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CONTRIBUTION OF IMPALA (AEPYCEROS MELAMPUS) FAECAL PELLETS TO NUTRIENT CYCLING IN VARYING SEASONS AND ITS EFFECTS ON PLANT SPECIES DIVERSITY. THE CASE OF MUKUVISI WOODLAND

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APPROVAL FORM

The undersigned people certify that they read and recommend Midlands State University to accept this dissertation entitled**;** Contribution of impala (Aepyceros melampus) faecal pellets to nutrient cycling in varying seasons and its effects on plant species diversity. The case of Mukuvisi Woodland by Abigal Mabasa registration number R10494R submitted in partial fulfillment of Social Science Honors Degreein Geography and Environmental Studies.

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ABSTRACT

A study to assess the contribution of impala (Aepyceros melampus) to nutrient cycling was conducted in Mukuvisi woodland, a Nature reserve in Harare. The aim of this study was to assess the contribution of impala faecal pellets to nutrient cycle of Mukuvisi Woodland. In this study stratified random sampling method was used to assess decomposition rate of impala faecal pellets in two seasons (summer and winter), and also to determine the amount of soil nutrients contributed by impala faecal pellets into the nutrient cycle. Two zones were sampled and these zones were selected according to soil type, 10 samples were selected in each zone. The mean decomposition rates showed that there was high decomposition rate in sand zone than in the gravel zone. Also overally soil nutrient content was observed to be high in the sand zone than in the gravel zone. This showed that impala faecal pellets contribute to soil nutrients. The t-test results indicated that soil type significantly influences ($p<0.05$) rate of impala pellet decomposition. Thus the hypothesis that soil type does not influence impala faecal pellet decomposition rate was rejected in favour of the hypothesis that soil type influences decomposition rate. This research recommends that Mukuvisi Woodlands staff and National Parks Authorities should further studies focusing on the influence of animal wastes of various species on soil nutrient within the woodland so that they know which animal species to keep in order to enhance soil nutrient content since it’s a small woodland.

DEDICATION

I dedicate this project to my parents Mr and Mrs Mabasa, my sister Amanda Mabasa and all my friends.

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Iwould like in a special way to thank my industrial supervisor Mr G Nhokwara for allowing me to carry out my third year studies at His institution. I would like to thank Daniel Nyamajiwa and Simbarashe Makanza my immediate supervisors for their assistance during data collection. My thanks also to my academic supervisor, Mr M Matsa for editing and offering suggestions towards the development of my project. I would like also to thank my parents Mr and Mrs Mabasa for their greatest efforts and unwavering financial support during the period I carried out this research project.

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CHAPTER ONE: INTRODUCTION

1.1 Background

Impalas (Aepyceros melampus) have turned out to be the largest part of all animals in the game parks and nature reserves in Southern Africa because of its rapid increase in population (Gerber, 2006). They are mixed feeders which browse and graze short sweet grass (less than 8cm). A low crude-fibre diet of less than 40% is vital, together with high protein content of 8% in winter and 16% in summer (Klein and Fairall, 1986). Inhumidenvironmentspasture makes up 79-92% of impala diet, as well as herbs, dicot forbes and little shrubs and in dry winter the lignin content of grass increases. Main species are-grass: cynodon,panicum, digitaria, eragrostis, brachiaria, pogonaarthria, melinis, themeda, urochloa-forbs: asparagus, cleome, justicia, sida, tephrosia, waltheria-browse:, acacia, carissa, combretum, dichrostachys, grewia, mundulea, terminalia, ziziphus, securinega, capparis, mopane, fallen pods,fruits and berries are a very essentialsupply of protein for the duration of dry winter months (Furstenburg, 2010).

Favoredgrazing height is 40-100cm, but the full range extends from ground level to 130cm. by overstocking of impala a discrete line forms at 130cm, the herbaceous foliagecover gets eradicated and the decreaser meadowtype get replaced by increaser species resulting in lesser ground cover (Okello et al, 2002).

Nutrient cycling is the process of the movement and exchange of organic matter into the production of living matter (Pastor and Cohen, 1997). This process is regulated by food web pathways that decompose or reduce matter into mineral nutrients. Nutrient cycling occurs within the ecosystem both aquatic and terrestrial. Movement of nutrients within the ecosystem is cyclic and the major nutrient cycles include nitrogen, phosphorus and carbon cycle.

Animals play an important part in nutrient cycling in ecosystems through excretory processes. Animals provide nutrients at rates similar to the main nutrient sources like decaying plant and animal matter. Nutrient cycling by animals can sustain a largequantity of the nutrient demands of primary producers (Vanni, 2002). Animals might also have many indirect effects on nutrient fluxes due to effects on their prey or alteration of the physical surroundings. Animals play a part of recycling nutrients in itsterritory or translocating nutrients across territories in an ecosystem.

Herbivores modify nutrient cycling by excretement, by altering the amount and value (nutrient content and decayspeed) of plant debris, and by sequestering nutrients into their bodies. Herbivores also reduce plant abundance and can only boost plant abundance if enhancement of nutrient cycling exceeds the depressing effect of consumption (Belovsky and Slade, 2000).

According to Pastor and Cohen (1997), most herbivores have shown that they feed selectively and that the choice of feed is determined by a similar compound that determines decay rate. Foliage that is usually selected habitually has an upper nutrient level, higher growth rates and quicker disintegration rates.

Herbivores may change the competitive equilibriumamong functional different growth rates because of the changes they would have caused in the availability of soil nutrients (Bokdam, 2001). Large herbivores change soil nutrient availability for vegetation through changes in soil nutrient cycling rates and spatial redistribution of soil nutrients (Ritchie et al 1998) adapted from Cornelis 2011. In an experiment, open lands showed a boost in impalas because they preferred open sites to avoid predation (van der Waal, 2011).

There is growing evidence that herbivores show favoritismamongstaccessible foods on the basis of their chemistry, mainly the concentration of nutrients and carbon compounds that control digestion rates (Pastor 1997). Belosvsky and Slade (2000) suggest that herbivores affect nutrient cycling. In this research nutrient cycling has been divided into parts the slow cycle and the fast cycle. Nutrient discharge from excretement and dead herbivores has been termed the fast cycle, because this detritus rapidly decomposes and release nutrients for plant uptake. Discharge of nutrients from plant litter has been termed the slow cycle, because this accumulation slowly decomposes and releases nutrients for plant uptake.

Insects have a significantpart in the decomposition of animal dung, these mainly include dung beetles, and termites. Decomposition is largely brought about by the activity of microorganisms (Lee and Wall, 2006), while the activity of invertebrates and the weather influence the rate at which this process proceeds.

1.2 Problem statement

Impala (Aepyceros melampus) is one of the most abundant medium sized herbivores in the savannah. Mukuvisi Woodlands is a community dominated by Aepyceros melampus which make up approximately 70% of the total animal biomass. Impala have been said to have detrimental effects to the ecosystem and nutrient cycling. With overstocking of impala, a distinct browse line develops at 130cm. the herbaceous vegetation layer gets eradicated and the desired decreaser grass species get replaced by increaser species resulting in lesser ground cover (Okello et al, 2002). Due to its selectiveness and its gregarious behavior, impala is a high impact animal upon veldt condition and therefore need to be strictly managed. However, impalas also play a part of defecating faecal pellets and urine which are considered to be important in nutrient cycling in ecosystems. Impalas spatially reallocate nutrients they acquire in from one area and excrete in other areas (mainly resting places). The contribution of these species to ecosystem nutrient cycling in this regard has not been adequately documented. Impala is well exceptive towards additional and artificial feeding and take both dried lucern and concentrate antelope. In cases of mineral deficiencies in natural feed in dry seasons impalas are fed with concentrate licks, approximately 4 liters of water is taken every second day by impalas (Sponheimer, 2003). Being mixed feeders they are considered to play an important part in returning nutrients to the soil within woodlands. This project seeks to assess the contribution of impala faecal pellets to the nutrient cycle in varying seasons and its effects on plant species diversity in Mukuvisi Woodlands.

1.3 Objectives

1.3.1General objective

To assess the contribution of impala faecal pellets to the nutrient cycle in varying seasons and its effects on plant species diversity in Mukuvisi Woodlands.

1.3.2 Specific objectives

- To determine the influence of soil type on the decomposition rate of impala faecal pellets.
- To determine the influence of season on the time taken by impala faecal pellets to disappear from the ecosystem.
- To assess changes in soil nutrients due to impala dung and urine.
- To determine the effects of impalas on plant species diversity.

1.4 Research hypothesis

Ho: Soil type has no significant influence on decomposition rate of impala faecal pellets.

Ho: impala faecal pellets do not significantly improve soil nutrient content.

1.5 Justification of study

In grassland systems, ungulate grazing is said to enhance nutrient cycling due to the addition of urine and dung, which are easily utilized nutrient sources (Bardgett and Wardle 2003). Impala have been said to be destructive to the ecosystem due to their creation of open areas and this has been said to have detrimental effects to the ecosystem and nutrient cycling. This project seeks to bring out the importance of impala to nutrient cycling especially the extent to which they contribute to the soil nutrient content.

The study, upon being successfully carried out will benefit the researcher, the Midlands State University and future geography and environmental studies students as well as Mukuvisi Woodlands. Mukuvisi Woodlands would benefit from the recommendations the researcher would come up with to get the knowledge on whether to stock more impalas or not. The MSU students would get an insight into the problem and the manner researches are to be done, upon reading this research, and also they get a platform to further their studies and focus on the influence of different soil types on defecated animal waste of various species within Mukuvisi Woodlands and also by identifying the main plant species that make up the impala diet within the Woodland so that they plant more of those species to reduce expenditure on supplementary food and also enhancing soil nutrients within the woodland.

1.6 Study area

Mukuvisi Woodlands which is 263 hectares is situated 3.5 km to the South-East of the city of Harare and found between the latitudes 99^{0}N and 26^{0}S. The Woodland was first identified as a potential reserve area in 1910 by dedicated natural historians. This was vetoed on the grounds that it was far from town. Until 1977 it served as an area of recreational enjoyment for individuals interested in trees and birds. Official protection from developers was granted in 1977 in terms of a short 33 year lease and the Mukuvisi Woodland was created. This was further ratified in July 1991, when an agreement was reached with the City of Harare to lease the Woodlands (263 ha) to the Mukuvisi Woodlands Association which is represented by the Chairman Mr. Simon Pitt, on the basis of a 99 year lease. The Woodland was established to promote and support the conservation and management of the natural habitats of Harare for the enjoyment, inspiration and benefit of its inhabitants and so foster environmental conservation in urban areas.

70% of Mukuvisi is light and heavy woodland and 30% is vlei which is water logged for 3 to 4 months of the year. Dominant tree species include *Brachystegia speciformis, Brachystegia bohemia* and *Julbernardia globiflora*. The area has a diverse vertebrate fauna that includes mammals, birds, reptiles and fish. Mammals include six species of herbivores which include giraffes, elands, impalas, wildebeests, zebras, kudus, and no carnivores. The community is dominated by *Aepyceros melampus* which make up approximately 70% of the total biomass (Buckle,2010).Miombo birds include, Spotted creeper *(Salpornis spilonotus)*, Violet Backed Sunbird *(Anthreptes longuemarei)*, Miombo Blue-eared Starling *(Lamprotornis elisabeth)* ,White-eared Barbet*(Stactolaema leucotis)*.

Mukuvisi Woodland is in a summer rainfall area where annual rainfall ranges from 650-850mm per year. This is recorded between the months of November and March with the highest falls being in January and February (Bolton, 2000). Winds across the Mukuvisi Woodland are generally north-westerly and the windiest months are September and October before the commencement of the rainy season. January and February are generally the hottest times of the year where minimum and maximum temperatures range from 20-29°C. In winter, temperatures range from 16-23°C, temperatures at night fall to between 7°C and 10°C with ground temperatures of zero or below often recorded in June. Frost is common in May and June, mostly in vlei and along Chiraura and Mukuvisi river banks. Humidity is fairly low in winter months and highest in January and February when it exceeds 80% (Hyde *et al*, 2012).

The Woodland is comprised mostly of sandveld and clay which is found in the vlei areas. There are a number of quarry sites where a mixture of sand and stones are found (gravel) and granite outcrops .Greenstones make up about 10% of the area and are characterised by scarce outcrops and dark red soils.85% of the area is coarse crystalline (3-5mm) granite. A wide quartz vein runs north from the quarry in the game area towards the dam where a fault displaces it to the west where it forms the Hillside Ridge. The quartz vein is one of the Great Dyke Satellite fractures while the Chiraura fault is parallel to the older Umwinsidale Shear Zone (Buckle, 2010).

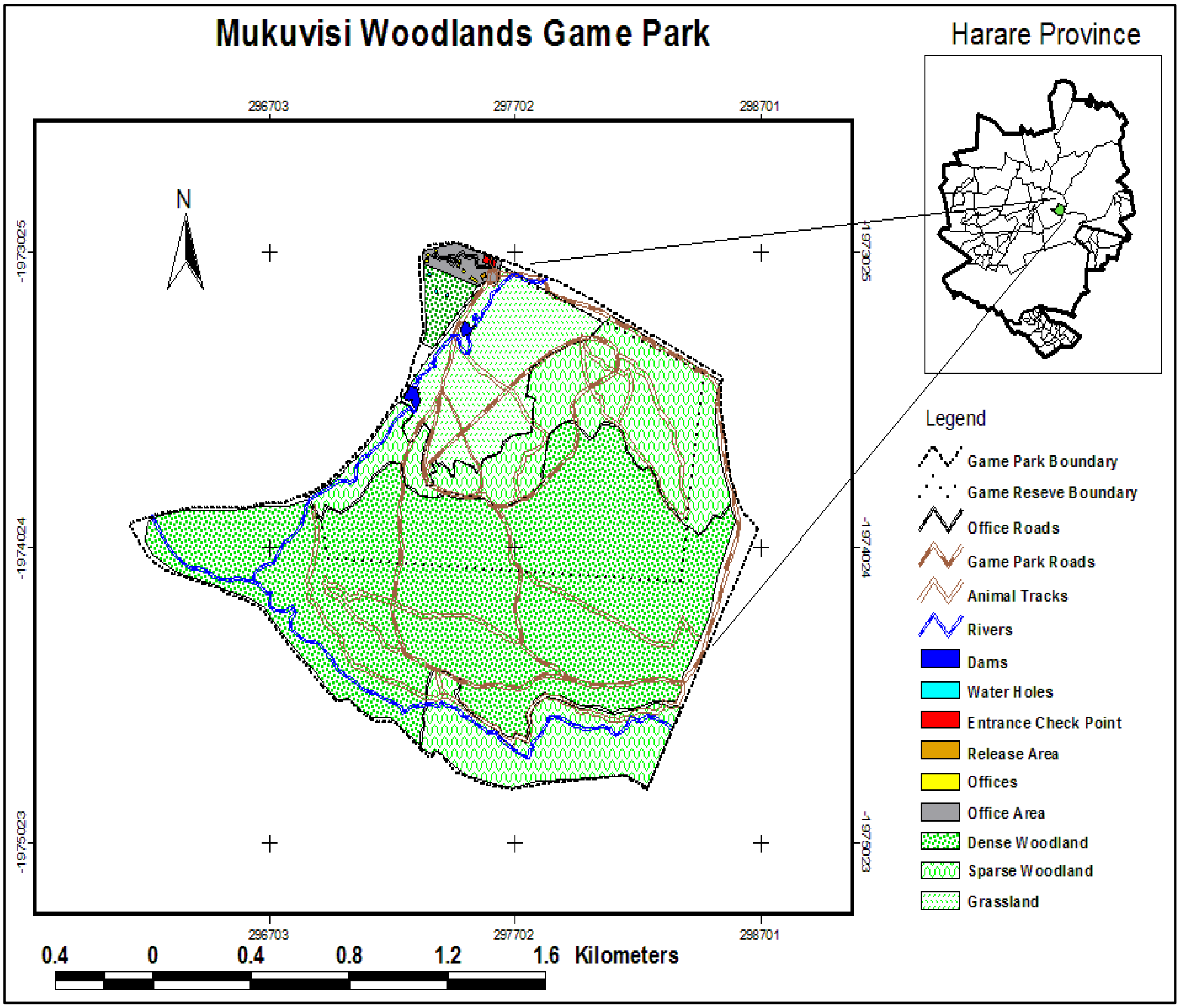

Figure 1.1Map of Mukuvisi Woodlands

CHAPTER 2: LITERATURE REVIEW

2.1 Distribution and feeding behaviour of impala

The common impala is one of the most abundant antelopes in Africa, with about one-quarter of the population occurring in protected areas. The largest number occurs in areas such as the Masai Mara and Kajiado (Kenya); Serengeti, RUAHA AND Selous (Tanzania); Luangwa Valley (Zambia); Okavango (Botswana); Hwange, Sebungwe and the Zambezi Valley (Zimbabwe); Kruger National Park (South Africa) and on private farms and conservancies (South Africa, Zimbabwe, Botswana and Namibia). The rare Black-faced impalas survive in Etosha National Park and private farms in Namibia adapted (online) available from http://happytoursug.com/impala29-Oct -2013.

Most of the studies on impala feeding behaviour are exclusively in the same group and are frequently found in the same vicinity. Northern savanna vegetation types (Wronski 2002; Attwell and Bhika 1984; Monro 1982) are their natural habitat. In this environment, their feeding behaviour shows a preference for graze in the rainy wet season, with an increase in browse in the dry season when graze quality is lower. The rainfall pattern of the area also appears to affect the foraging behavior of impala. The studies of Attwell and Bhika (1984); Monro (1982) and Dunham (1980) all shows the feeding behaviour described above with a uni-modal rainfall pattern. However, Wronski (2002) studied the feeding behavior of impala in the presence of a bimodal rainfall pattern and found different foraging behaviour. During hotter day hours they become less active mostly keeping to shade. They feed for 38% out of 24 hours of which less than 35% takes place during night hours. In his studies, there appears to be no significant differences in feed selection for impala between dry and wet seasons.

2.2 Effect of herbivores on nutrient cycling

Animals can either reprocess nutrients in theirterritory, or translocates nutrients across the ecosystem (Vanni 2002). deAngelis et al (1989), stated that the cycling of nutrients is critical for the existence of ecosystems. Many studies have been done in marine ecosystems and cycling of nutrients which are most likely to limit primary production (*nitrogen N and phosphorus P*)has been paid attention to (Rosemond et al 2002).

Herbivores may continue to alter the competitive balance between functionally different growth forms because of the changes they would have caused in the availability of soil nutrients (Bokdam, 2001). Large herbivores alter soil nutrients availability for plants through changes in soil nutrient cycling rates and spatial redistribution of soil nutrients (Ritchie et al, 1998). In an experiment bush cleared patches showed an increase in impala dung deposition, this is probably because impala preferred open sites to avoid predation (van der Waal, 2011).

There is growing evidence that impalas discriminate among available foods on the basis of their chemistry, particularly the concentration of nutrients and carbon compounds that control digestion rates (Hartley et al, 1995). Belovsky and Slade (2000) suggest that impalas affect nutrient cycling and plants, depending on the plants consumed in a modeling study. In the study nutrient cycling has been divided into two parts: the slow cycle and the fast cycle. Nutrient release from excrement and dead herbivores has been termed the fast cycle, because this detritus rapidly decomposes and releases nutrients for plant uptake. Release of nutrients from plant litter has been termed the slow cycle, because this detritus slowly decomposes and releases nutrients for plant uptake.

Grazer effects on soil nitrogen occur at every temporal scale from months to years to decades in this ecosystem. Decadal effects occur due to cattle management, which generates spatial heterogeneity in soil nutrients through bomas (typically 0.5–1.0 ha) that are distributed across the landscape and eventually develop into glades (Augustine 2003a). On an annual basis, herbivores influence the N budgets of different patches within the landscape. In glades, impala created a net N input due to high rates of dung and urine deposition during dry seasons when no forage is being consumed from these patches (Augustine and others 2003).

By contrast, the presence of mammalian browsers can arrest or reverse the development of a mature woody layer and promote grassland or the development of “shrubby” growth forms (Augustine and McNaughton, 2004; Belsky, 1984; Dublin et al., 1990; Levick and Rogers, 2008; Makhabu et al., 2006; Strang, 1973). Such an effect has been evident along the Chobe River in Botswana: a crash in the browser guild and heavy elephant hunting in the late 1800s promoted the development of riverine woodland but subsequent increases in elephant and impala (Aepyceros melampus) populations have resulted in deterioration to a prevalence of shrubs (Moe et al., 2009)

Conversion of organic compounds into mineralized forms readily accessible to plants can also occur during digestion by impalas, with subsequent deposition of urine and faeces rich in compounds such as nitrates and urea (Begon et al., 1996; Mohr et al., 2005; Pastor and Cohen, 1997). In many systems, nutrient cycling is relatively faster through herbivores dung and urine than through decomposition of senescent plant material (McNaughton et al., 1988), primarily because structural materials such as cellulose are partially broken down during digestion.

Decomposition of animal tissue also returns elements to the soil rapidly (Begon et al., 1996).However, the animal-mediated route can be highly complex. Nutrients may be exported from the local site if animals are large or highly mobile (de Mazancourt and Loreau, 2000b), and plants' production of secondary metabolites in response to herbivory may impact on decomposers and result in slow decomposition and nutrient cycling rates (Harrison and Bardgett, 2004; Kay et al., 2008; McNaughton et al., 1988; Pastor and Cohen, 1997).

Ruminants egests large quantities of well-digested (i.e. fine textured) plant matter. Feces are rapidly broken down by microbial and insect activities and mechanical erosion (such as raindrop impact) (Masunga et al., 2006; Plumptre and Harris, 1995). The nutrients present in the dung are therefore returned to the soil in forms that can be readily utilized by plants (McNaughton et al., 1988). Animal-mediated nutrient cycling is typically faster than via the plant decomposition cycle (de Mazancourt and Loreau, 2000b; McNaughton et al., 1988; Thompson Hobbs, 1996), although herbivory-induced secondary metabolite production may limit decomposition rates (Pastor and Cohen, 1997). Furthermore, small antelope tend to utilize latrine sites or maidens (Kingdon, 1997; Lunt et al., 2007), which results in local concentration of nutrients in the soil. This may promote plant growth and vegetation succession, and maintain habitat heterogeneity by generating pockets of nutrient-rich soil (Davidson, 1993; McNaughton et al., 1988; Thompson Hobbs, 1996).

2.3 Role of insects and on speeding up dung decomposition

Insects have asignificantpart in the decomposition of animal dung, these mainly include dung beetles, and termites. Disintegration of dung is mainly facilitated as a result of the action of microorganism (Lee and Wall, 2006), while the activity of invertebrates and the weather influence the rate at which this process proceeds. Invertebrates tunnel through the dung, increasing the area available for microorganisms and enhance degradation through fragmentation, aeration, removal by assimilation, conversion into insect faeces and burying or mixing large amounts of dung with the surrounding soil (Lee 2006) thereby increasing the rate of decomposition of dung (Vessby, 2001, Floate et al 2005).

2.3.1 Termites

Termites are commonlyspreadall over the tropical and subtropical regions of the planet, with the maximumvarietyoriginate in tropical forests (Eggleton, 2000). Termites act as well as decomposers, feeding on a wide range of living, dead or even decaying plant material (Bignell and Eggleton, 2000; Traniello and Leuthold, 2000), including the consumption and turnover of large volumes of soil rich in organic matter and fungi. There are reports of termites foraging for mammalian dung from around the globe: Africa, Asia, Australia and north-/central-/south-America. Most observations were made in Australia and Africa, potentially at the feeding habits of termites living in grass and bush lands on these continents. Termites feed on the dung of a total 18 mammalian species and impala (*Aepyceros melampus*) was among these species Freymann et al, adapted(online) available on http://www.isoptera.ufv.br/file.pdf 19-Jul-2010. According to Freymann et al, (2008) termites show no clear, distinct preference for mammalian dung over other plant food items.

These feeding habits make termites important ecosystem engineers, which over long periods of time can modify the physical properties of soil such as texture, water infiltration rates and nutrient content, at various spatial scales (e.g. Dangerfield et al.,1998). (Calviño et al 2006,Coe 1977) estimates that in the Tsavo (East) National Park (Kenya) termites remove up to 8.7 × 103 kg faeces per km2 per year from the surface of the soil. This results in a nitrogen turnover of about 12 kg/ha/year based on the nitrogen content of 1.39% for fresh elephant dung reported by (Freymann 2008,Anderson and Coe (1974). Basappa & Rajagopal (1990) examined the physical and chemical properties of termite modified soils in India. This revealed that the water holding capacity, pH, organic carbon, organic matter, total nitrogen, the cation exchange capacity, as well as the exchangeable cations, like calcium, magnesium, potassium and sodium, were higher in termite modified soils than in surrounding soils (Basappa & Rajagopal,1990).

2.3.2 Dung beetles

Dung beetles are in Scarabaeidae and Geotrupidae insect families, they are an important group of insects associated with the decomposition of animal manure around the world. They consume large amounts of dung as adults and larvae. Some species prefer woodland habitats while others are common on pastures. Their actions have been credited in reducing pasture fouling, adding nutrients to soil, and aerating soil Henderson (2010). Herrick and Lal, (2006) suggests that dung beetles are responsible for the removal and burial of almost all dung during the wet season. Losey and Vaughan (2006) also states that dung beetles are generally responsible for nutrient recycling from dung, it appears that this is however, only true for the wet season since adult dung beetles feed exclusively on the liquid component of the dung by means of specialized filtering mouth paths (Holter, 2000). They rely on the availability of dung with a high water content. This will cause termites to become important in speeding up the composition of dung in the dry season compared to dung beetles, but however termites are less effective because they are less mobile compared to dung beetles.

2.4 Decomposers

The decomposer community, though not readily visible because of its small size, is an important component in speeding up decomposition rate of either animal or plant waste. The term decomposition is used to describe organisms like bacteria and fungi in the process where organic material will be releasing nutrients nitrogen (N) and phosphorus (P), (Alkemade et al, 1992). This process creates a key link in transfer of energy and cycling of nutrients between various trophic groups in an ecosystem. Decomposers play an important role in formation of soil organic matter this by degrading energy rich organic compounds and in the process generating materials such as humus. In addition, several species of decomposers produce humic acid-like substance that could contribute substantial amounts (330 Kg/ha) to the annual input of humic substance into the soil (Filip and Alberts, 1993). It is rarely possible to separate microorganisms from the decaying plant material and sediments where most of the decomposition occurs. Hence, soil organic matter consists of these partially decayed plant residues, the microorganisms and the small fauna involved in decomposition, and the byproducts of decomposition.

2.5 Soil type, structure, moisture and temperature

Soil type plays a part in nutrient cycling, Burke et al, (1998) observed that primary production and nutrient cycling differ in locations with different soil types. The activity of living organisms in soil helps to control its quality, depth, structure and properties. The climate, slope and bedrock also contribute to the nature of soil in different locations and the interactions between these multiple factors are responsible for the variation of soil types.

Soil structure in different locations may also be found to support very different biological communities. These complex communities contribute significantly to the continuous cycling of nutrients within the ecosystem. Gravel soils, facilittes disintegration at a quicker rate, to an extent that nutrient cycling is more rapid, thereby enhancing nutrients in the soil. Coarse soils have a low CEC (cation exchange capacity and low water holding capacity (Ladd et al, 1993). Fine-textured soils preserves nutrients longer in the rooting zone. Infiltration is slower than on coarse-textured soils.

Soil temperature and moisture content are very important factors affecting decomposition rates. According to Moorhead et al., (1999) favored moisture conditions; increasing temperature results in an exponential increase in decomposition rates. At a constant temperature, soil moisture content shows a parabolic effect on decomposition rates with a maximum rate at intermediate levels of moisture. High moisture content limits soil gas exchange leading to low oxygen concentrations and potentially anaerobic conditions. At low moisture content, the lack of water limits microbial metabolism. In addition to temperature and moisture acidity extremes ($pH<4$ or >9) may reduce decomposition rate (Carter et al, 2007).

2.6 Roles of impalas on plant species diversity.

Small antelope are selective browsers and feed at low levels, and therefore potentially alter plants' inter specific and intra specific relationships. Being selective browsers, they influence seedling recruitment, alter competitive interactions among woody plants of differing palatability and between woody and herbaceous plants; in the medium term they alter the structure of the under storey, which in turn may affect canopy structure in the long term.

In African forests, impalas (Aepyceros melampus) are important seed dispersal agents (Eves, 2003), although dispersal of soft-seeded species is limited due to repeated oral mastication

(Feer,1995).In savanna ecosystems, a large number of woody plants produce fleshy, palatable fruits that are eaten by antelope (Coates-Palgrave, 1996; Prins et al., 2006; Wilson, 1966) and savanna antelope play a similar role to their forest counterparts. By ingesting fruits, impalas transport seeds away from the parent plant, and either egests them in their faeces, or expel them orally during rumination (Bodmer, 1991; Feer, 1995). Chemical and mechanical scarification of the seed coat, which occurs during mastication and digestion, may stimulate germination of hard-seeded species (Raven et al., 1986; Traveset et al., 2008), but be lethal to soft-seeded species (Feer, 1995). Faecal matter acts as a fertilizer, which can promote seedling growth (Argaw et al., 1999; Cosyns et al., 2006), and removal of seeds from the vicinity of the parent plant may reduce intra specific competition and promote gene flow (Berger et al., 2008; Calviño-Cancela et al., 2006; Wiegand et al., 2008).

The leaves of seedlings and new growth are high in protein, and during this rapid-growth phase, little indigestible or unpalatable material is produced (Cebrian and Duarte, 1994). Feeding on a seedling is energetically advantageous to the herbivore, but may easily be lethal to a plant, especially if it is completely defoliated. Thus, small antelope may have a negative effect on seedling recruitment, even of species that are unpalatable when mature, and are likely to influence the competitive relationships among species. However, at the community level, removal of seedlings can be advantageous, reducing stem competition (Duncan et al,2009; Wiegand et al., 2008) and limiting woody development (Augustine and McNaughton, 2004; Belsky, 1984; Roques et al. 2001). In the medium term, and depending on the species browsed, the structure and density of the under storey may also be altered.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Research design

According to Gorard 2013, research design is a detailedoutline of how an investigation will take place. It will typically include how data is to be collected, what instruments will be employed, how the instruments will be used and the intended means for analyzing data collected (Gorard 2013). Research design provides the glue that holds the research project together. It is used to structure the research, to show how all of the major parts of the research project the samples or groups, measures, treatments or programs, and methods of assignment work together to try to address the central research questions (Creswell 2012). There are two major types of research designs namely qualitative which is used to describe life experiences and give them meaning and quantitative which is a method used to describe, test relationships, and examine cause and effect relationships .The researcher has used the quantitative research precisely the experimental design which is the design of any information-gathering exercises where variation is present, whether under the full control of the experiment or not (Adebayo 2000). It ensures that the right type of data and enough of it is available to answer the questions of interest as clearly and efficiently as possible.

In Mukuvisi Woodlands there are 56 impalas consisting of 19 juveniles, 27 females 10 males. They are divided into 2 territories where the ram is the head. They live in a light woodland with little undergrowth and grassland of low to medium height. Impalas have an irregular distribution due to dependence on relatively flat lands with good soil drainage and water. Impalas stay near water in the dry season; but they can go for weeks without drinking if enough green fodder is available.

3.2 Research sampling zones

The study area was divided into two zones; this was according to soil type. In Mukuvisi we have mainly three soil types which are clay, sandy and gravel. However the clay section was not included in the research because in that area there was hyparrehenia grass which is very tall and unpalatable so impalas are not usually found in this area since they prefer open areas, because they can see better and act faster when they are attacked by predators. Impalas are said to be attracted to disturbed areas of vegetation (van der Merwe, 2010).They choose areas with little or no vegetation.

3.3 Determination of decomposition rate

Fresh night faecal pellets deposits were marked the following morning and monitored until fully decomposed. Sites were marked using painted rocks and visits to the impala faecal pellet piles were done after every three days. Four points around the impala faecal pellet pile (the controls) were marked in the four major compass directions, (North, South, Eastand West) at a distance of one meter. The control sites were covered with thorns to avoid deposition of dung by the same animal under the study or any other species in the same ecosystem. After complete disappearance of pellets at the dunging site, soil samples are collected from both dunging site and control sites in the two zones. Soil from control sites were combined into a composite sample so as to provide more representative estimates of mean concentrations than could be achieved by the same number of discrete samples (Correll 2001).

The underlying assumption was that no animal had deposited its dung on the control site during the whole process. GPS was used to mark points. Twenty points were randomly selected and marked (10 points in gravel zone and 10 points in sand zone, in each zone 5 points where under tree cover and 5 where in an open area) because impalas browse under trees as the areas will be dominated by cynodon, mopane as well as berries, fruit and fallen pods and also they use under trees as habitats. The effect of tree cover was only assumed to affect rate of decomposition and not soil nutrient content. There was also recording of insect activity at points because dung beetles, earthworms, *bugs*, and other creatures dig and digest the dung and dead plants into fertile soil,(points with insect activity were recorded as 1 and points with no insect activity were recorded as 0).

The period taken for complete decomposition of faecal pellets on all points was recorded on data sheets and from this decomposition rate was determined using the formulae by Forys and Humfrey, 1997.

$$Decomposition rate = \frac{Number of faecal pellets defecated at point}{Time taken for complete decomposition \ (in days)}$$

3.4 Soil sample analysis

To contrast the fertility of the points where impala faecal pellets decomposition had occurred with the surrounding soils, soil samples were collected randomly and taken for nutrient tests. Soil samples were tested for the amount of nitrogen (N), phosphorous (P), pH and bases which include calcium (Ca), magnesium (Mg) and potassium (K). A volume of (10cm×10cm×10cm) was dug out and mixed thoroughly then only 500g of the sample was taken for testing. Soil samples were collected from 2 experimental points and also 2 composite soil samples from control points in each zone (stratum) giving a total of 8 soil samples. Testing for nutrients helped to analyze if impalas are contributing to nutrient cycling. The soil samples were tested at the Chemistry and Soil Research Institute, Department Of Research And Specialist Services, Ministry of Agriculture.

3.4.1 Phosphorus

Total phosphorus was determined using the Ultra violet machine. Firstly phosphorus was sieved because only fine particles were to be used for the test of phosphorus present in the soil samples. Samples were later leached using 1.25 molar of sodium hydroxide aqueous solution. It was leached again using 1.25 molar of hydrochloric acid aqueous solution. A yellow color was formed to show good leaching. After this at least 100ml of distilled water was added to solution because it will not leach minerals, 20ml of solution was pipette from samples to develop color using ammonium molybdate and stannous chloride solution. Solution changes color from colorless to blue if there is available phosphorous, the intensity of color determines amount of available phosphorous using the U.V machine with standards 0.25-0,275ppm (Anderson and Ingram, 1993).

3.4.2 Bases

Total bases were determined using the Atomic Adsorption Spectrophotometer (A.A.S). A mass of 5g of soil sample was added to 50ml of ammonium acetate and shaken for 1hr; this was to suppress all the other elements. After this the samples were filtered and the filtrates were analyzed using the Atomic Adsorption Spectrophotometer (A.A.S) where they were measured. Each base had standards which act like boundaries which should not be exceeded. These boundaries helped to check for anomalies in results for Calcium 10 and 20m equivalent, Magnesium 1.5 and 10m equivalent, Potassium 0.1, 0.4 and 0.8m equivalent and for Sodium

0.22, 0.43 and 0.87m equivalent. The A.A.S uses different lamps for testing different bases, this is because the different bases require different wavelengths and hence the need of different lamps which produce different wavelengths.

3.4.3 pH

Total pH was determined using a pH meter. A mass of 15g of soil sample was mixed with 75ml of calcium chloride; calcium chloride was used because it is stable. It was shaken for an hour and then taken to the pH meter, where pH tests were carried out. 50ml of buffers 4 and 7 were used to standardize the pH meter.

3.4.4 Nitrogen

Total nitrogen was determined using the Ultra Violet machine. A mass of soil samples were mixed with potassium chloride (KCI) and shaken for 30 minutes intervals and after that, they were put into 5ml dividers. The 5ml of filtrate were then mixed with sodium hydroxide pellets to enable the filtrate to later react. The solution was later heated using a steam distill because it allows one to distill the high boiling liquid at a significantly lower temp, after this it was changed color using Nesslers and later U.V machine was used to measure amount of nitrogen using standards 0,350-0,72ppm. The incubation method was used to quantify the amount of nitrogen in the soil samples (Coetsee et al, 2008).

3.5 Data presentation and analysis

In this study the utilization of a hypothesis called for a statistical analysis of data using statistical measures like the chi-square. This assisted the researcher to confirm or reject the hypothesis. Tabulated categories of data were analyzed using One Way- Analysis Of Variance (ANOVA). This method can handle a variety of situations and it also enabled the researcher to compare group means by analyzing comparisons of variance estimates. An independent sample t-test was carried out to test the significant change in means of pH and nutrients in sample soils in the zones. A paired sample t-test was also carried out to compare the significant difference in decomposition rate between the two zones.

Data was presented in a tabular form. Tabulation condensed a large mass of data and brought out the distinct pattern in the data. It enabled comparison to be made easily among classes of data and took up less space than data presented in narrative form. For better visual impact; data was presented in form of pictures, pie chart and bar charts.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 The influence of soil type on the decomposition rate of impala faecal pellets.

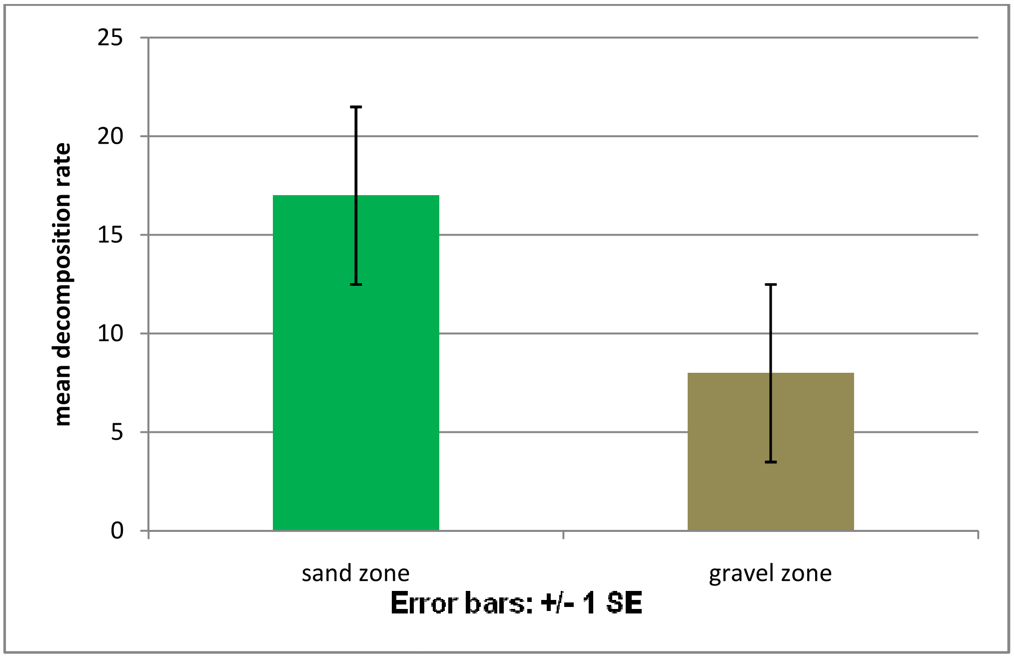

Figure 4.1. Comparison of the impala faecal pellets decomposition rate means for sand and gravel zones.

Soil type significantly affects rate of decomposition of impala faecal pellets, hence influencing nutrient cycling. A paired samples t-test shows a significant increase ($t=2.077$, $df=9$, $p<0.05$) of impala faecal pellet decomposition rate in the sand zone compared to the gravel zone (Fig 4.1). Impala faecal pellets decomposition rate was high in sand soils unlike in gravel, this was because in sand, soils insects' activities were high compared to that in gravel soils.

This was in agreement with the researches carried out by Lee and Wall(2006); Vessby(2001) and Floate et al, (2005) that insects play an important part in speeding up the rate of decomposition of impala faecal pellets. However, sandy soil has smaller particles compared to gravel and this had an effect on insect action on faecal pellets, insect activity proved to be high in sandy soil than in gravel and this opposed Ladd et al, (1993) who observed that decomposition rate is rapid in coarse textured soils. Termites were observed to be the most dominant insects, and as was stated by Bignell and Eggleton(2000); Traniello and Leuthold(2000) termites acted as decomposers of impala faecal pellets in some points this was done through covering the faecal pellets with large volumes of soil, thereby increasing rate of decomposition.

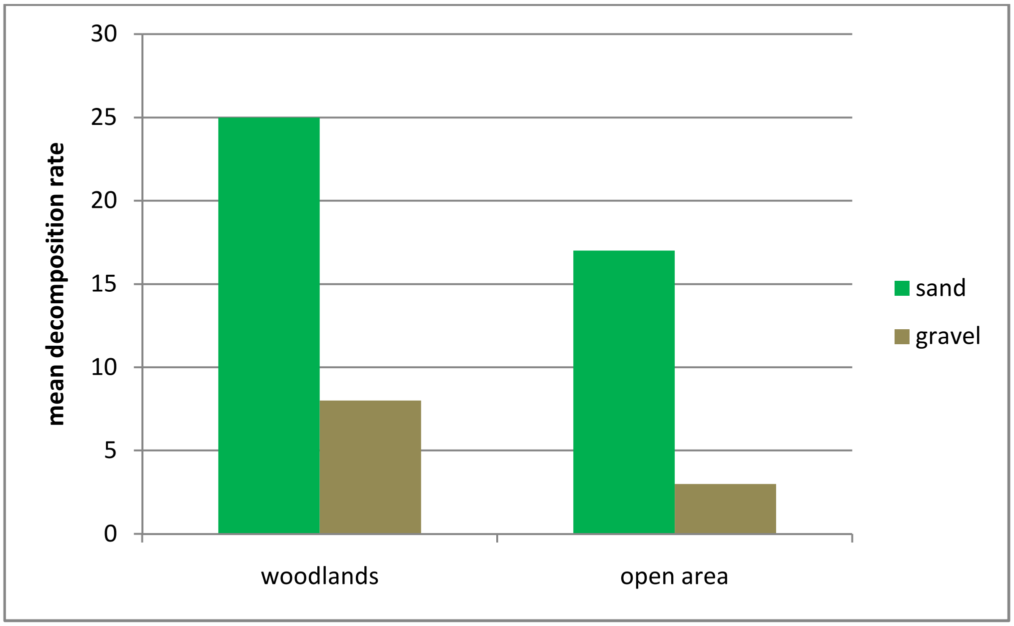

Figure 4.2 Impala faecal pellets decomposition rate in gravel and sand soils under tree cover and open area.

There is a significant difference ($t= 3.611$, $df= 4$, $p< 0.05$) in mean decomposition rate of impala faecal pellets under tree cover compared to those on open area (Fig 4.2). Decomposition was observed to be high in areas with vegetation cover compared to open areas because there is reduced soil moisture loss in the woodland area unlike in the open area.Moorhead et al, (1999) observed that soil moisture plays an important part in microbial activities hence increasing rate of decomposition. This was also observed in Mukuvisi Woodlands, area with vegetation cover had faster decomposition rates than those in open areas because soil moisture content was high in the woodland area unlike in open areas and this increased microbial activities.

4.4 Changes in soil nutrients due to impala dung and urine.

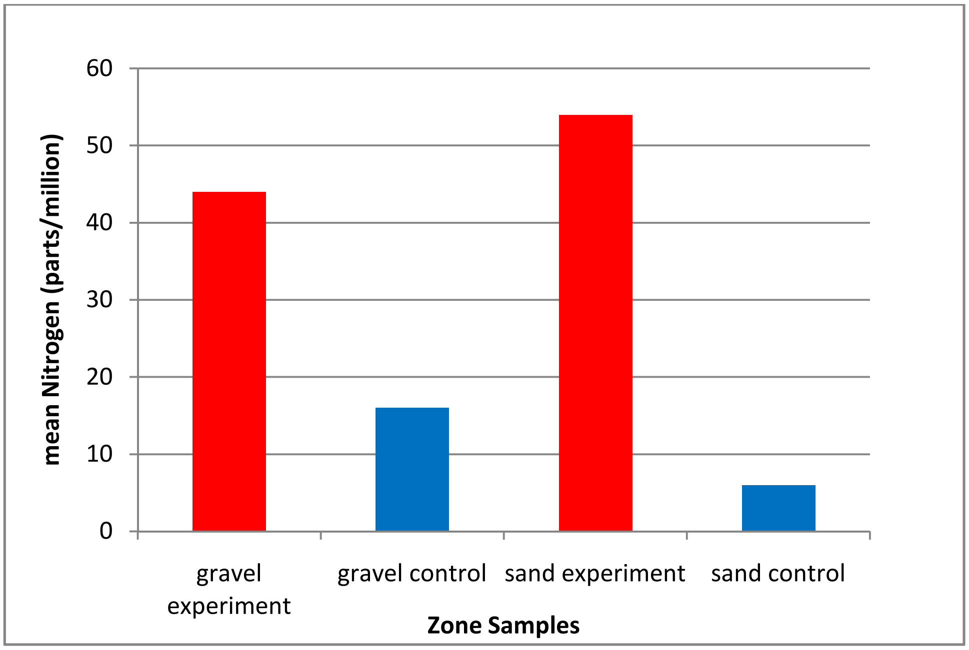

Figure 4.3 Average nitrogen content (parts/million).

There is a significant increase in nitrogen ($p < 0.05$) in both gravel and sand zone experiments thus comparing with respective controls. Nitrogen levels increased much in the sand zone compared to the gravel zone (Fig 4.3).

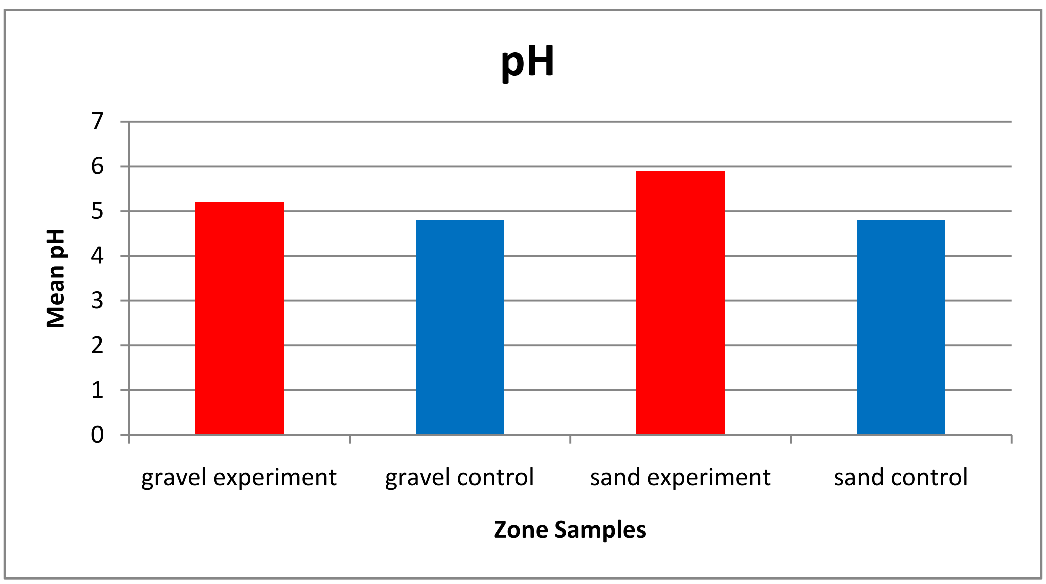

Figure 4.4 Average pH levels.

pH levels were found to be almost the same in controls of both zones. However, at experiment points there was a slight increase of the pH level in the gravel zone and also an increase by 1 in the sand zone as shown in figure 4.4. The pH increase was not significant in both zones ($p > 0.05$).

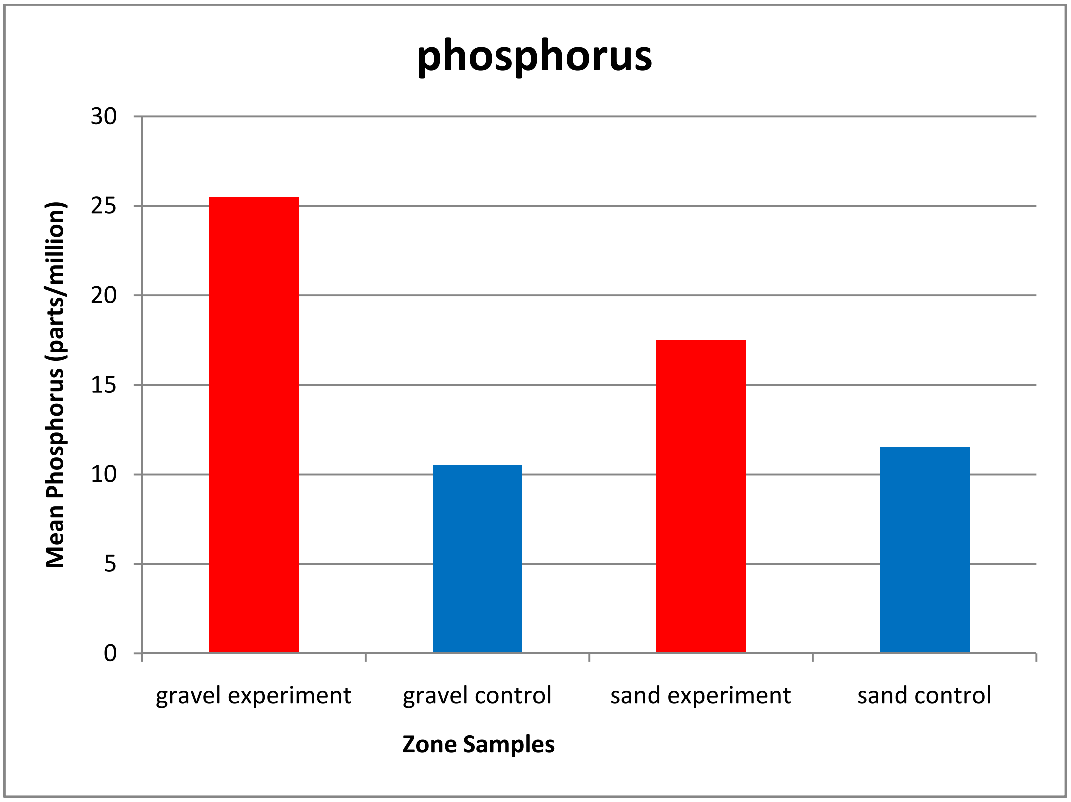

Figure 4.5 Average phosphorus content (parts/million).

The gravel zone had the highest increase in phosphorus concentration compared to the sand zone. However in both zones there was a significant increase ($p < 0.05$) in phosphorus compared to control points (Fig 4.5).

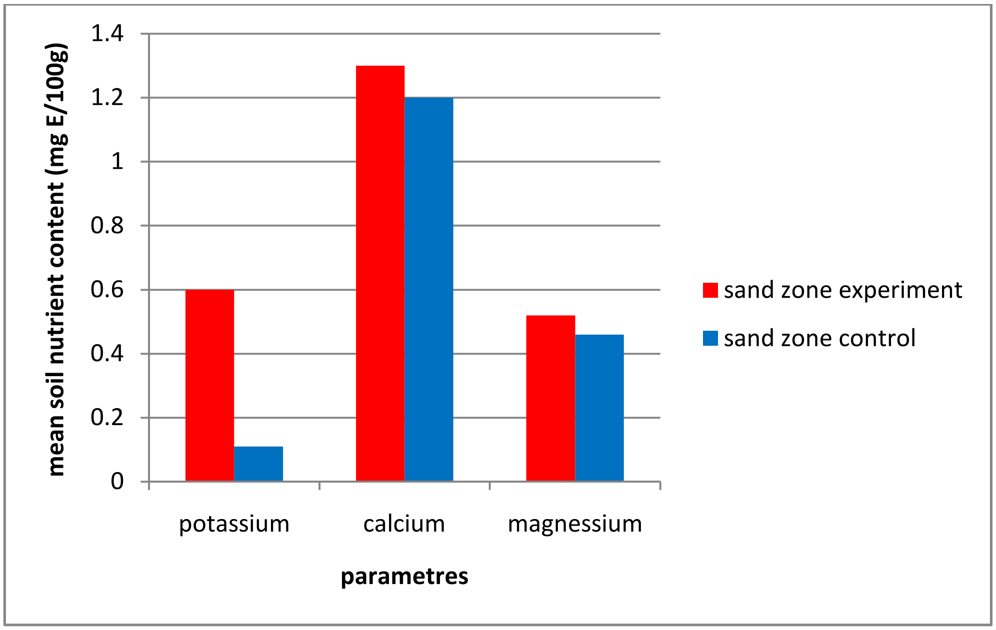

Figure 4.6 Average potassium, calcium and magnesium content (milligrams equivalent per 100g) in the Sand Zones.

There was a significant increase ($p<0.05$) in levels of potassium in the experiment points compared to the control points. As for calcium and magnesium there was no significant change ($p> 0.05$) as shown on Fig 4.7.

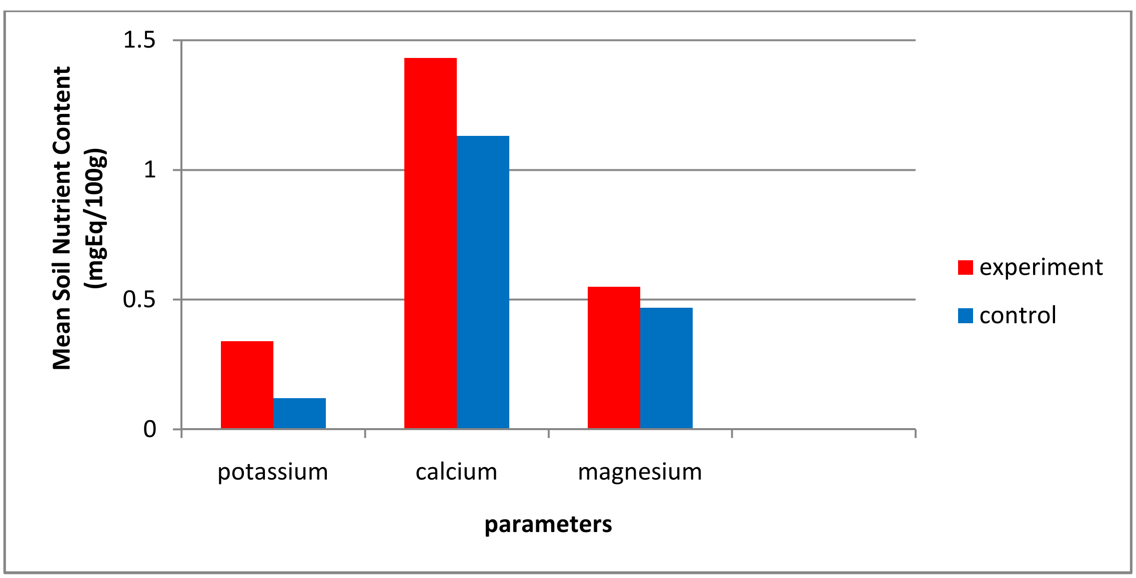

Figure 4.7 Average potassium, calcium and magnesium content (milligrams Equivalent per 100g) in the Gravel Zones

There is a significant increase ($p<0.05$) in the levels of potassium and calcium. As for magnesium there was no significant change ($p> 0.05$) (Fig 4.7).From the soil analysis results it is observed that impala faecal pellets contribute significantly to soil nutrient content. However the nutrient concentration is different in the two zones because of the difference in soil type. This is similar to what Burke et al, (1998) observed, that primary production and nutrient cycling differ in locations with different soil types. Ladd et al , (1993) stated that coarse soils have a low cation exchange capacity or nutrient holding cycling. However, this is different from what was observed in this research.

In this research, concentrations of nutrients under study varied in different soil types. Concentrations of nitrogen, potassium and the pH level were high in the sand zone and less in the gravel zone. And as for the concentrations of phosphorus and calcium were high in the gravel zone compared with the sandy zone. This was possibly due to influence of different soil types on different nutrients which could have been in the soil before the research. Also for points which were in the woodland the plant species near the points might also have influenced or altered nutrients available in the soil, (that is utilizing the nutrients before the soil sample analysis).

4.5 Influence of season on the time taken by impala faecal pellets to disappear from the ecosystem

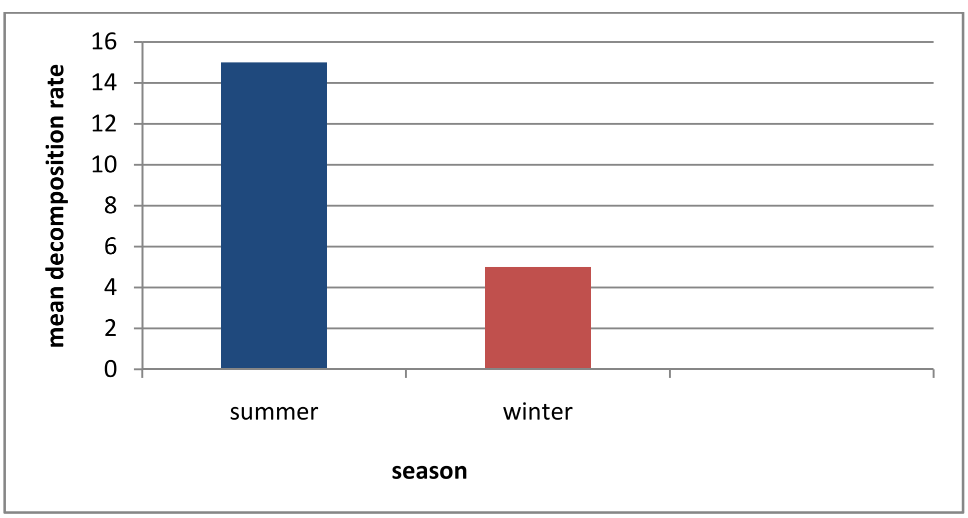

Figure 4.8 Comparison of the impala faecal decomposition rate means for the summer and winter season.

Season significantly affects rate of decomposition of impala faecal pellets, hence influencing nutrient cycling. A paired samples t-test shows a significant increase ($t=2.077$, $df=9$, $p<0.05$) of impala faecal pellet decomposition rate in summer compared to winter season (Fig 4.8).

4.6 Effects of impalas on plant species diversity.

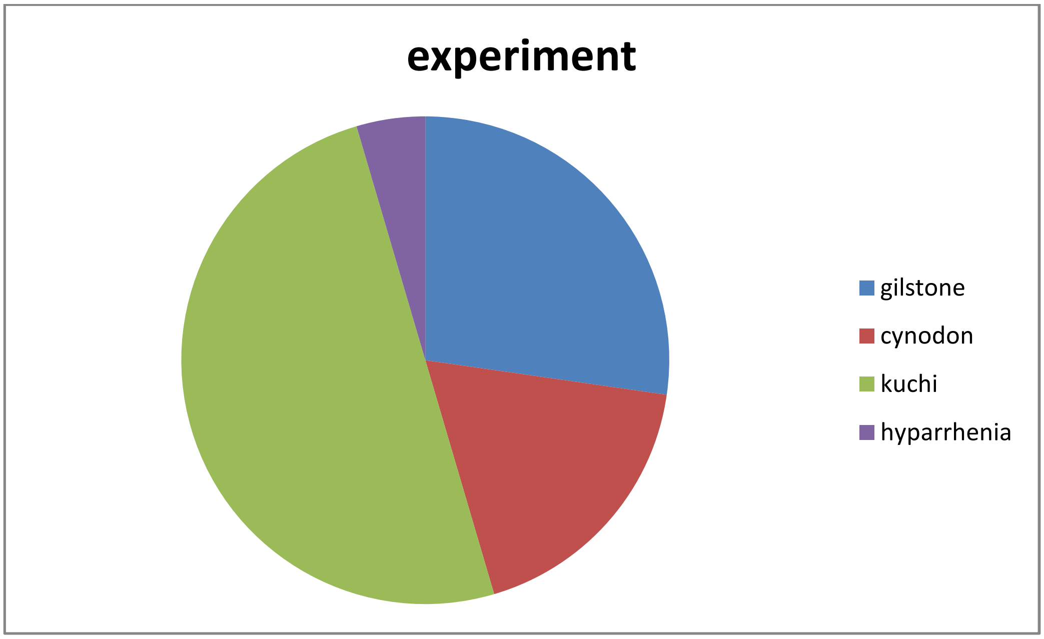

Figure 4.9 The effects of impala on plant species diversity on experiment.

Kuchi grass mainly dominates in the game reserve area, and this is where impalas are mostly found as evidenced by many medians (*a place where impalas defecates*) in this area, resulting in positive seed recruitments as shown on fig 4.9. Faecal matter acts as a fertilizer, which can promote seedling growth, and removal of seeds from the vicinity of the parent plant may reduce intra specific competition and promote gene flow.Impalas in Mukuvisi Woodlands also feed on gilstone and cydon grass which are found near water points.

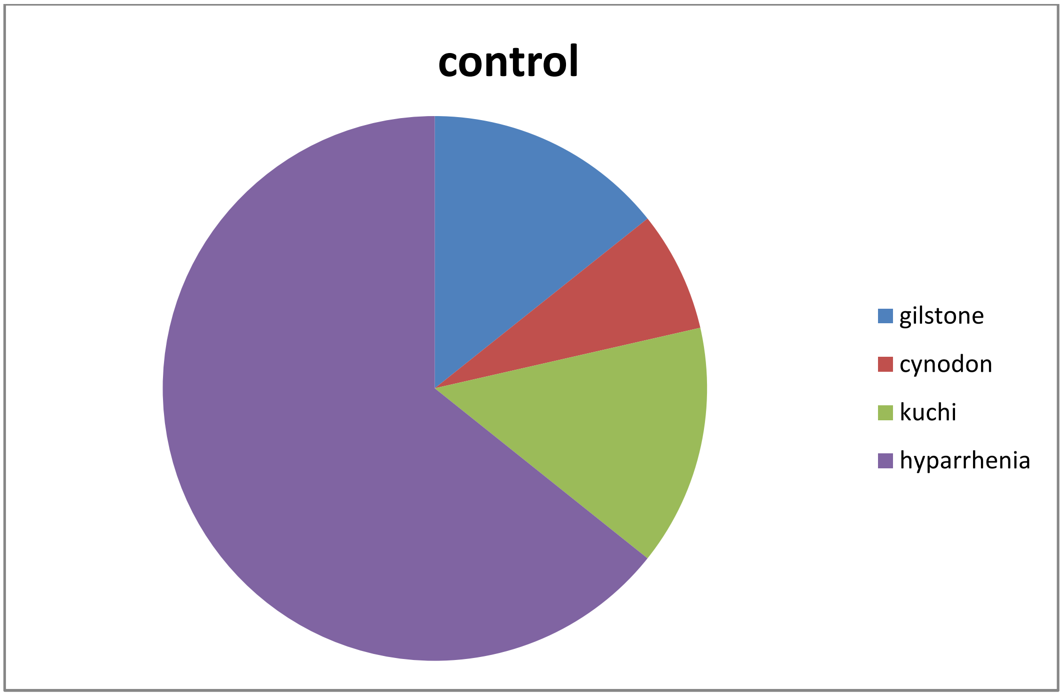

Figure 4.10 Effects of impala on plant species diversity on controlled site

Gilstone, cydon and kuchi grass where found on the control site, this was believed to be a result of seed dispersal due to impala movement as they are going to resting places. By ingesting grass seedlings, impalas transport seeds away from the parent grass, and either egests them in their faeces, or expel them orally during rumination and they collect pollen grains and disperse in resting places causing germination of different grass species. Hyparrhenia grass dominates the area since impalas do not feed on it (Fig 4.10).

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Soil type has a significant influence on the decomposition rate of impala faecal pellets. Therefore the null hypothesis which states that soil type has no significant influence on decomposition rate of impala faecal pellets is rejected in favor of the alternative hypothesis which says soil type has a significant influence on decomposition rate of faecal pellets.Impala faecal pellets decomposition rate due to insect activity was high in sandy soils unlike in gravel.It can be concluded that insect activity is also influenced by soil type. Season has a great influence on the time taken by impala faecal pellets to decompose. The decomposition rate was high in summer compared to winter season due to rainfall as Mukuvisi Woodlands is in a summer rainfall area. Impala faecal pellets significantly improve soil nutrient content, and here the null hypothesis which states that impala faecal pellets do not significantly improve soil nutrient content has been rejected in favor of the alternative hypothesis which states that impala faecal pellets significantly improve soil nutrient content. To sum up impalas contribute to nutrient cycling through defecation of faecal pellets which acts as fertilizer onto the ecosystem, thereby promoting seedling growth. They remove seeds from the vicinity of the parent plant which may reduce intra specific competition and promote gene flow of plant species though defecation and during oral rumination.

5.2 Recommendations

After assessing the contribution of impala faecal pellets to the nutrient cycle in varying seasons and its effects on plant species diversity in Mukuvisi Woodlands the following recommendations were made-:

- Mukuvisi Woodlands staff and National Parks Authorities should further studies focusing on the influence of different animal waste of various species on soil nutrient within the woodland so that they know which animal species to keep in order to enhance soil nutrient content since it’s a small woodland.
- Mukuvisi Woodlands staff should identify the main plant species that make up the impala diet within the woodland so that they plant more to reduce expenditure on supplementary food.

- Mukuvisi staff should provide supplementary food for the impalas in case of mineral deficiencies in natural feed in dry seasons.
- The Mukuvisi Woodlands management should control fires within the woodland, as this may result in nutrient loss when impala faecal pellets or waste from any other animal species within the woodland are burnt.
- The Mukuvisi Woodlands management should clear another water point by removing weeds so that impalas will have many drinking points thereby defecating at different points in the woodland, spreading the nutrients.

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APPENDICES

Appendix 1: Sample Field Data Sheet

Date…………………………………. **Observer………………………………………..**

Site………………………………….. **Soil type………………………………………**

Sample no	**No. of faecal pellets**	**Any insects observed on faecal pellets**	**Time taken for complete decomposition (in days)** Summer	Winter	**Decomposition rate**

Appendix 2: Soil Analysis Report

CHEMISTRY AND SOIL RESEARCH INSTITUTE, DEPARTMENT OF RESEARCH AND SPECIALIST SERVICES, MINISTRY OF AGRICULTURE

SOIL ANALYSIS REPORT

NAME MABASA ABIGAL

REFERENCE NUMBER......................

All results are expressed in terms of the air-dried sample passed through a 2-mm sieve.

Laboratory number	Your Reference	Colour (See key below)	Texture (see key below)	pH (calcium chloride)	Free Carbonate (see key below)	Conductivity micromhos	Total Nitrogen %	Mineral Nitrogen Parts/million Ammonia + Nitrate N		Available Phosphorus Resin Extract Parts/million of P2O5	EXCHANGEABLE CATIONS mg equivalents per 100g			
								Initial	After incubation		Potassium	Calcium	Magnesium	Total bases
23/PS	A SAMPLE A	PB	Mgs	5·5				76	105	50	1·09	6·06	1·94	
24/PS	B SAMPLE B	PB	Mgs	5·4				51	87	43	0·83	6·75	1·99	
25/PS	G1C	PB	Mgs	5.5				4	60	38	0.47	1.41	0.57	
26/PS	G1E	PB	Mgs	5.0				5	46	17	0,20	1,13	0,61	
27/PS	S1C	PB	Mgs	4.7				8	27	10	0,11	1,58	0,53	
28/PS	S1E	PB	Mgs	5.5				28	33	10	0.28	1,72	0,52	
29/PS	S2C	PB	Mgs	4.8				4	30	13	0.11	0,83	0,38	
30/PS	S2E	PB	Mgs	6.2				30	74	25	0.91	0,84	0.52	

COLOUR KEY

R = red or redish
Y = yellowish or yellowish
B = brown or brownish
G = grey or grayish
W = White
BL= black
O = olive

d = dark
I = light
P = pale
s = strong
wk= weak
du = dusky
v = very

TEXTURE KEY

S = sand
LS = loamy sand
L = loam
CL = clay loam
C = clay
HC= heavy clay

Sa = sandy
Si = silty
fg = fine grained
mg = medium grained
cg = course grained
v = very

CALCIUM CHLORIDE pH VALUE

Below 4, 0, extremely acid
4,0 to 4,5, very strongly acid
4,5 t0 5,0, strongly acid
5,0 to 5,5, medium acid
5,5 to 6,0, slightly acid
6,0 to 6,5, neutral
6,5 to 7,0, mildy alkaline
7,0 to 7,5, alkaline
above 7,5, strongly alkaline

FREE-CARBONATE KEY

T = trace
S = small amount
M = moderate amount
L = large amount