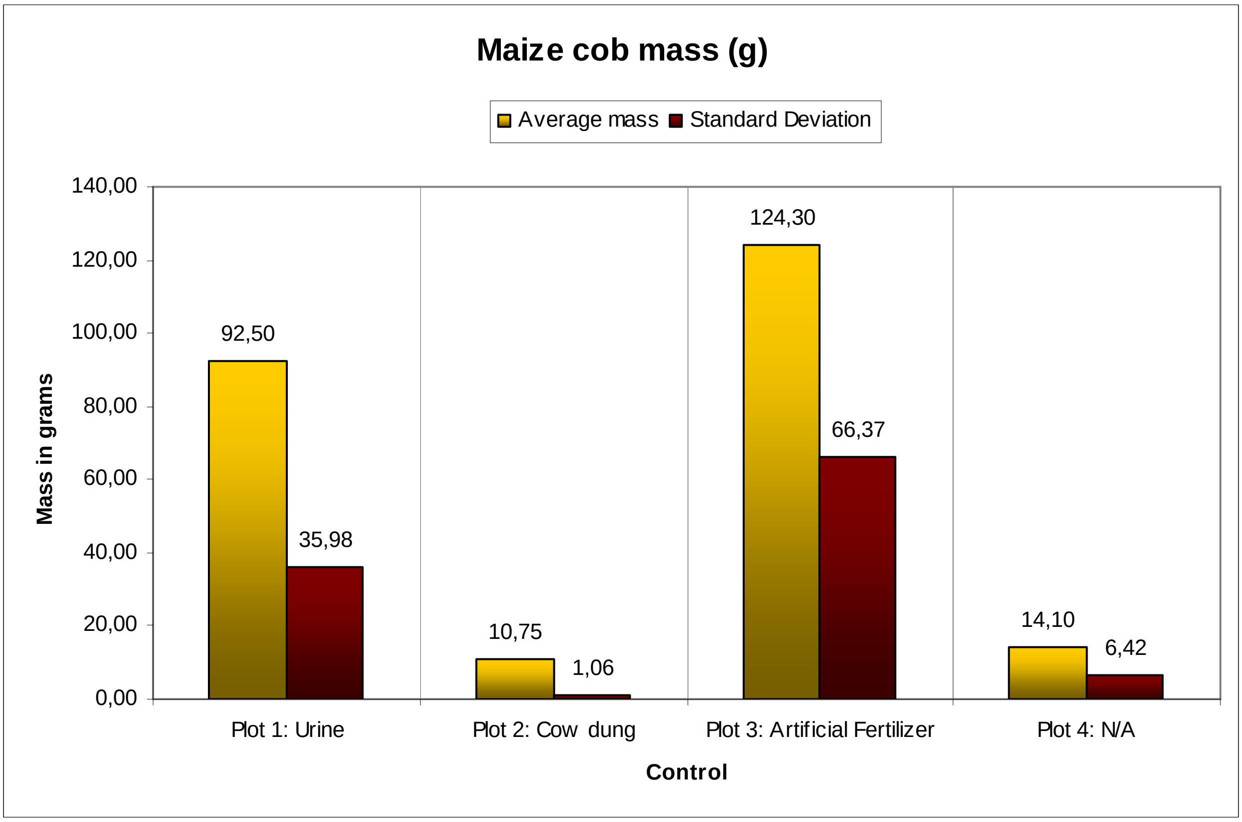

Figure 11. Maize cob mass in different fertilizer treatments.

Table 4. Maize cob length in centimeters with different fertilizers. Results with different letters are significantly different. (ANOVA, LSD, $p<0.05$)

Maize cob length (cm)							
Plant number:	**1**	**2**	**3**	**4**	**5**	**Average**	**Standard Deviation**
Plot 1: Urine	17,0	15,5	17,0	18,0	13,5	16,2 **a**	1,75
Plot 2: Cow dung	8,5	8,0				8,3 **b**	0,35
Plot 3: Artificial Fertilizer	20,0	15,0	17,0	19,0	16,5	17,5 **a**	2,00
Plot 4: N/A	7,5	8,0	10,0	9,0	8,0	8,5 **b**	1,00

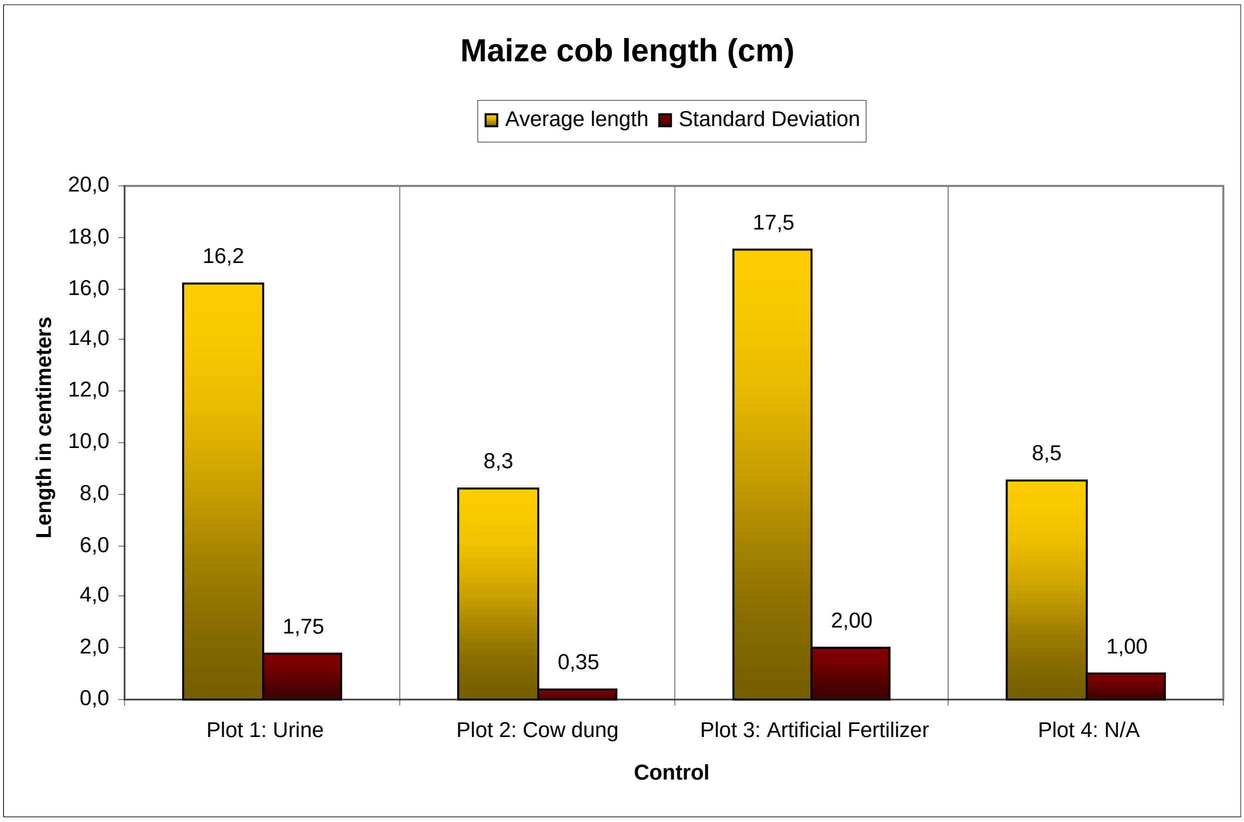

Figure 12. Maize cob length in different fertilizer treatments.

Table 5. Maize cob width in centimeters with different fertilizers. Results with different letters are significantly different. (ANOVA, LSD, p<0.05)

Maize cob width (cm)							
Plant number:	**1**	**2**	**3**	**4**	**5**	**Average**	**Standard Deviation**
Plot 1: Urine	3,5	3,0	4,0	4,0	2,5	3,4 **a**	0,65
Plot 2: Cow dung	1,0	1,5				1,3 **b**	0,35
Plot 3: Artificial Fertilizer	5,0	3,0	3,0	5,0	4,0	4,0 **a**	1,00
Plot 4: N/A	1,5	1,5	2,5	2,0	1,5	1,8 **b**	0,45

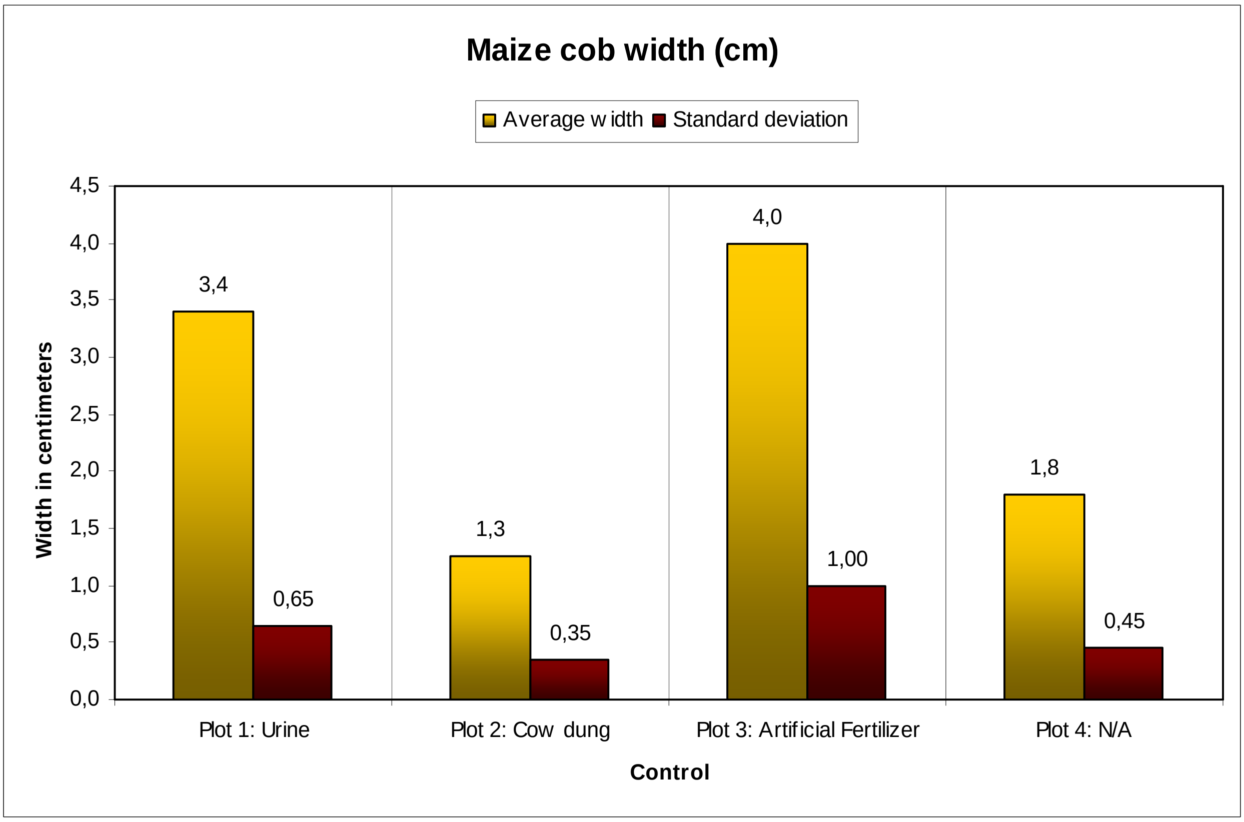

Figure 13. Maize cob width in different fertilizer treatments.

6 DISCUSSION

6.1 Outcome

The results of this study were better than anticipated. Because of multiple setbacks and problems faced during the experiment, directly and indirectly affecting the results, the expectations were not high. The problems experienced are looked through more thoroughly in chapter 6.2. It can be seen from the results that urine is comparable to artificial fertilizer in terms of mass growth of cabbage and maize. There are various possible explanations why the yield from the plot fertilized with urine remained somewhat lower than the one from the plot where compound D was used. The reasons most obviously affecting the results were the insufficient amount of urine that was possible to be used, and the nutrient loss because of improper storing of the urine in the beginning. It also has to be remembered that the urine used in the experiment was only estimated to contain 3 grams of nitrogen per liter, whereas with compound D the exact amount was known. In reality the urine might have contained significantly less nitrogen than estimated. Nevertheless, even the plot fertilized with compound D gave reasonably low yield especially with maize, indicating the soil fertility was not good in the test site or something was done wrong during the course of the study. The latter is not probable as locals who have been cultivating in the area for decades were counseling me during the study. It is known that the amount of nutrients applied, namely nitrogen, was substantially lower than recommended, but as no more urine was available, nothing could be done. As the soil was not studied before the experiment, it is hard to specify if there was lack of some important nutrients and if so, what those nutrients were, or if the salinity of the soil was too high or characteristics of the soil in some other way poor for cultivation.

Cabbage showed no external signs of any kind of nutrient deficiency, but remained smaller than the species normally should. There was a noticeable difference in the average size of cabbage from different plots, but also a lot of variations within the plots. The biggest cabbage weighed 1483 grams (plot 3: artificial fertilizer) as the smallest one was only 168 grams (plot 2: cow dung). All of the cabbage seedlings planted did not survive and reach the mature phase, but the percentage was still rather good considering the setbacks faced.

The tests attained with maize were not as satisfactory as with cabbage. Even though comparison to some extent was possible to be done, it should only be considered suggestive. The maize suffered substantially from nutrient deficiencies, remaining small and not producing cobs as it should. The yellow streaks on most of the leaves result most likely from magnesium deficiency, but without further research, it is hard to be sure. According to the headmaster of Luansobe-school, Mr. Hanyama Habanyama, the soil is also poor in boron (B) of which deficiency affects the uptake of many elements by plants. Surprising is that only two maize cobs were possible to be collected from the plot fertilized with cow dung and also the plants seemed to remain smaller than in any of the other plots. One explanation for this is the lack of sunshine, as the plot received least sun. The foliage of the trees north of the garden kept the plot mostly shady during midday. This did not seem to have any effect on cabbage though. The stems of maize in the plot fertilized with compound D were clearly taller than in any of the others, reaching two meters in height, whereas on plots 2 (cow dung) and 4 (nothing) the stems barely reached the height of one meter. The ones fertilized with urine remained reasonably small in size, but produced large cobs in relation to the plant size. The dimensions of cobs collected from all the plots were rather small, but the ones collected from plots 2 (cow dung) and 4 (nothing) were ridiculously small, weighing less than 20 grams and not even reaching the length of 10 centimeters. Even the larger cobs collected from plots 1 (urine) and (compound D) seemed immature though.

6.2 Problems faced during the study

In the course of this study, various problems were faced and several setbacks experienced. Some of these were directly affecting the results of fertilizing tests, but most of them caused indirect consequences. As the objective was to test urine as fertilizer, the problems most directly affecting the results were the difficulties in the collection, storing and application of urine. Before I entered the project area, I was under the impression that urine had been collected and stored for months and there was plenty of it available for use. In reality, only one 20 liter container of urine was in store and it was not sealed properly, allowing the nitrogen to evaporate, thus reducing the fertilizing value. Basically the collection had to be started from the beginning with the schedule already being tight. The collection proved to be harder than expected. At the beginning of the study, there was only one finished dry toilet in Kaloko, where the urine was collected. The problem was not that there were not enough people in Kaloko who would have had the possibility to use the latrine, but the will to do so was missing. During a two-month period, only 100 liters of urine was obtained and applied to the garden, even though only Luansobe-school itself has almost one thousand pupils. These pupils had taken part in the sanitation trainings earlier during the project, having the knowledge on how to use the dry toilet. Even so, I was told that the pupils do not use the dry toilet either because they do not know how to do it, or because the dry toilet is situated further away from the school than the other latrines. The motivation of the villagers to use the dry toilet was also poor, leading to insufficient amounts of urine available for the study.

Transportation turned out to be a big problem not only in my part of the project, but also in the project as a whole. Kaloko is quite isolated, situated far away from main road. The project did not have a car at its disposal and transportation to the nearest city could be arranged only once per week, making it hard to acquire the required materials hastily. From time to time, even when transportation was available, it was hard to find adequate equipment to conduct scientific research. The equipment purchased locally was somewhat simple to perform accurate measurements.

Some of the cabbage seedlings were eaten by cows before planting and as mentioned, portion of maize seeds were rotten on purchase and had to be handpicked. Initially the school garden gate and fence were broken, but were soon fixed to keep the animals out. The latrines for teachers, situated in the garden turned out to be a problem though. Even though the gate was fixed, it was often left open by the teachers or other school staff using the latrines in the garden. Therefore, pigs and chickens from nearby farms entered the garden on several occasions, feeding on the seedlings and turning the soil around. Weather also played a significant role especially in urine application. For instance, on 10th of March, there was a heavy rainstorm soon after applying the urine, likely flushing out some of the urine from the beds. All in all, the workload was quite heavy for one person to keep an eye on things round the clock.

7 CONCLUSIONS AND FUTURE PROSPECTS

The study can be considered successful, even though it will take time to see how the locals begin to implement what they have learned in the course of this project. The results from the fertilizing tests were not as good as desired, but sufficient to demonstrate the potential of urine as a fertilizer to the locals, as part of the ZASP-programme. Many of the local people did not have any kind of knowledge of urine’s potential as a fertilizer before the programme was initiated.

Cultural and religious traditions are strong in Zambia and Africa in general, thus making it challenging to import ideas and knowledge from western countries. The dry toilet technology has been brought to Zambia to prevent diseases from spreading and to offer fertilizer that is affordable. Dry toilets and utilizing human waste as fertilizer cross cultural boundaries, therefore being something the local people are not used to. Even though most of the local people know the importance of sanitation, they might have trouble adapting to something so different. Handling of human waste has a stigmatic status and some people relate it to Satanism. For many people cultural traditions are more important than improving sanitation. When interviewing the local people, it was also noticed that some fail to understand the objective of the project and that it is executed for their benefit. Many of the locals are not motivated or willing to do anything unless they are paid, which is a major problem in this kind of project. The local people need to be motivated by convincing them that they are the ones who will benefit from the project also in the long run. /5/

When implementing a project of this nature to a country of significantly different culture, it takes a lot of time to achieve results. Perseverance is required to reach the objective. Three-year time frame might be too short for this project and it is good that there is a plan to continue the project if funding can be arranged. A lot of dry toilets have been built in the project area, but I find it vital to further improve people’s knowledge on the use of them by arranging training.

This study and fertilizing tests in Kaloko were just small parts of the whole project but they are hoped to take the project forward as a whole. This was the first time the urine collected from the dry toilets built in the project was utilized. New toilets have been built in the neighboring communities and more urine tests are being planned and conducted by the locals. It remains to be seen how things develop and what kind of results are achieved when the locals have matters in their own hands.

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APPENDICES

Appendix 1. Growth monitoring

Date 12.3 (after 30 days) Plant	Plot 1 (Urine)	Plot 2 (Cow dung)	Plot 3 (Artificial fertilizer)	Plot 4 (Nothing)
Maize (length from the ground to leaf tip in cm):	54	50	87	56
	47	48	91	60
	46	35	87	34
	38	60	70	56
	29	46	100	77
	52	54	58	80
	55	45	92	43
	43	54	56	60
	42	58	90	64
	64	44	60	77
Average:	47	49.4	79.1	60.7
Cabbage (leaf width in cm):	6	5	12	4
	8	4	7	8
	7	9	8	8
	5	9	10	10
	6	12	7	12
	8	12	8	8
	8	9	14	4
	9	7	14	8
	5	9	15	9
	10	6	13	5
Average:	7.2	8.2	10.8	7.6
Date 27.3 (after 45 days) Plant				
Maize (length from the ground to leaf tip in cm):	74	78	147	100
	127	66	150	87
	101	90	133	76
	132	82	190	87
	105	99	210	121
	103	80	170	124
	77	85	147	103
	123	93	113	69
	101	92	164	111
	102	73	120	102
Average:	104.5	83.8	154.4	98
Cabbage (leaf width in cm):	15	10	15	12
	21	18	21	11

	19	13	21	12
	17	14	18	9
	11	9	15	15
	18	9	11	7
	17	11	15	13
	13	11	18	9
	15	12	16	16
	18	9	24	18
Average:	16.4	11.6	17.4	12.2

Appendix 2. Fertilizing plan

	Plot 1	**Plot 2**	**Plot 3**	**Plot 4**
Size	$30m^2$	$30m^2$	$30m^2$	$30m^2$
Fertilizer	Urine	Cow dung	Compound D	Nothing
Amount	300g (N) = 100 litres of urine (5 x 20)	6 wheelbarrows (180kg)	300g (N) = 2 x 1500g of Compound D	x
Application rate	5 times (15.2, 29.2, 14.3, 28.3, 11.4)	Beginning	2 times(18.2, 24.3)	x
Observations	10.3 Heavy rainfall after application		Compound D: 10% N 20% P 10% K 6% S	