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Dynamics of diet quality of large herbivores in Senegal

Diploma thesis

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I hereby declare that this thesis entitled Dynamics of diet quality of large herbivores in Senegal is my own work and all the sources have been quoted and acknowledged by means of complete references.

In Prague 24.4.2015 Oldřiška Kučerová

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Abstract

Dynamics of diet quality of large herbivores in Senegal

This thesis is focused on the diet quality of large herbivores, their feeding strategies and their partitioning of forage resources. Particularly were examine concentrations of macro elements (nitrogen, phosphorus, calcium, magnesium and potassium) and fibre fractions (NDF, ADF and lignin) from the faeces of the large herbivores from two reserves in Senegal (Bandia and Fathala) Data from faeces were evaluated for content of macro elements and fibre fractions and compared from different points of view. There was evaluated difference between five species of large ungulates (*Taurotragus oryx*, *Taurotragus derbianus*, *Syncerus caffer brachyceros*, *Hippotragus equinus* and *Equus burchelli*), between animals with grazing, browsing and intermediate foraging strategy and difference between different morphological adaptations of digestive tract. The results show how the concentrations of macro-element and fibre fractions fluctuate during different seasons in reserves Bandia and Fathala and how are concentrations influenced by species, morphology or foraging strategy. Lowest concentrations at ruminant species suggest that non-ruminants have lower diet quality than ruminants ad high concentrations at browser can be affected by reserves management.

Key words: foraging ecology, antelope, nitrogen, phosphorus, West Africa

Abstrakt

Dynamika kvality potravu u velkých býložravců v Senegalu
Tato práce je zaměřena na kvalitu potravy velkých býložravců, jejich potravní strategie a jejich rozdělení pastevních zdrojů. Konkrétně byly zkoumány koncentrace makro prvků (dusík, fosfor, vápník, hořčík a draslík) a frakce vláknin (NDF, ADF a lignin) ve výkalech velkých býložravců. Údaje z fekálií byly vyhodnoceny na obsah makro prvků a vláknin a porovnány z různých úhlů pohledu. Byl hodnocen rozdíl mezi pěti druhy velkých kopytníků (*Taurotragus oryx*, *Taurotragus derbianus*, *Syncerus caffer brachyceros*, *Hippotragus equinus* and *Equus burchelli*), mezi pasoucími se zvířaty, zvířaty preferujícím okus a zvířaty spojující obě předchozí strategie a rozdíl mezi různými morfologickými adaptacemi trávicího traktu. Výsledky ukazují, jak se pohybují koncentrace makro-prvků a vláknin v různých ročních obdobích v rezervacích Bandia a Fathala a jak jsou koncentrace ovlivněné druhem zvířete, morfologií a potravní strategií. Nejnižší koncentrace u ne-přežvýkavců naznačují, že ne-přežvýkavci mají nižší kvalitu potravy než přežvýkavci a vysoké koncentrace N u zvířat preferujících okus, mohou být ovlivněny vedením rezervací.

Klíčová slova: potravní ekologie, antilopa, dusík, fosfor, západní Afrika

Obsah

1. Introduction

1.1 Digestive tract of animals

Division of digestive tract of large mammalian herbivores can be based on type of digestion. First group uses autoenzymatic digestion which means that animals use their own sets of digestive enzymes. Other three groups use microbes for digestion groups are called alloenzymatic. First alloenzymazic group differ by place where digestion occurs. The biggest part of digestion happens in hind-gut. This group can be generally called non-ruminants with simple one chambered stomach. The other two groups have foregut fermentation and generally can be called ruminants (Caroline *et al*, 2003).

1.1.2 Non-ruminants - Hind-gut fermenters

First step of the hind gut fermentation is the chewing and swallowing of food which than goes to esophagus tube which runs from the back of the oral cavity (pharynx) to the stomach. Food is passed down the esophagus by peristalsis which is the contraction and relaxation of muscles, pushing food down to the stomach in wave like motion. Chewed food stopped in the stomach which has some important roles in digestion. Stomach serves as a reservoir for food, a sterilizing chamber, due to the low pH (high acid content – HCL), a churning chamber to mix food with digestive gastric juices , the initial site of protein digestion, primarily by pepsin – secreted by the epithelial lining of the stomach. Food is moved to the next site of digestion, the small intestine, by peristalsis. The small intestine is a long and narrow ‘tube’ with a structure and epithelium that maximizes surface area. This is important because the small intestine is the primary site of digestion by enzymes. Food continues to travel along the small intestine by peristalsis. The small intestine can be divided into the duodenum, jejunum and the ileum. The pancreatic duct connects the pancreas to the duodenum – the majority of the digestive enzymes enter the small intestine by this duct. To aid in lipid digestion, bile is secreted by the liver (stored in the gallbladder). Bile emulsifies lipids which gives them a larger surface area, increasing enzyme efficiency. The small intestine joins to the large intestine, which consists of the enlarged caecum, colon and rectum. Due to the large amounts of fiber and other difficultto-digest components of the diet, the complete digestive tract is much longer. Caecum is site of bacterial fermentation. The majority of food reaches the caecum undigested. Bacterial fermentation occurs in the caecum and colon allowing some volatile fatty acids to be absorbed, but then the digested food is excreted (along with the micro flora) (Vetsci, 2010).

1.1.2 Ruminants – Fore-gut fermenters

Fore-gut fermenters are animals which ferment their food before it reaches the 'true' stomach. The stomach of a ruminant exists as four chambers which are the **rumen, reticulum, omasum** and **abomasum** (true stomach). Ruminants digest food more efficiently than hind-gut fermenters as they are able to consume food into the rumen – the site of fermentation, allow microbial digestion and then regurgitate the 'cud' and chew it more. This means by the time the ingested food reaches the abomasum, all the extractable nutrients have been metabolized (some micro flora from the rumen may also be digested in the abomasum which increases nutrient intake) (Vetsci, 2010).

1.2 Feeding strategies (bulk and roughage eaters, concentrate selectors, intermediate types)

It is obvious that different types of digestion need different amount food. According to Van Soest (1994) and Hofmann (1989) the basic division of herbivores is division into three groups according their food preferences. Those categories are: concentrate selector intermediate feeder and bulk and roughage feeder. Concentrate selectors are for example dikdik (*Madoqua kirkii* Günther, 1880) or giraffe (*Giraffa camelopardalis* Linnaeus, 1758). Intermediate feeders are for example Thomson gazelle (*Eudorcas thomsonii* Günther, 1884) or impala (*Aepyceros melampus* Lichtenstein, 1812). Bulk and roughage feeders are for example buffalo (*Syncerus caffer* Gray, 1837) or oryx (*Oryx gazella* Linnaeus, 1758) (Hofmann, 1989). Concentrate selectors can be further divided in to fruit and foliage selectors and tree and shrub browsers. Intermediate feeder according their name can prefer forbs or browsing or prefer grass. Bulk and roughage feeders are divided in three subgroups too. Those subgroups are fresh grass grazers, roughage grazer and dry region grazers. Concentrate selectors are in base connected mainly with browsing animals and bulk and roughage feeders are connected in base with grazing animals that is the reason why is this system mainly based on the proportion of grass matter in the total amount of food.

This system also counts with low food selectivity at grazers and high selectivity at browsers. This prediction is in most of cases valid, but there are some exceptions of very selective grazers and very tolerant browsers.

Main difference between concentrate selectors and bulk and roughage feeders is in the ability to digest fibres; all food preferences and feeding strategies are influenced by that. Concentrate selectors are not able to digest or even tolerate large amounts of fibres amounts of fibres and from that reason they have to feed on low-fibre portion of plants. They are adapted on browsing. Bulk and roughage feeder otherwise are able to tolerate huge amounts of fibre, and their digestion is able to digest cell wall components. It is obvious, that bulk and roughage feeders can feed on plants in large amounts. Those animals prefer graze than browse. Name intermediate feeder shows that animal sort into this category are mix of both groups. They are able to adapt themselves to browsing and grazing in one time. Some of intermediate feeders can eat relatively large volumes of feed but in their digestive tract is used of plant cell wall components is only limited. They change their feeding behaviour according the possibility of forage (Van Soest, 1994).

With the adaptation on different diet related adaptation of morphology. Concentrate selectors have larger salivary glands, bigger liver, large reticulum, thin pillars, small abomasum, small simple rumen, small omasum, shorter intestine (in comparison with bulk and roughage eaters). They have rapid passage trough digestive tract with high fermentation rata. Bulk and roughage eaters have small salivary glands, small liver, large rumen, small reticulum, 2-3 distinct blindsacs, larger abomasum, large omasus, very long intestine (in comparison with concentrate selectors) (Hofmann, 1989).

There is a theory that short-term food intake often increases with plant biomass. First case occurs at ad libitum feed intake which can declines with biomass due to a reduction in digestive tractis associated with the digestion of low quality forage of senescent plants. This can lead us to the prediction that daily energy intake should be maximized at intermediate biomass (Bergman *et al*, 2001).

1.3Minerals

In the simplest way the term ‘food’ describes all edible materials. For example grass and hay, if we are talking about herbivores. In more scientific way is possible to say that food is material that, after ingestion by animals, is capable of being digested, absorbed and utilised. The components capable of being utilised by animals are described as nutrients. Main components of food are water and dry matter. Dry matter is divided on organic and inorganic matter. Organic matter is divided on carbohydrates, lipids, proteins, nucleic acids, organic acids, vitamins and minerals (McDonald *et al*, 2002).

1.3.1 Function of minerals

In first part let a take a closer look at minerals. Minerals have some necessary functions in animal live.

One of them is structural function. Minerals can form structural components of body organs and tissues. This function performs mainly calcium, phosphorus and magnesium. In the body is possible to find them in bones and teeth (for example silicon) and in muscle proteins (phosphorus and sulphur). Zinc and phosphorus are parts of molecule membranes and help to keep their stability.

Other function of minerals is physiological function. This function perform minerals occur in body fluids and tissues as electrolytes concerned with the maintenance of osmotic pressure, acid–base balance, membrane permeability and transmission of nerve impulses. As an example of minerals providing this function is possible to present sodium, potassium, chlorine, calcium and magnesium in the blood, cerebrospinal fluid and gastric juice.

Next function is catalytic function. Minerals can act as catalysts in enzyme and endocrine systems, as integral and specific components of the structure of hormones or as activators (coenzymes) within those systems.

Last but not least is regulatory function. Minerals regulate cell replication and differentiation. This is shown on calcium ions which influence signal transduction and selenocysteine influences gene transcription (Suttle, 2010).

1.3.2 Macro and micro elements

Minerals can be divided into macro elements which are: calcium, phosphorus, potassium, sodium, chlorine, sulphur and magnesium; and into minor elements which are: iron, zinc, copper, molybdenum, selenium, iodine, manganese and cobalt. This division is based on essential need of particular element. Need of major elements is usually measured in g/kg and need of trace element is usually measured in mg/kg (McDonald *et al*, 2002).

1.3.2.1 Calcium

Calcium is the most abundant mineral element in the animal body. Calcium has an important role in the skeleton and teeth. In bones and teeth is possible to find almost 99% of calcium presented in body. Calcium is essential constituent of living cells and tissue fluids and is essential for the activity of a number of enzyme systems, including those necessary for the transmission of nerve impulses and for the contractile properties of muscle. Another important function of calcium is its role in blood coagulation.

It is obvious that lack of calcium can lead to fatal problems with skeleton. Adequate intake of calcium is mostly important in young animals. The lack of calcium at young animal can cause illness called ricket which is presented by bad bone formation (misshapen bones, enlargement of the joints, lameness and stiffness). In adult animals lack of calcium can cause osteomalacia when bones become weak and easily broken. Adequate intake of calcium is important for milking females. Lack of calcium in this state can cause illness known as milk fever. Animal with milk fever have muscular spasms and in extreme cases it can lead to paralysis and unconsciousness (McDonald *et al*, 2002). Of course at avian species is calcium necessary for egg shell creation. Absorption of calcium from food is happening in small intestine under the control of parathyroid hormone (PTH) and the physiologically active form of vitamin D3, dihydroxycholecalciferol (1,25-(OH)2D3, also known as calcitriol) (Suttle, 2010).

1.3.2.2 Phosphorus

Phosphorus is associated with calcium processes in the bones, occurs in phosphoproteins, nucleic acids and phospholipids. It plays a vital role in energy metabolism in the formation of sugar-phosphates and adenosine di- and tri-phosphates. In bone is possible to find 80-85% of phosphorus the reminder is in the soft tissues and fluids. Same as calcium lack of phosphorus at young animals can cause rickets and osteomalacia. Other illness caused by lack of phosphorus is depraved appetite known as pica. Animals with this illness have abnormal appetite and they are used to chew wood, bones, rags and other foreign materials. Chronic phosphorus deficiency can lead to stiff joints and muscular weakness. Low intake of phosphorus can lower fertility of animals, lead it to dysfunction of ovaries and depression or irregularity of oestrus (McDowell & Arthington, 2005).

1.3.2.3 Potassium

Potassium is very important for osmotic regulation of the body fluids and in the acid base balance in the animal. It is a one of main cations of extracellular tissue fluids and it is principally the cation of cells. Potassium plays an important role in nerve and muscle excitability and takes a part at carbohydrate metabolism.

Lack of potassium is very rare in mild climate, but more common in tropical and subtropical zones, where is primarily lack of potassium in soil and thereby is lack of potassium in plant tissues and grazing animals have low opportunity to get to the natural potassium. Deficiency of this element can cause retarded growth, weakness and tetany followed by death. Other symptom of deficiency is paralysis (McDowell & Arthington, 2005).

1.3.2.4 Magnesium

Magnesium is same as calcium and phosphorus mainly in skeleton. It is possible to find almost 70% of magnesium in bones and the rest of it is distributed in soft tissues and fluids. Magnesium is the most common enzyme activator; it is involved in cellular respiration and many other cellular reactions. Magnesium ions moderate neuromuscular activity and are in cell membrane integrity for its ability to bind phospholipids.

First symptoms of magnesium deficiency are increased nervous irritability and convulsions. Those symptoms are mainly observed at juveniles. In adults even in young is possible to find hopomagnesaemic tetany, which is associated with low levels of magnesium in blood. This illnesses have very fast develop and among clinical sings belong nervousness, tremors, twitching of the facial muscles, staggering gait and convulsions (Suttle, 2010).

1.3.3 Nitrogen

The biggest amount of N comes to the animal body from proteins and nucleic acids. Proteins are complex organic compound. They contain carbon, hydrogen and oxygen, but in addition they all contain nitrogen and generally sulphur. Proteins are found in all living cells, where they are intimately connected with all phases of activity that constitute the life of the cell. Nucleic acids are high-molecular-weight compounds that play a fundamental role in living organisms as a store of genetic information; they are the means by which this information is utilised in the synthesis of proteins. Nucleic acids are a mixture of basic nitrogenous compounds (purines and pyrimidines), a pentose (ribose or deoxyribose) and phosphoric acid.

Faecal N is just a residue from digestion of proteins (McDonald *et al*, 2002).

1.3.4 Fibre fractions

The matrix of cell walls is comprised cellulose, hemicellulose, pectins, lignin and small amount of bound protein. Cellulose is the most common part of plant and is consisted of glycosidic linkage, monometric sugars and phoysaccharide chains. Hemicellulose is non-cellulose polysaccharide fraction that is readily hydrolyzed with acid. Pectin is composed of chains of galactouronic acid galactans and arabinans. The toughest path of cell walls is lignin polymer of phenylpropanoid units. Another compound of cell walls can be chitin. Chitin is polysacharid comprising chains of N-acetyl-D-glucasamin (Caroline *et al*, 2003).

A method how to analyze plant cell walls that can be applied across in many fields is detergent analysis. This method yields the neutral detergent fibre (NDF; hemicellulose, cellulose, and lignin), acid detergent fibre (ADF; cellulose and lignin), and acid detergent lignin (ADL) fractions of plant cell walls (Codron *et al*, 2006).

1.4 Diet quality

One of the best measurements of diet quality is faecal nitrogen which reflects percentage of crude protein in diet. Crude protein is method how to measure total amount of proteins in the food by multiplying total amount of faecal nitrogen. Those are factors which influence total food quality. Lower values of faecal nitrogen mean lower protein intake and lower food quality. Another factor influencing diet quality is total amount of fibres in faeces. Codron *et al* (2007) show in their research that diet quality is tightly connected with body mass. With increasing body size the intake of grass is increasing. While grass intake is increasing, the level of diet quality remains similar. Comparison between large grazer and small browsers shows that browsers usually eat more nutritionally valued food like sterns and shoots and large grazer take less nutritionally valued grass. But in closer look we can see, that tree parts have higher content of low digestible lignin in contrast with fibre highly digestible grasses the diet quality doesn't differ very much (Codron *et al*, 2007).

Dörgeloh *et al* (1998) use the faecal nitrogen for estimation diet quality in their research of roan antelopes. Levels of faecal nitrogen and faecal phosphorus were used for estimation forage digestibility between seasons and concentrations of proteins and fibres were used for estimation of seasonal forage quality. Concentrations of N were highest from January to March and concentrations of P were highest from October to December. Lowest concentrations of both elements were during July to September. That shows that best forage is during summer (related to wet season) when protein content is high and content of fibres is low (Dörgeloh *et al*, 1998).

The lack of nitrogen in food during winter confirm too Wrench *et al* (1997) and add information that content of tannins in browse can increase faecal nitrogen (Wrench *et al*, 1997).

1.5 Resource partitioning

The term resource partitioning gives us quite good clue to imagine what it means. We can talk about resource partitioning when two or more species have to share some source of energy, like food or water. We can distinguish three different types or resource partitioning. First is temporal partitioning. This category is based on simple principle: one resource is shared by animals in different time. Good example can be representatives from genus *Acomys*. Those insectivorous mice feed on same insect and to avoid competition, one spiny mouse feed on it during the day and the other during the night. Time schedule is not limited only by diurnal cycle, but can be long term (Kronfeld-Schor and Dayan, 1999).

Second type is spatial partitioning. This type is very simply and we talk about spatial partitioning when two competitive species use the same resource by occupying different habitats within the range of occurrence of the resource. This partitioning can be very broad scale: from microhabitat differentiation to geographical differentiation (Bastolla *et al*, 2005).

The last type of resource partitioning is morphological differentiation. This name is used, when two competing species evolve differing morphologies, to allow them to use a resource in different ways. As an example of this morphological differentiation can by bumblebees. Bumblebees with long proboscis will more often feed on flowers with long corolla and bumblebees with short proboscis will more often feed on flowers with short corolla (Pyke, 1982).

In Africa is resource partitioning is in general different between dry and wet season. In the dry season the diets of all herbivores is considered mainly of grasses, followed by old grass stems and sheaths, and the leaves, flower buds and fruits. In the wet season the selection for grasses was much higher. Grass takes almost 90% of the animal diet (De Iong, *et al*, 2011). The next example shows Voeten & Prins (1999). They present example form Tanzania how the feeding sites of animals are changed during seasons. All groups of animals during early wet season have quite small and overlapping feeding areas which are growing with time. In the early dry season the feeding areas are very big and spread, sometimes overlapping, but in dry season get smaller (not so small like in wet season) and they are not overlapping (Voeten & Prins, 1999).

There is almost 46 ungulate species in Africa in different sizes. Those different sizes help to sort ungulates into the guilds. Of course there exists separation between browsing and grazing guilds and between different high ungulates in browsing guild. With this is connected Jarman-Bell Principle which says that an increase in ungulate body size is associated with an increase in dietary tolerance. Dietary tolerance is measured by digestibility of herbage which can animal tolerate as food. In contrast with small guild herbivores, which prefer feed selectively on the highest quality food, guild of larger herbivores are able to accept more abundant food of lower quality, because their body requirement force to accept such kind of food. Smaller size herbivores feed mostly on sterns; shoot ends or whole leaves in lower part of trees. Larger herbivores feed more on whole leaves which have lower quality than shoots and sterns (Woolnough & Toit, 2001).

2. AIMS of the thesis

The general aim of the thesis was to investigate the seasonal dynamics of diet quality and resource partitioning of five species (*Taurotragus oryx*, *Taurotragus derbianus*, *Syncerus caffer*, *Hippotragus equinus*, *Equus burchelli*) of large herbivores in two nature reserves with contrasting climatic and vegetation conditions in Senegal on the basis of nutrient content (macro elements and fibre fractions) in animal faeces.

The particular research aims were:

1) To determine the seasonal dynamics of diet quality of five species (*Taurotragus oryx*, *Taurotragus derbianus*, *Syncerus caffer*, *Hippotragus equinus*, *Equus burchelli*) of large herbivores in the Bandia and Fathala reserves in Senegal;
2) To compare the diet quality of the animals between different climatic and vegetation conditions of two reserves;
3) To compare the diet quality among animal species in each reserve;
4) To compare the diet quality among groups of animals with different foraging strategy (grazers, browsers, intermediate feeding type) and different physiology (ruminant and non-ruminant species).

3. Materials and methods

3.1 Study areas

3.1.1 Bandia Reserve

The study area is a fenced part of classified forest Bandia, laying 65 km south-east of Dakar, capital of Senegal (14°35'N, 17°00'W). The Bandia Reserve(3500 ha) lays on the south-western border of forest on banks of Somone River due to which there are sandy soils impoverished by leaching, clay and salty soils on the mostly flat area of the reserve. Rainy season in the Bandia Reserve lasts from July to October with mean annual precipitation of 484 mm (350-742.4 mm). The average temperature is 25°C in January when is middle of dry season and 30°C in September when is high dry season (Hejcmanová *et al.*, 2010).

Phytogeograpically the Bandia Reserve belongs to Sudan-Sahelian area where original vegetation is made up of *Acacia ataxacantha-Acacia seyal* bush land. Because of high state of degradation in time of fencing area we can find areas with dominant grass cover. These originally tree abundant areas were deforested due to fuel wood harvesting and cattle grazing. Dominant grass species are *Brachiaria distichophylla*, *Brachiaria lata*, *Digitaria velutina*, *Pupalea lappacea*, *Penisetum violaceum*, *Digitaria abyssinica*. Other herbaceous species are representative mainly by *Blainvillea gayana, Cassia tora, Corchorus sp., Indigofera sp., Sesbania sesban* and others. As a sign of restoration of ecosystem can serve *Calotropis procera* which quickly colonises newly created biotopes and represent a stage of development of newly restored savannah. In the bushy savannah, which is second stage of restoration, is possible to find species as *Acacia ataxcantha, Acacia macrostachya, Acacia seyal* and *Tamarindus indica.* The oldest part of reserve involved a tree and bush savannah where is dominant original species like *Adansonia digitata, Acacia seyal, Balanites aegyptiaca, Boscia senegalense, Combretum micrantum, Grewia bicolor, Feretia apodanthera, Ziziphus mauritiana,* and others. Non original species are *Azadirachta indica* and *Eucalyptus alba*. By the river banks is possible to find *Khaya senegalensis, Lonchocarpus sericeus, Lonchocarpus laxiflorus, Celtis toka* and *Cordia senegalensis. Tamarix senegalensis* in river corridor is indicator of salt in the soil.

The Bandia Reserve is managed as a private nature game reserve for touristic and conservation purposes. There is quite high number of introduced animals. From other parts of Senegal from 1991-1999 were introduced African buffalo (*Syncerus caffer*), kob (*Kobus kob*), Defassa waterbuck (*Kobus ellipsiprymnus defassa*), roan antelope (*Hippotragus equinus*), red-fronted gazelle (*Gazella rufifrons*), dama gazelle (*Gazella dama mhorr*), bushbuck (*Tragelaphus scriptus*), warthog (*Phacochoerus africanus*), Nile crocodile (*Crocodylus niloticus*) and tortoise (*Geochelone sulcata*). In later years were introduced group of western Derby elands (*Taurotragus derbianus derbianus*) (Antonínová et al. 2006) and a group of Asian buffalo (*Buballus buballis*). From foreign countries from 1994 were introduced animals like Ostrich (*Struthio camelus*) from Holland. Other imported animals were caama hartebeest (*Alcephalus buselaphus caama*), blesbok (*Damaliscus dorcas phillipsii*), defassa waterbuck (*Kobus ellipsiprymnus ellipsiprymnus*), common eland (*Taurotragus oryx*), greater kudu (*Tragelaphus strepsiceros*), impala (*Aepyceros melampus*), giraffe (*Giraffa camelopardalis giraffa*), gemsbock (*Oryx gazella gazella*) and southern white rhinoceros (*Ceratotherium simumsimum*) (Nežerková *et al*. 2004).

3.1.2 Fathala Reserve

The Fathala Reserve (2000 ha) is a fenced part of the Fathala Forest in the Delta du Saloum National Park. This reserve lays in western Senegal (13°39' N 16°27' W). Fathala Forest Reserve was fenced in 2000.

Mean annual precipitation is 839 mm. The major rainy season last from November to May and the major rainy season last from July to October. Mean day temperature is 31.2°C in May and 26°C in January. Soils in Fathala Forest Reserve are mainly tropical ferric luvisols and nitrosols on plateaus and weakly developed gleyosols in the lower valley (Nežerková-Hejcmanová *et al.*2005). Vegetation in the Fathala reserve belongs to Sudanese and Sudano-Guinean savannah. The vegetation is made up of three main formations: wooded grassland, woodland, and transitional woodland on the plateaus, with vegetation types *Combretum nigricans-Prosopis africana* woodland, *Bombax costatum-Pterocarpus erinaceus* woodland, *Piliostigma thonningii-Dichrostachys cinerea* thicket turning in humid valleys to *Erythrophleum suaveolens-Dialium guineense* gallery forests. In grassy vegetation dominate *Andropogon gayanus* and *Schizachyrium sanguineum.*

Similarly as in the Bandia reserve, many animal species were introduced into the Fathala reserve. Native animal species in the reserve are bushbuck (*Tragelaphus scriptus*), warthog (*Phacochoerus africanus*) and patas monkey (*Erythrocebus patas*). From other parts of Senegal and other world were introduced roan antelopes (*Hippotragus equinus*), several heards of defassa waterbuck (*Kobus ellipsiprymnus defassa*), kob (*Kobus kob*) and African buffalo (*Syncerus caffer*). From Bandia were introduced giraffes (*Giraffa camelopardalis*), common elands (*Taurotragus oryx*), a pair of white rhinos (*Ceratotherium simum*) (Nežerková *et al*. 2004) and Western Derby elands within the conservation breeding programme conducted under the auspices of the Czech University of Life Sciences in Prague (Koláčková *et al*, 2011).

3.2 Investigated animals

Animal species for investigation were selected according to their food preferences, digestion type and their size. The selection covered large herbivores with weight variation about hundreds of kilograms (200-900 kg). Another criterion for selection was the presence of animals in the both reserves. African buffalo (*Syncerus caffer*), roan antelope (*Hippotragus equinus*), Common eland (*Taurotragus oryx*) and Western Derby eland (*Taurotragus derbianus derbianus*) were selected as representatives of ruminants. Plain zebra (*Equus burchelli*) was selected as the only one representative of non ruminant species.

Selected ruminant species belong to order Artiodactyla and family Bovidae. African buffalo and both elands belong to subfamily Bovinae. Roan antelope belong to subfamily Hippotraginae. Plains zebra belong to order Perissodactyla family Equidae (Wrobel, 2006). Into group of ruminants were sort *Taurotragus derbianus*, *Taurotragus oryx*, *Syncerus caffer* and *Hippotragus equinus*. Group of non-ruminants were presented by *Equus burchelli*. According their feeding strategies was created three groups named for simplification as grazer, browser and intermediate. Grazer group cover all bulk and roughage feeders and was presented by *Syncerus caffer* and *Equus burchelli*. Browser group cover all concentrate selectors and in this data was presented by *Taurotragus derbianus*. Intermediate group cover all intermediate feeders and was presented by *Taurotragus oryx* and *Hippotragus equinus* (Van Soest, 1994).

3.2.1 Common eland (*Taurotragus oryx* Pallas, 1766)

Common eland belongs to largest antelope species in the world. Males of common eland have height in shoulder 163 cm, average weight 500-600 kg and females measure 142 cm and weight 340-455 kg.

The horns are presented in both sexes. Males have 1-2 tight spirals thick and shorter (43-67 cm, mostly 54 cm) than females (51-69.6 cm, mostly 60.5 cm). Colour varies with geographical occurrence. General tawny colour darkening with age, youngest animals is reddish brown. All animals have narrow white stripes (10-16), dark dorsal crest, white marking on legs and black garters on upper forelegs and around hooves. Head is short and comparatively small with small narrow ears. At common eland is prominent dewlap starting on the neck and hock-length cow like tail with black terminal tuft (Estes, 1992).

Common elands are most spread in south-east part of Africa. Common eland are very adaptable. Their home range varies from sub desert environment, acacia savannah, *miombo* woodland, flood plains and mountains up to 4600 m. This variance of environment reflects extremely variable diet.

Elands are relatively good heat adaptation on desert conditions. They can survive almost without drinking and the water deprivation result with temperature changes of the body. To saving of water help producing of concentrate urine, excreting dry faeces, lowering the metabolic rate, slower and deeper breathing and behavioural adaptation (hiding in shadow during the heat of the day).

Eland are gregarious, non territorial and nomadic animals. Create unisexual or bisexual groups, there is bind between mother and calve. Herds of eland are entirely open. (Estes, 1992)

Elands feed mostly by browse. But some studies show that the average eland consumes a small but detectable fraction (18%) grasses. With this information we can sort them as intermediate feeders (Cerling *et al*, 2003).

3.2.2 Derby eland (*Taurotragus derbianus* Gray, 1847)

Males of Derby eland have shoulder height 150-176 cm and weight 450-950 kg. Females shoulder height is about 150 cm and weight 440 kg. Because of this body size is Derby eland often marked as giant eland (Nežerková *et al.*, 2004).

Neck dewlap of Derby elands begins on the chin. Horns of Derby eland are bigger, than horns of common eland (1-1.2 m). They have dark ruff on the neck, round ears. The coloration of derby eland is paler with less conspicuous markings.

Derby elands with shorter snout and narrowed hooves (in comparison with common eland) are adapted on the broad-leafed, deciduous *Isoberlinia* woodlands.

Range of critically endangered Derby eland is quite small because of low number of individuals. Main home range of Derby elands is in western Africa

Adaptations of Derby eland as its herd structure and patterns of behaviour are quite similar to adaptations of common eland (Estes, 1992).

Diet of Derby elands is mostly consisted from browse with very small amount of graze. Portion of grass in diet is lesser than 2%. According those information we sort derby eland into browser group (Hejcmanová *et al*, 2010).

3.2.3 West African buffalo (*Syncerus caffer brachyceros* Gray, 1837)

West African buffalo is geographic variation of African buffalo. It is spread in Guinea savannah, gallery forests, Sudan savannah and wettest parts of Sahel from Senegal to Cameroon. Horns are presented at both sexes in West African buffalo are cow-like with less well-developed bosses and shorter span in the bulls.

Buffalos can create from small to very large groups, where most animals stay whole life (Kingdon *et al,* 2013).

Buffalos have mostly grazing diet and their forage is consisted only from grass in 95% (Cerling *et al*, 2003).

3.2.4 Roan antelope (*Hippotragus equinus* Desmarest, 1804)

Forth largest antelope on the world is typical with sand-colour fur and long horns. Height of males is 126 – 126 cm and weight 280 kg weight of female is 260 kg.

Horns are curved, massive and heavily ringed, relatively short with length about 75 cm. Coloration is geographically changed from pale gray to rufous, with black mask and nostrils contrasting with white lips, jaws and eyebrows. Ears are light-colour with dark terminal tuft.

Both sexes are quite similar. Horns are present at both sexes. Males compared to females are more robust, mask is blacker, and pendant penile sheath often dark tipped.

Natural habitat of roan antelopes is associated with wooded savannah but is present in on grasslands and tree savannah, tolerate taller grass and higher elevations including montane grasslands.

As many other antelopes are roan antelopes herd animals. They keep in smaller herds of females and young animals. For group of females are typical 6 – 20 individuals in herd.

Males are very territorial and stay with female groups until 2 years. After leaving female groups young males create bachelor groups about 10 animals and stay there until sixth year.

Females are dominant and the oldest crow is the leader of group (Estes, 1992).

Roan antelopes are dominantly grazers to pure grazers. Grass part of forage has quite wide range (from55% to 89%) that is why we sort roans in this study in to intermediate types (Dörgeloh *et al*, 1998).

3.2.5 Plains zebra (*Equus burchelli* Gray, 1824)

Zebras are horse like animals with black and white stripes. Plains zebra is with male height about 127 – 140 cm and weight about 250 kg the smallest from all zebra species.

Zebras are very adaptable animals. They are primarily grazer and from that are deducing their habitat. Plains zebras live mostly on savannah habitats from treeless short grasslands to tall grasslands and open woodlands.

Zebras as most of Equids are non-territorial species living in one-male harems. Groups are consisting of one leading stallion and group of mares with young. In group is usually 5 – 6 females. Young males live in bachelor group. Number of individuals in bachelor group is from 2 to 15 animals (Estes, 1992).

Zebras are considered to be grazers based on the observations that they have 5±15% browse in their diets (Cerling & Harris, 1999).

3.3 Data collection

Samples of fresh faeces were collected at three sampling dates representing specific season: in December 2011 (cold dry season), April 2012 (hot dry season) and August 2012 (wet season) in the Fathala and Bandia reserves. Sample collection was combined with observation of animals to avoid collection of unidentified samples. Observed animals were adult males and females (not lactating, with any calves). From each reserve 4 -5 samples from one species in each sampling date were taken.

After collecting fresh samples, faeces were dried on place to avoid rot. Each sample were marked with code, where was written state, reserve, species, date of collection and number of sample. After transport were samples dried on 60°C for 72 hours and then were send in to EKO-LAB Žamberk for analysis nutrient content in 100% dry matter.

3.4 Chemical analyses of samples

From faeces the concentration of dry matter, potassium, calcium, magnesium, phosphorus, nitrogen, ADF (acid detergent fibre), NDF (neutral detergent fibre) and lignin were analyzed. All values of nutrient content were in g/kg.

The N concentration was determined using an automated analyser TruSpec (LECO Corporation, USA) by combustion with oxygen in an oven at 950 °C. Combustion products were mixed with oxygen and the mixture passed through an infrared CO_2 detector and through a circuit for aliquot ratio where carbon is measured as CO_2. Gases in the aliquot circuit were transferred into helium as a carrying gas, conducted through hot copper and converted to N. Faeces samples were burnt in a microwave oven at temperature of 550 °C and weighed in order to determine ash content. After that were samples mineralized using *aqua regia* and P, K, Ca and Mg concentrations were then determined in the solution using ICP-OES (Varian VistaPro, Mulgrave, Vic., Australia). NDF, ADF and lignin contents were determined by standard methods of AOAC (1984).

3.5 Data analyses

All analyses were carried out in the Statistica 12 programme (StatSoft, Tulsa).

All analysed data (concentrations of macro-elements and fibre fractions) were tested for the normality by Kolmogorov-Smirnov test and as they met assumptions of normality (all $P > 0.10$), parametric tests were used in all analyses.

Two-way analyses of variance (ANOVA) were used for all analyses according to particular questions and tests. The tested dependent variables were the concentrations of macro-element (N, P, K, Ca, Mg) and fibre fractions (NDF, ADF, lignin) in all analyses; analyses were performed for each macro-element and fibre fractions separately. The categorical predictors varied in analyses according to relevant question tested and were following: 1) concrete animal species (*Taurotragus oryx*, *Taurotragus derbianus*, *Syncerus caffer*, *Hippotragus equinus*, *Equus burchelli*) or foraging strategy (grazer, browser and intermediate) or type of digestion (ruminant and non-ruminant), 2) seasons (3 seasons: wet, dry, hot dry) or reserve (Bandia, Fathala), 3) the interaction of the two predictors entered in the analyses. After two-way ANOVA, the post-hoc HSD Tukey tests were performed to detect significant differences in ANOVA results.

4. RESULTS

4.1 Seasonal dynamics of diet quality of five species of large herbivores in the Bandia and Fathala reserves in Senegal;

The most common trend in comparison of minerals concentration in all species in Bandia and Fathala in all seasons shows that concentrations of macro elements are mostly comparable or higher in Bandia. Some species reach very high or very low values of nutrient concentration without high difference between reserves. But always there is exception in this trend like in the case of concentration of N *Taurotragus derbianus* which has higher values in Fathala than Bandia and the concentration of N in this specie is much higher than at any other species. Comparable is only values of concentration at *Taurotragus oryx*. Same phenomenon of difference in *Taurotragus* genera compared to others species we can observe in Ca levels where values get highest peaks in Bandia reserve. Interesting are very low concentration in P level in *Syncerus caffer* and *Hippotragus equinus* at Fathala reserve in comparison with other species (Fig 1). The next exception creates *Equus burchelli* which has in most macro elements with quite low concentrations, but in K its peak reach highest peak from all species. In comparison of high concentrations of *Equus* remain concentrations at *Hippotragus* with very low levels of K in Fathala reserve. (Fig 2)

Next to macro elements stays concentration of fibre (NDF, ADF and lignin) which are significantly higher in Fathala than in Bandia. The exception is concentration of NDF at *Taurotragus oryx* which is higher in Bandia. Between species are concentrations of minerals quite comparable. The biggest difference is in lignin concentration at *Taurotragus derbianus* where peak reach higher concentration than any other species and in ADF concentration, where *Syncerus caffer* reach in comparison with other species very low concentrations at Bandia reserve (Fig 2).

In case of concentrations of minerals influenced by seasons we can observe that that most common pattern shows highest concentrations of macro elements in wet season as it is in case of N, P and Mg (Fig 3). In cases of Ca an K wet season is highly comparable with dry season and hot dry season (Fig 4). Exception is *Taurotragus oryx* which has very high concentration of N in hot dry season, far higher than other species (Fig 3) and high concentration of K in hot dry season (Fig 4). *Equus burchelli* has very high concentration on K in wet season, far higher than other species (Fig 4) and very low concentrations of N in dry and hot dry season and similarly low concentration of Ca in wet and hot dry season. *Taurotragus derbian*us and *Taurotragus oryx* have in cases of P, Ca, and Mg highest concentration in wet season than any other species. The most noticeable is difference in Mg where peaks exceed all other concentrations. Quite well balanced concentrations in dry season are disrupted by concentrations of *Equus burchelli* in case of N and by very low concentration of *Syncerus caffer* in same macro element (Fig 3).

Difference in concentrations of fibres is obvious. There are significantly higher concentrations of NDF, ADF and lignin in dry and hot dry season than in wet season. Concentrations in dry and hot dry season are mostly balanced only exception are *Taurotragus oryx* in ADF and mainly lignin concentration where reach higher concentrations in hot dry season than other species and on the other side remains *Syncerus caffer* with very low concentrations in dry season in all three fibre fractions. Concentrations in wet seasons are quite low and comparable with one high peak in *Taurotragus derbianus* ADF and lignin concentrations (Fig 4).

4.2 Diet quality of the animals between different climatic and vegetation conditions of two reserves;

Most common pattern in wet season shows higher concentration in Bandia with few exceptions. Concentrations in Fathala are higher than in Bandia at *Taurotragus derbianus* in case of N and P, at *Taurotragus oryx* in case of P and Mg (Fig 5) and at *Syncerus caffer* in case of K (Fig 6). Biggest difference between reserves is at *Taurotragus derbianus* at N and P, where concentration in Fathala highly exceed concentration in Bandia, and at *Syncerus caffer* where concentration of Ca in Bandia highly exceed concentration in Fathala and same case at *Hippotragus equinus* concentration Mg. Species between them are quite comparable, only exceptions are *Taurotragus derbianus*, *Taurotragus oryx* with the highest concentration at N (only *Taurotragus derbianus*), P, Ca and Mg (only *Taurotragus oryx*) (Fig 5) and *Equus burchelli* which has the highest concentration of K (Fig 6).

Concentrations of fibre fractions are balanced with few extremes such as very low concentration of NDF and ADF in Fathala at *Taurotragus oryx* which create huge difference between Bandia and Fathala. Opposite extreme is very high concentration of lignin in Fathala at *Taurotragus derbianus* (Fig 6).

There is main problem with missing data from Fathala in dry season at *Taurotragus oryx* that may bias data. At other species are concentrations of N mostly balanced or little bit higher in Fathala. Concentrations of P are very high at *Equus burchelli* and *Taurotragus derbianus* in Fathala. Concentration at *Syncerus caffer* in Bandia is not so high at previous ones, but it significantly higher than concentration in Fathala at the same species. Concentration of Ca is only in one case higher in Fathala than in Bandia. It is in the case of *Equus burchelli* where concentrations in Fathala highly exceed concentrations in Bandia. *Syncerus caffer* are concentrations in both reserves balanced. In other species concentrations in Bandia highly exceed concentrations in Fathala. Concentrations of Mg are mostly balance with one high peak in Fathala at *Hippotragus equinus* (Fig 7). In concentrations of K outbalance higher concentrations in Bandia with exception, where *Equus burchelli* has higher concentrations in Fathala and this concentration exceed other species.

In case of fibre fractions is most common balance between reserves. This pattern is not valid at *Syncerus caffer* where concentrations in Bandia are lower than in Fathala in all three fibre fractions (Fig 8).

It is possible to say that concentrations in hot dry season are higher in Bandia than in Fathala. In case of P and Ca is this pattern corrupted only by missing data at *Taurotragus oryx* in Bandia which again can bias data at all observed minerals. In case of N is partly valid previous pattern and partly is possible to observe balance between reserves with exception at *Taurotragus derbianus* where concentration in Fathala is higher than in Bandia. Concentrations of Mg are mostly higher in Bandia and at *Equus burchelli* is concentration higher in Fathala (Fig 9). Concentrations of K are very similar to concentrations of N, where valid previous pattern and one exception at *Taurotragus derbianus* are shows concentration higher in Fathala. (Fig 10) There are some extremes between species where concentrations reach very high concentrations which exceed over other species. In case of N it is *Taurotragus oryx* in Fathala, in case of P it is *Syncerus caffer* in Bandia, in case of Ca it is *Taurotragus derbianus* in Bandia, in case of Mg it is *Syncerus caffer* in Bandia and *Taurotragus derbianus* in Bandia (Fig 9) and in case of K it is *Equus burchelli* in Bandia, *Taurotragus derbianus* and *Taurotragus oryx* in Fathala (Fig 10).

Fibre fractions are without exceptions higher in Fathala. Concentrations in Fathala are mostly comparable only at lignin is two higher peaks at *Taurotragus derbianus* and *Taurotragus oryx*. In Bandia are concentrations significantly lower than in Fathala and they are mostly comparable with higher concentration of NDF at *Equus burchelli*, very low concentration of ADF at *Syncerus caffer* and quite high concentration of lignin at *Taurotragus derbianus* (Fig 10).

4.3 To compare the diet quality among animal species in each reserve;

In Fathala all macro elements reaches the highest concentrations *Taurotragus oryx* and *Taurotragus derbianus*. In case of N *Taurotragus derbianus* reach highest concentrations in wet season and *Taurotragus oryx* in hot dry season. Other seasons and species are quite comparable slightly higher in wet season without any big extremes. In case of P both species reach the highest concentrations in wet season. Other species have normal concentrations slightly higher in wet season except *Equus burchelli* where concentrations reach very high peak in dry season. Absolutely same situation is in concentrations of Ca. There is one more extra ant that is lower concentration in wet season at *Syncerus caffer*. Concentrations of Mg are at *Taurotragus* genera the highest in the wet season and other species have higher concentrations in wet season to except *Syncerus caffer* with higher concentration in dry season (Fig 11). In case of K *Taurotragus oryx* and *Taurotragus derbianus* reach the highest values at hot dry season. On the same high concentration of K in wet and dry season are *Equus burchelli* and *Syncerus caffer* in wet season (Fig 12).

Fibre fractions are the highest in the hot dry season. At NDF all concentrations reach very high values except *Taurotragus oryx* in wet season where concentrations are very low and *Syncerus caffer* in wet season. Concentrations at other species are quite comparable. Concentrations of ADF are balanced in hot dry and dry season except *Syncerus caffer* where concentration in dry season is on the same level as concentration in wt season. In wet season are concentrations low, but balanced except *Taurotragus derbianus* where concentration in wet season is little bit higher. Lignin concentrations are the highest in hot dry season and the lowest in wet season. This pattern is corrupt only by *Taurotragus derbianus* where is concentration in wet season higher than in dry season (Fig 12).

In Bandia most macro elements the highest concentrations are in wet season. Without exception it is applied on concentrations of N. There are quite high concentrations in wet season, lower in hot dry season and concentrations in dry season are the lowest or comparable to hot dry season. Concentrations of P are highest in wet season at all species. Concentrations in dry and hot dry season are balanced. Concentrations of Ca are very variable; *Equus burchelli* has comparable very low concentrations in all season, *Hippotragus equinus* has high concentration in dry season and quite low concentrations in wet and hot dry seasons, *Taurotragus derbianus* has very high concentration in hot dry season and little bit lower concentration in wet and dry seasons, *Taurotragus oryx* has high concentration in wet season and lower in dry season, *Syncerus caffer*has comparable concentrations in wet and hot dry season and lower concentration in dry season. In concentration of Mg dominate wet season, where are concentrations the highest, except *Equus burchelli* where all three season have low, balanced concentration. Hot dry season has mostly higher concentration than dry season (Fig 13). Concentrations of K are quite low and perfectly balanced only at *Equus burchelli* reach concentration the highest values of all species (Fig 14).

Concentrations of fibre fractions are the highest in dry season except *Syncerus caffer* which has in all three cases concentrations in dry season lowest than other two seasons. In case of NDF the highest concentration reach *Equus burchelli* in dry season and the lowest concentration reach *Syncerus caffer*i n dry season. In case of ADF reach the highest concentration *Taurotragus derbianus* in dry season and the lowest concentration reach *Syncerus caffer* in dry season. In case of lignin the highest concentration reach *Taurotragusderbianus in dry season* and the lowest concentration reach *Equus burchelli* in wet season. Wet and hot dry season are in most cases comparable, only exception is *Equus burchelli* where are at concentrations of NDF and ADF quite big differences between these two seasons (Fig 14).

4.4 Diet quality among groups of animals with different foraging strategy and different physiology

Concentrations of nutrients of animals with different strategy in both reserves and all seasons are in the case of N very low at grazers and balanced concentration on both reserves; intermediates have slightly higher concentrations in Bandia and both reserves concentrations are higher than in grazers; browsers have higher concentrations in Fathala. Fathala concentration is the highest of them all and concentration in Bandia is comparable with intermediate concentration in Fathala. In case of P are results quite similar like previous ones, but there is no such significant difference between grazers and others. Concentrations of Ca concentrations in Bandia at intermediate and browser reach very high values, especially browsers ones. Concentrations in Fathala and Bandia at grazer are only slightly different between them and against the Bandia concentrations at intermediate and browser are quite low. Mg is quite similar to Ca, but concentrations at grazer are higher in Fathala, concentrations in Bandia are lowest of them all, and all concentrations in Fathala are higher than in previous case (Fig15). Potassium concentrations are opposite to others. There are higher concentrations at grazer in Bandia, and Fathala concentrations reach quite high values too. Intermediate have lowest concentrations, but balanced between reserves and browser have higher concentration in Fathala than in Bandia (Fig 16).

NDF concentrations reach the highest peak at grazer in Fathala followed concentration at browser in Fathala. Intermediate on both localities and concentrations in Bandia are similar. ADF concentrations are mostly balanced, only concentrations at browser in Fathala and concentration at grazer in Bandia are different. Browser concentrations in Fathala are the highest of them all ant grazer concentration in Fathala are the lowest of them al. Lignin concentration are rising step by step starting at grazer in Bandia, continues to grazer in Fathala, then goes to intermediate in Bandia and Fathala followed by browser in Bandia. Browser concentration in Fathala reaches the biggest concentration and creates biggest difference between reserves (Fig 16).

Changes in seasons on both localities are highest concentrations in wet season. Smaller concentration in wet season than other seasons is in case of Ca at grazer (Fig 17) and in case of K at intermediate and browser (Fig 18). In previously mentioned cases are differences between seasons quite small. The biggest differences are mostly at browser in

N, P and Mg (Fig 17) and at grazer K concentration where concentrations at wet season reach very high concentrations and exceed other seasons (Fig 18).

Fibre fractions have the highest concentrations at hot dry season in all animal groups except browser NDF concentration where all seasons are very similar and dry season is slightly higher. Lowest concentration at NDF reaches intermediate at wet season and at ADF at grazer and intermediate in wet season (Fig 18).

In the wet season grazers and intermediate types have higher concentrations of macro elements in Bandia and browsers have mostly balanced or slightly higher in Fathala. Exception is higher concentration of Mg in Fathala at grazer (Fig 19, Fig 20).

Concentrations of fibre fractions are at grazers and browsers balanced or higher in Fathala and intermediate types have higher concentrations in Bandia (Fig 20).

At all macro elements have grazer types during dry season higher concentrations in Fathala. Intermediate types have higher concentrations in Bandia in case of N, P, Ca (Fig21) and K (Fig 22). Concentration of Mg is higher in Fathala. Browsers have higher concentration mostly in Fathala only concentration of Ca (Fig 21) and K (Fig 22) is higher in Bandia. Concentrations of P have very big differences between reserves at grazers and browsers. In case of Ca are quite big differences between reserves at all three groups (Fig 21).

Concentrations of fibre fractions are mostly balanced on the same level. In concentrations of NDF there is big difference between Bandia and Fathala at grazer and big difference between reserves is in concentration of ADF at grazer too (Fig 22).

Concentrations of P, Ca and Mg are in hot dry season the highest in Bandia. Browsers have very big differences between reserves in concentrations of Ca and Mg. Big difference between reserves have gazer in concentration of P. Concentrations of N are higher at Fathala in case of intermediate and browser type and balanced at grazer (Fig 23). Concentrations of K are higher in Fathala at intermediate and browser type and higher in Bandia at grazer. Intermediate and browser have between reserves quite big difference (Fig 24).

Fibre fractions are always higher in Fathala. Concentrations in Bandia are very low at all three cases. Concentration of lignin at browser in Bandia and concentration of NDF at grazer in Bandia are higher than other concentrations in Bandia. Others are quite balanced. There is a big difference between concentrations of lignin in Fathala at grazer and other two types (Fig 24).

In Fathala in all seasons concentrations of N are at grazer and browser the highest in wet season and at intermediate at hot dry season. In all three cases other season are balanced between them at each strategy type. Concentrations of P are at intermediate and browser higher in wet season and at grazer in dry season. In grazer and browser are other season different and at intermediate are balanced. Concentrations of Ca are the highest in wet season at browser, slightly higher in wet season at intermediate and high in dry season at grazer. Other season are balanced only at browser is small difference. Concentrations of Mg are higher in wet season at grazer and browser and intermediate type has balanced concentrations in wet and dry season. Between other seasons are quite big differences, only grazer has balanced concentrations in other season (Fig 25). Concentrations of K are at intermediate and browser higher in hot dry season and at grazer in wet season. At grazer is big difference between dry and hot dry season and small difference between wet and dry season. Other seasons at intermediate are comparable and at browser is dry season smallest (Fig 26).

Fibre fractions are highest at hot dry season. Concentrations of NDF are mostly comparable only concentration in wet season at intermediate is very low. Concentrations of ADF are the smallest at wet season higher in dry season and the highest in hot dry season. In Browser are wet and dry season balanced. In concentration of lignin is situation similar to previous one, only concentration at browser in wet season is higher than in dry season and almost balanced with concentration at hot dry season (Fig 26).

Most concentrations of macro elements are in the Bandia highest in wet season. In case of Ca is at browser concentration the highest in hot dry season, at intermediate is balanced between dry and wet season and at grazer is slightly higher concentration in hot dry season. Concentration of Mg is higher in hot dry season at grazer too (Fig 27). Concentrations of K are mostly balanced, with slightly higher concentrations in wet season, only at grazer peak in wet season highly exceed others (Fig 28). Other seasons are mostly without difference between seasons.

Fibre fractions are mostly the highest at dry season and other seasons are balanced or with small difference. Concentration of NDF at grazer is balanced between dry and hot dry season and same situation is in concentration of ADF at grazer. Concentrations of lignin at grazer are balanced (Fig 28).

Animals with different physiology in both reserves and in all season have concentrations of macro elements usually higher at ruminant species than in non-ruminant (Fig 29). Only exception is K concentration which is higher at non-ruminant species (Fig 30). In N concentration ruminant species have higher concentration peak in Fathala and non-ruminant species have higher peak in Bandia and difference in both animal types is very significant. P concentrations are balanced between reserves and higher in ruminant species. In case of Ca there is very high concentration in Bandia at ruminant specie, far higher than other concentrations. Non-ruminant species have very low concentration of Ca in Bandia and slightly higher in Fathala. Almost same situation is in concentrations of Mg, where non-ruminant species have low concentrations in Bandia and much higher in Fathala and ruminants have very high concentration in Bandia and lower in Fathala (Fig 29). Concentrations of K are absolutely opposite. There is very low concentration in both reserves in ruminant species and very high concentration at non-ruminant species in Bandia and lower concentrations in Fathala (Fig 30).

We can observe repeating pattern in fibre fractions, where all concentration at both types are higher in Fathala. Concentration of NDF in Bandia is higher in non-ruminant specie than in ruminant. In cases of ADF and lignin have higher concentrations in Bandia ruminant species (Fig 30).

Most common pattern in between concentrations between seasons shows highest concentrations in wet season in both categories. Concentrations of Ca are highest at non-ruminant specie at dry season and wet and hot dry season are balanced on very low concentration. In Mg concentration there is no significant difference between seasons in non-ruminant specie. Ruminant species have highest wet season concentrations and concentrations at dry and hot dry seasons are balanced or very slightly different (Fig 31). Only exception creates K, where is the highest concentration at hot dry season and all concentrations are very low compared to concentrations at non-ruminant species (Fig 32). Concentrations at wet season create usually big gaps between them and other seasons. Slightly comparable are exceptions mentioned before, therefore Mg at non-ruminant species (Fig 31) and K at ruminant specie (Fig 32). Comparable is distance between peaks at wet and dry season of P at non-ruminant specie (Fig 31).

Fibre fractions are lowest in wet season in all cases. Dry and hot dry seasons are balanced. There is no significant difference between dry and hot dry season (Fig 32).

During wet season in non-ruminant species are concentrations higher in Bandia except Ca where are concentrations identical and Mg where is concentration higher in Fathala. In ruminant specie is situation halt to half. Concentrations of N and P are higher in Fathala and concentrations of Ca and Mg are higher in Bandia (Fig 33). Concentrations of K at ruminant specie are identical. Concentrations of K are only case where non- ruminant species have higher concentrations than ruminant specie (Fig 34).

Fibre fractions are mostly higher at ruminant species in Bandia. NDF concentrations are higher at non-ruminant species and in Fathala is the highest concentration of NDF. ADF concentrations are quite balanced at non-ruminant species ant higher in Bandia at ruminant species. In case of lignin concentration at ruminant species are high and quite identical in both reserves and little bit higher in Bandia at non-ruminant specie (Fig 34).

Ruminant and non-ruminant species have higher concentrations of macro elements during dry season higher in Fathala only ruminant have higher concentration of Ca and K in Bandia. Biggest difference between reserves is in concentrations of P at non-ruminant specie. Quite big difference is in concentration of Ca at both types of animals (Fig 35). Biggest difference between ruminant and non-ruminant species is in concentrations of K (Fig 36).

Concentrations of fibre fractions are balanced or higher in Fathala. Biggest difference is in concentration of ADF at non-ruminant specie. Other concentrations of fibre fractions have relatively small or none differences.

Most of the macro elements have during hot dry season higher concentrations in Bandia, except concentration of N at ruminant species, concentration of Mg at non-ruminant species (Fig 37) and concentration of K at ruminant species (Fig 38). There are significant differences between reserves at both types, except non-ruminant concentration of N and Ca where are no or very small differences (Fig 37).

Fibre fractions are without exceptions higher in Fathala. Difference between reserves is not significant, only at non-ruminant species concentrations of lignin (Fig 38).

In Fathala concentrations are mostly higher in wet season in case of P and Ca is higher concentration in dry season at non-ruminant species. Concentrations in hot dry season are in most cases extremely low, or comparable to concentrations in dry season. In case of N is concentration at non-ruminant specie in hot dry season higher than in dry season (Fig 39) and so it is in concentrations of K (Fig 40).

Fibre fractions are the highest in hot dry season and concentrations are growing from wet to hot dry season. Only in case of lignin are concentrations in wet and dry season balanced (Fig 40).

Biggest concentrations of macro elements in Bandia are in wet season and other seasons are mostly balanced. In concentration of Ca we can observe slightly higher concentration in hot dry season at ruminant specie and balanced concentrations at non-ruminant specie. In concentrations of Mg is biggest difference between dry and hot dry season at ruminant specie (Fig 41). Concentrations of K shows all three seasons balanced at ruminant specie (Fig 42).

Fibre fractions are the highest at dry season and other season are balanced except case of NDF where concentration is in wet season lower than in hot dry season. Same situation is repeated in concentrations of ADF (Fig 42).

5. Discussion

Selection of diet is influenced by many factors. There are factors which are tightly connected with the animal anatomy. Those factors are body mass (connected mainly with energy intake), anatomical composition of mouth (this can influence the selectivity of animal and even possibility to intake some kind of browse or graze) and digestive system. Other factors which influence diet are mainly external environment factors. Between those factors belongs mainly composition of vegetation cover. In that case animals choose their diet according availability, acceptability, digestibility and chemical composition of their food (Olivier, 2007). If we aim on the levels of nutrients in Fathala and Bandia it is possible to observe that most grazers and intermediate animals have higher concentrations of macro elements in Bandia. In this reserve is dominant grass cover with very small amount of shrubs and trees, which is great environment for grazers (Hejcmanová, 2010). Grazers are able to digest highly fibrous material because of a larger rumen and slower passage of food through the digestive system, whereas browsers are considered to be concentrate selectors, foraging on an easily digestible diet rich in crude protein and with a low lignin content (Tixier *et al*., 1997). Fathala than is more rich on woody plants (Nežerková-Hejcmanová *et al*, 2005). That composition gives animals more opportunity for browse. This can explain why browse species (*Taurotragus derbianus*) and intermediate feeders (*Hippotragus equinus* and *Taurotragus oryx*) have higher concentrations of macro elements in Fathala. In case of Derby and common eland plays a significant role supplement feeding in the reserves. This consists of peanut hay, „Jarga“ granules produced in Senegal for horses and livestock (nutritional values: 87 % dry matter, 13.8 % proteins, 8 % cellulose, 0.5 % fats, 9 % minerals, 0.9 % phosphor, 1.2 % calcium), cotton seed and *Acacia albida* pods. In Fathala supplement feeding is mainly in hot dry season and in Bandia is whole year. In Fathala is supplement feeding available for other species in Bandia is available mostly for elands (Nežerková *et al*, 2004).

In both reserves we can observe high levels of fibre fractions. In Bandia are concentrations slightly lower than in Fathala. As it was said before Bandia has more grassland areas than woody Fathala (Hejcmanová, 2010; Nežerková-Hejcmanová *et al*, 2005). Digestibility of the fibres, mainly of NDF and ADF is derived from content of lignin it the plant species. High content of lignin can decrease the digestibility of the fibre. Even thou that content of

NDF and ADFis lower in the woody plants, higher content of lignin in those species lower whole digestibility of the browse (Codron *et al*, 2007). Concentrations of lignin are the highest in at the browsing *Taurotragus derbianus* and intermediate *Taurotragus oryx*. Very low concentrations of NDF at common eland are possible to explain by missing data which biased whole results. Digestibility of fibres at zebra is possible to explain by different digestion. Non-ruminant species are able to tolerate forage with higher concentrations of fibres (Macadanza& Owen-Smith, 2014).

The best indicator of diet quality is faecal nitrogen (Codron *et al*, 2007). Stapelberg *et al* (2008) indicate limiting concentrations of faecal nitrogen on 13-16 g/kg for grazers, for other ruminants is this level rover only 11-12 g/kg (Stapelberg *et al*, 2008). From results is obvious that most of the animal are over this limiting value, but concentrations at zebra and buffalo are under or very close this limiting value. But this pattern is only in dry and hot dry season. In wet season are concentrations over the limiting edge. This can be explain by occurrence of plant proteins which have higher concentrations in young plants and rapidly growing plants than in old and mature plants following the same trend as digestibility (Olivier, 2007). High concentrations of macro elements in wet season confirm this theory. During wet season animals are more selective than during other seasons (Ego *et al*, 2003). Because nutrient concentrations in plant tissues decline during the course of the dry season as plants become dormant and green leaves become transformed to brown (Macadanza &Owen-Smith, 2014) the concentrations of nutrient is lowering and the animals have to change their intake of food to get requirement amount of macro elements. High peaks at *Taurotragus* species can be again explain by supplement feeding or biased data as was said before. Another explanation of exceptionally high values of faecal nitrogen can be concentrations of fibres. Higher fibre diet produces higher faecal nitrogen concentrations (Dörgeloh *et al*, 1998).

In the case of plains zebra (*Equus burchelli*) we can observe very low concentrations of Mg. This can be factor which can explain very high concentration of K at the same specie. Intake of K and Mg is highly connected. McDonald *et al* (2002) assume that high intake of K may have negative influence on Mg absorption. This significant difference between Mg and K is in all cases at zebra and the most striking is in wet season. (McDonald *et al,* 2002) This can be easily explained. The concentration of K in the grass species are highly increasing during wet season (Imoro *et al*, 2012).

Zebra and buffalo are only pure grazers in research. But at the buffalo the Mg and K ratio is stable without any exceeds. This can be explained by different resources of food. Both animals are grazer and feed on grasses, but zebras feed mostly on short grasses less than 25 cm (Knoop &Owen-Smith, 2006). In comparison a ruminant buffalos non-ruminant zebras have higher rates of digestive passage than ruminants are able to tolerate higher indigestible fibres and correspondingly lower nutrient concentrations in the food they ingest than ruminants (Macadanza& Owen-Smith, 2014). Buffalos feed mostly on perennial grasses and are able to change their diet preferences during limiting season with lack of nutrients. In the fenced areas where animals, not only buffalos, have no possibility to migrate into areas with better conditions, animals considered as pure grazers can became an opportunistic grazers, which can selectively browse not even graze (Ego *et al*, 2003). This is not case of zebras, which do not change their feeding habits but easily increase the intake of food (Beekman & Prins, 1989).

Intermediate feeders have optimal condition to change their diet according seasons and food ability. This is a case of common eland and roan antelope. Elands consume more grass during wet season when is abundance of plant material with high rates of nutrients content (Wallington *et al*, 2007). Roan antelopes are in most cases considered as grazers (Cerling *et al*, 2003) but the range of grass component can be very variable according the accessibility of forage (Knoop& Owen-Smith, 2006). There is potential competition between roan antelope, zebra and buffalo. Common eland is not potential competitor to these species because graze take lower part of diet than browse. But competition between roan and other species is quite low, because roan antelope feeds mainly on tall grasses which are about 50 cm tall (Knoop& Owen-Smith, 2006).

Derby eland feeds mainly on shoots, fruits and seeds and leaves of woody plants (Hejcmanová *et al*, 2010). That avoids it from competition with other species with different preferences. Roans prefer mainly graze and competition with common eland is quite low, because common eland usually feeds on small shrubs and dwarf shrubs (Watson& Owen-Smith, 2000) and Derby eland prefer higher trees (Hejcmanová *et al*, 2010).

In the interaction grazer, browser and intermediate we can see, that most limiting concentrations of nitrogen have grazers. But concentrations of faecal nitrogen are not lower than limiting value (13-16 g/kg) used by Stapleberg *et al* (2008). There we have to compare concentrations in reserves with concentrations in season, which mostly affect final results. Grazers with predominantly grassy forage (Van Soest, 1994) are in advantage during wet season when grasses are newly growth and have high concentrations of nutrients (Imoro *et al*, 2012). But with the passing time, nutrient concentrations are fading. Ostensibly low concentrations of faecal nitrogen at grazer in comparison with browser and intermediate can be explained by secondary compounds in browse. Generally browse has higher nitrogen and lignin compounds and lower NDF and ADF than grass (Osborn, 2004). With some secondary compound in browse, level of faecal nitrogen can be higher in the result. But those high values do not necessarily means higher forage quality (Codron *et al*, 2006). NDF concentrations in Fathala fit into this pattern set by Osborn (2004) but concentrations in Bandia are lower, on the same level as browser and intermediate concentrations. The most probable explanation is in data analysis. Some results connected with this particular one show quite high standard error which can bias the whole results. The same case can be in concentrations of NDF at intermediate. Concentrations of ADF should be at grazer higher than at browser. The results, both NDF and ADF, can be affected by tannins, which can negatively correlate the digestibility of food and this can lead to high concentrations of faecal fibres (Njidda & Nasiru,2010; Makkar, 2003). Intermediate feeders are in concentrations of NDF and ADF in the middle. That means that they are not negatively affected by any factor and represent the ability to feed grass and even on browse. The concentrations of lignin are nicely representative when they increasing with increasing browse part in the diet.

In Bandia at grazer species is the same problem like it was at zebra which is set in grazer group. The high intake of K can increase concentrations of Mg (McDonald *et al*, 2002). It is caused their predominantly grass diet which contain high rates of K mainly in wet season (Imoro *et al*, 2012). High values of Ca in the Bandia at intermediate and browser can be explained by higher concentrations of Ca in the woody plant than in the grasses (Žáčková *et al*, in preparation).

The ruminant and non-ruminant species can coexist side by side because of their different digestive tracts. Non-ruminants as hind-gut fermenters are capable to eat bigger amount of low quality forage than grazing ruminants which utilize same amount of nutrients from lower amount of higher quality forage (Duncan *et al*, 1990).

Non-ruminants have mechanism which helps animal to deal with fibrous material. The principle is in the excretion of fibres. Larger particles of fibres are separated from non fibrous material by peristaltic of intestines. Fibre particles move faster than the rest of forage and are excrete in faeces (Iason & Van Wieren, 1999). This can explain higher concentrations of NDF and ADF at non-ruminant species, even though only non-ruminant specie was used in the research. Lignin corresponds with the animal diet. In the ruminant group are included grazers, browsers and intermediate feeders with negligible woody part of diet and in non-ruminant group is only grazer with grassy diet.

6. Conclusion

The results revealed that zebra (*Equus burchelli*) with its grazing strategy and non-ruminant physiology have most limiting concentrations of Mg and intake of N was not as high as it was in other species. Browsers on the other hand have very high concentrations of N which indicate better diet quality. Non-ruminants have better utilization of low quality forage and that exclude competition with ruminants, which are dependent on high quality forage. Intermediates had concentrations usually between grazers and browser and indicated better adaptability to seasonal changes.

But from result was obvious that all animals have sufficient diet and are not limited by lack of any nutrient, even some species (mostly non-ruminants) was very close to the nutrient lack in some seasons. That could be useful for reserve management to provide some supplement food for non-ruminants by some pellets or highly nutritious hay.

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Annexes

List of annexes:

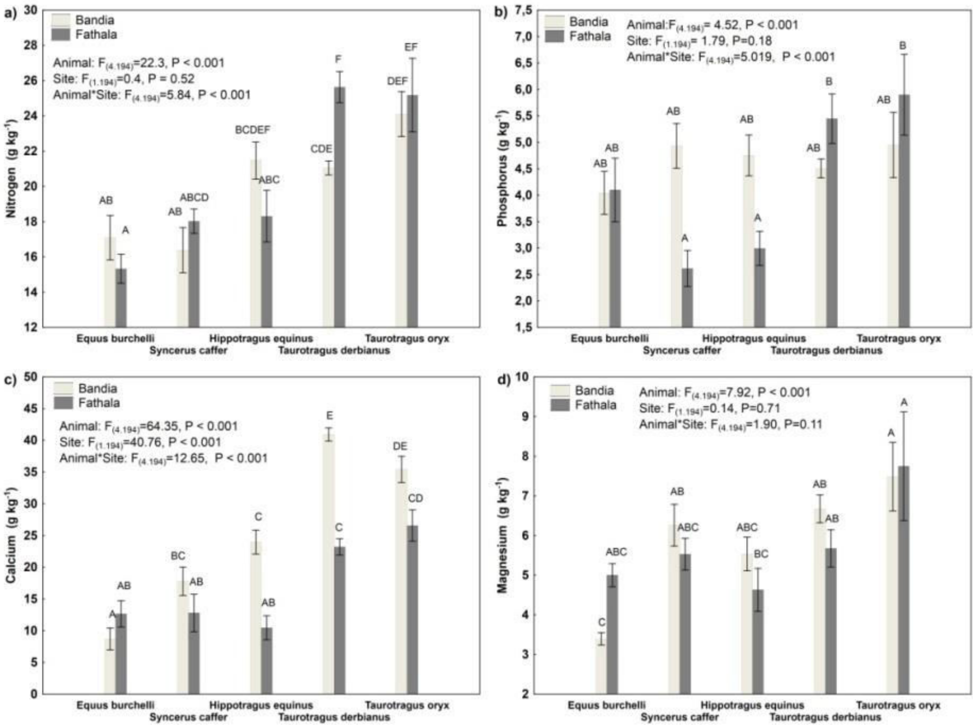

Fig 1 Concentrations of a)N; b)P; c)Ca;d)Mg in faeces of large herbivores in two reserves in all seasons together. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Site.

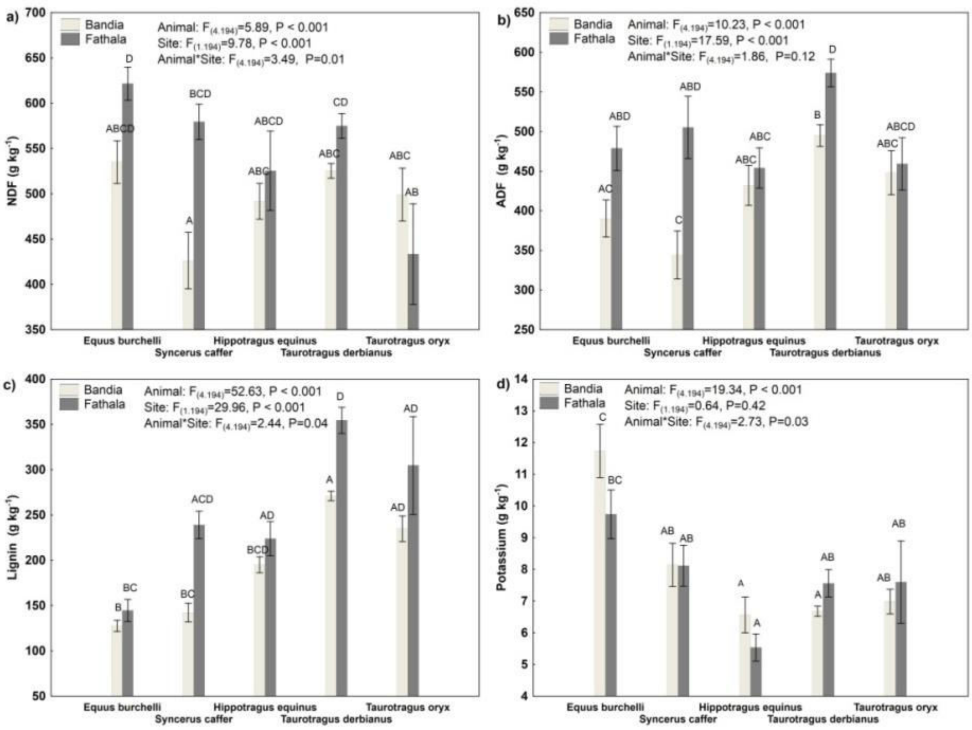

Fig 2 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in all seasons together. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Site

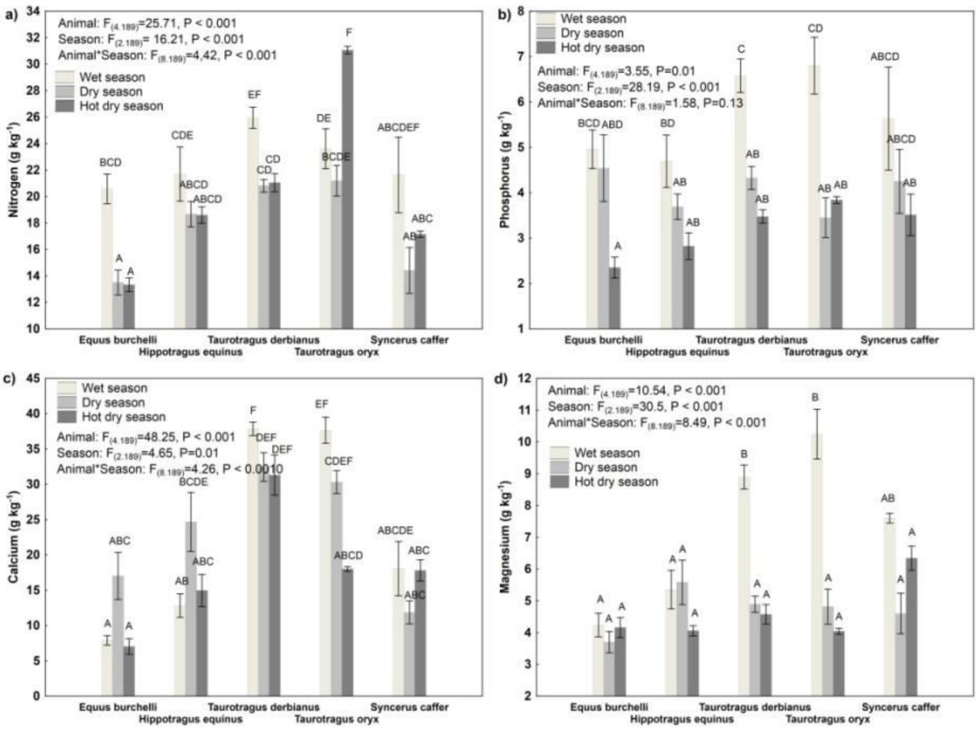

Fig 3 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in all seasons in two reserves. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Season

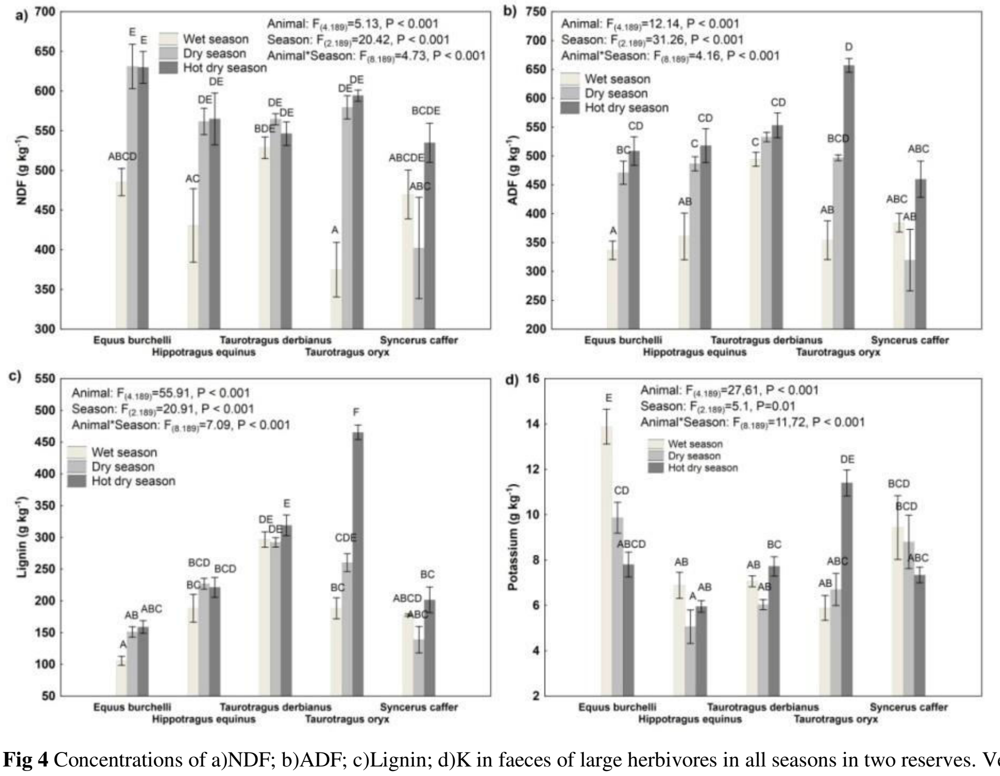

Fig 4 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in all seasons in two reserves. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Season

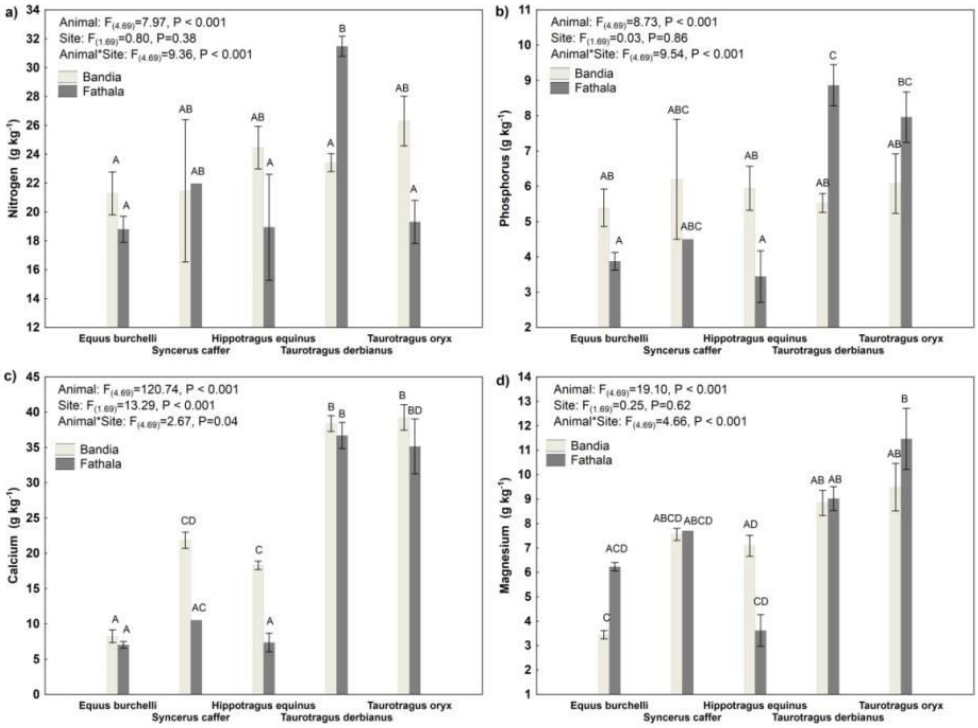

Fig 5 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in wet season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Site

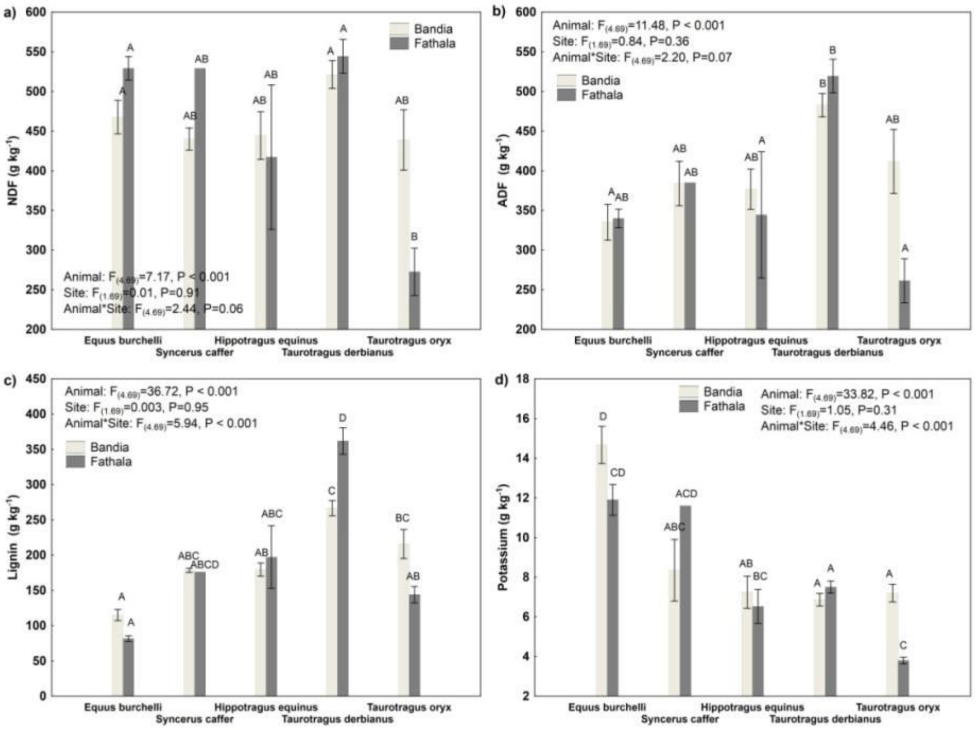

Fig 6 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in wet season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Site

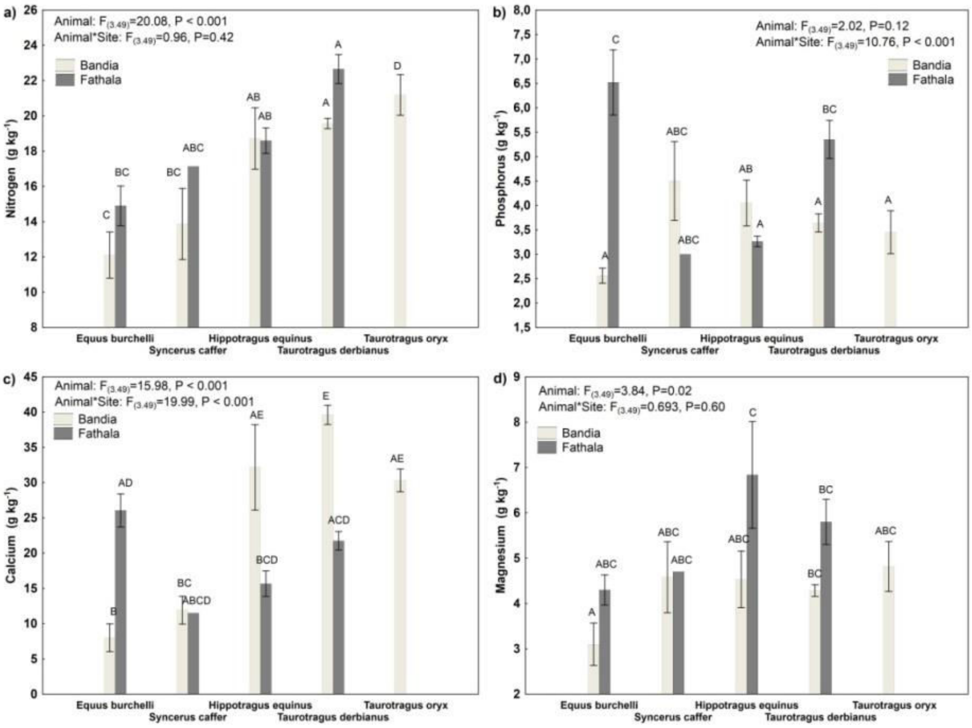

Fig 7 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Site

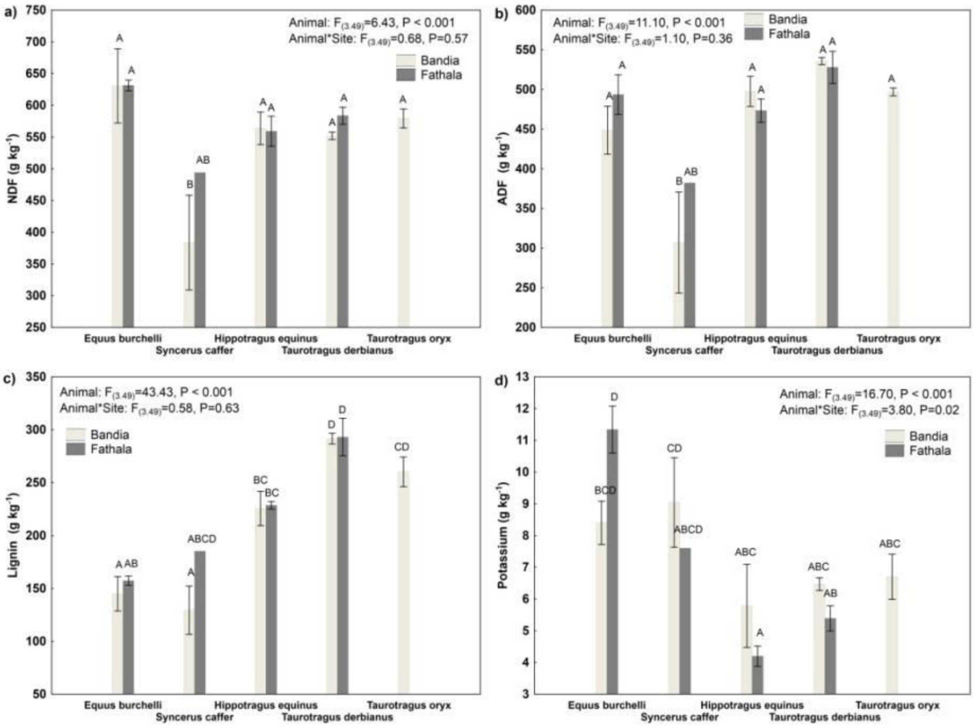

Fig 8 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Site

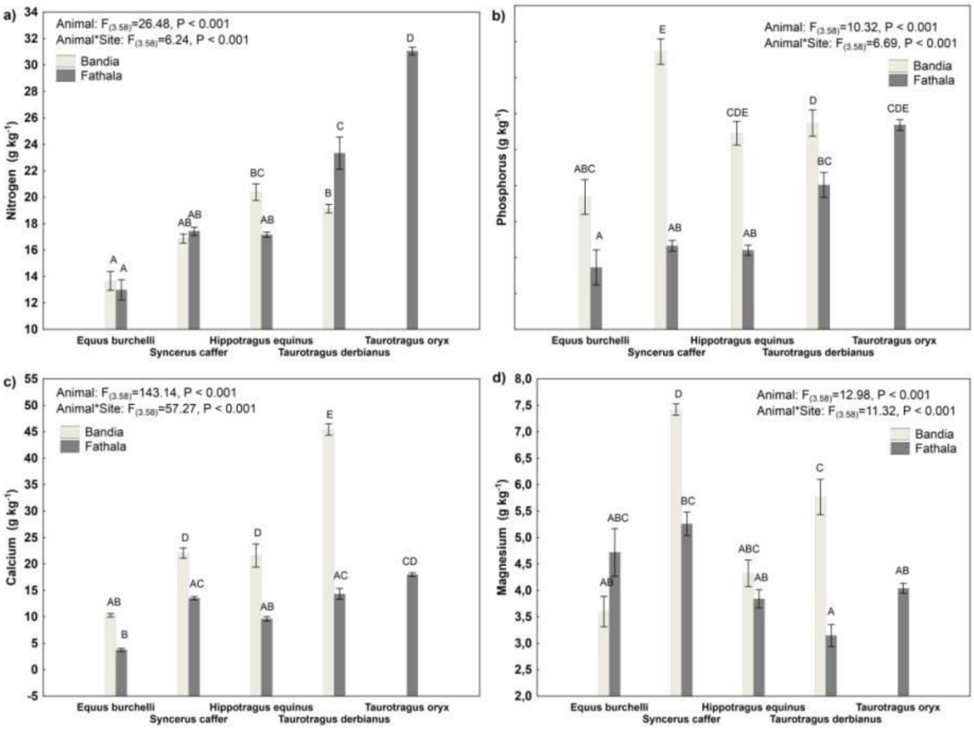

Fig 9 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in hot dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Site

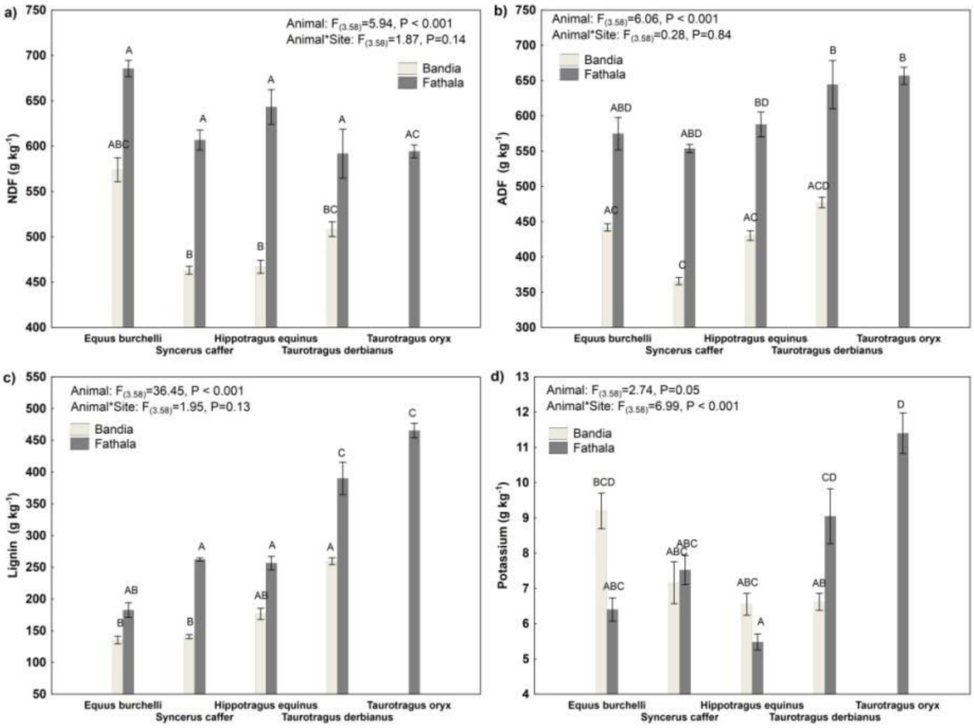

Fig 10 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in hot dry season season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Site

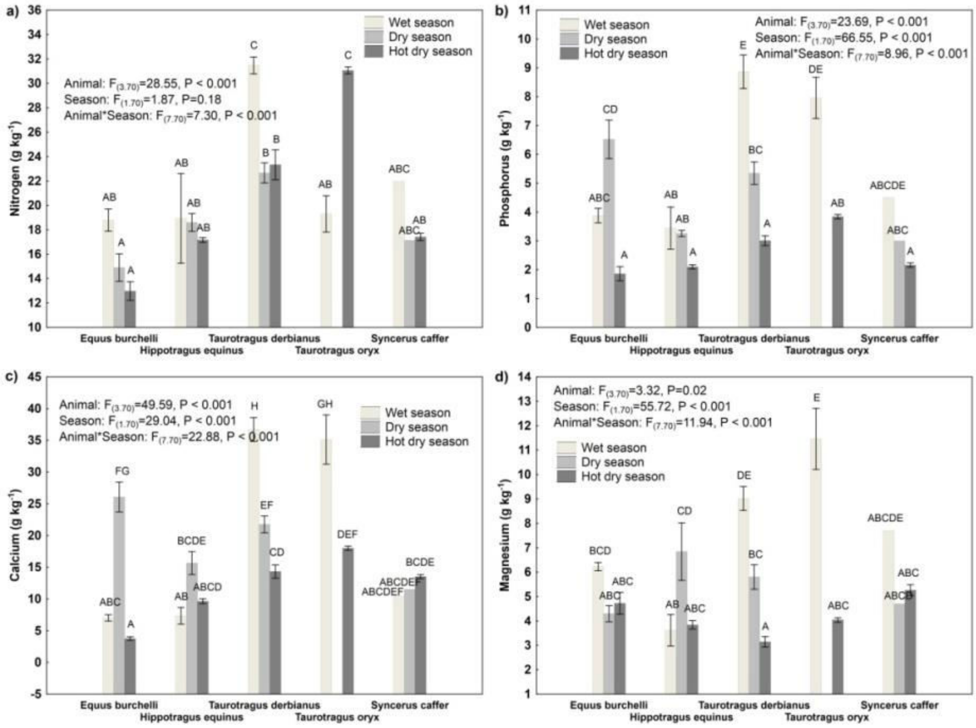

Fig 11 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in all seasons in Fathala. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Season

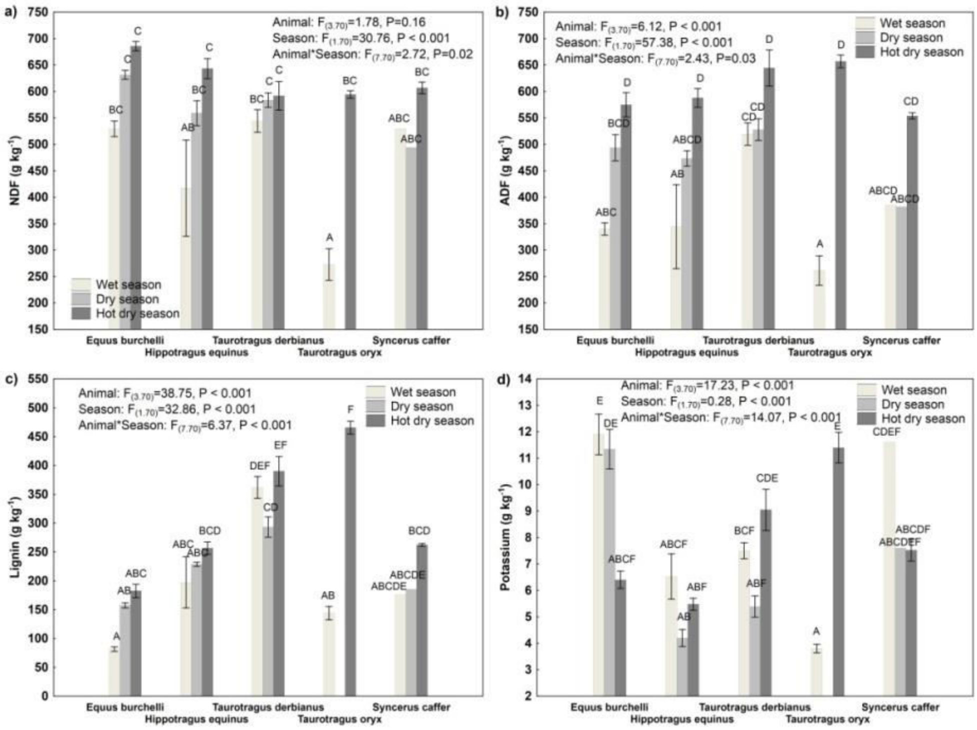

Fig 12 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in all seasons in Fathala. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Season

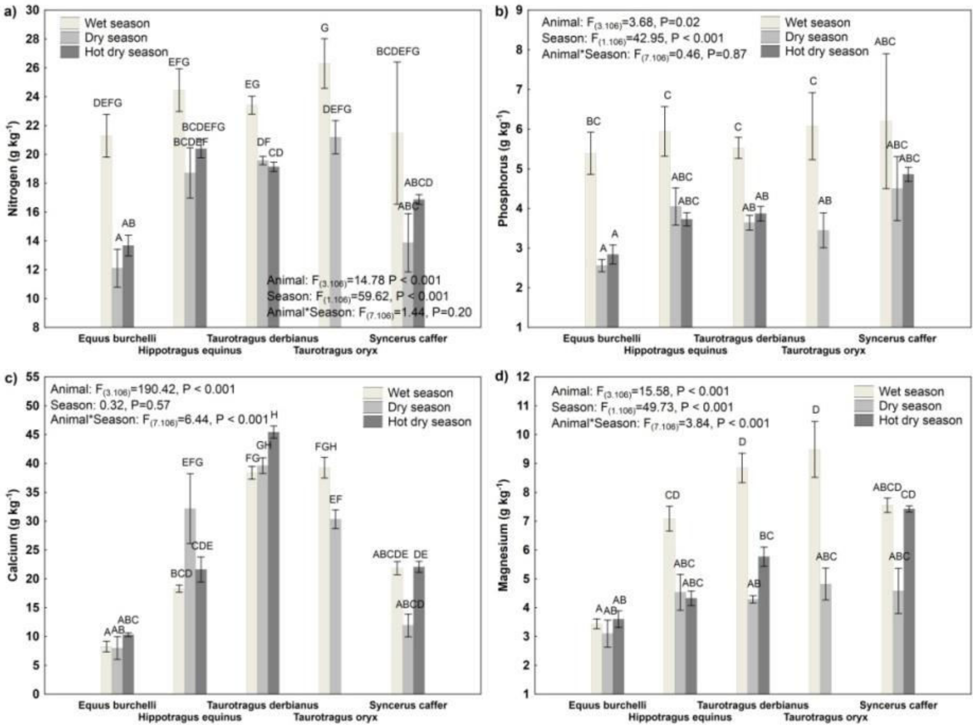

Fig 13 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in all seasons in Bandia. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Season

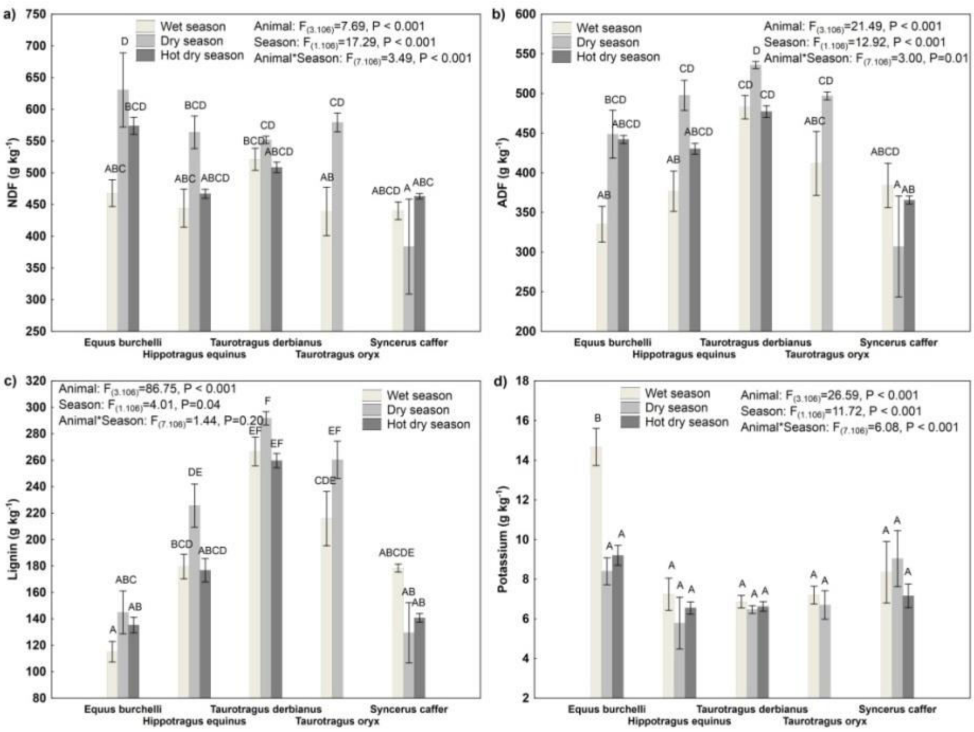

Fig 14 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in all seasons in Bandia. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Animal*Season

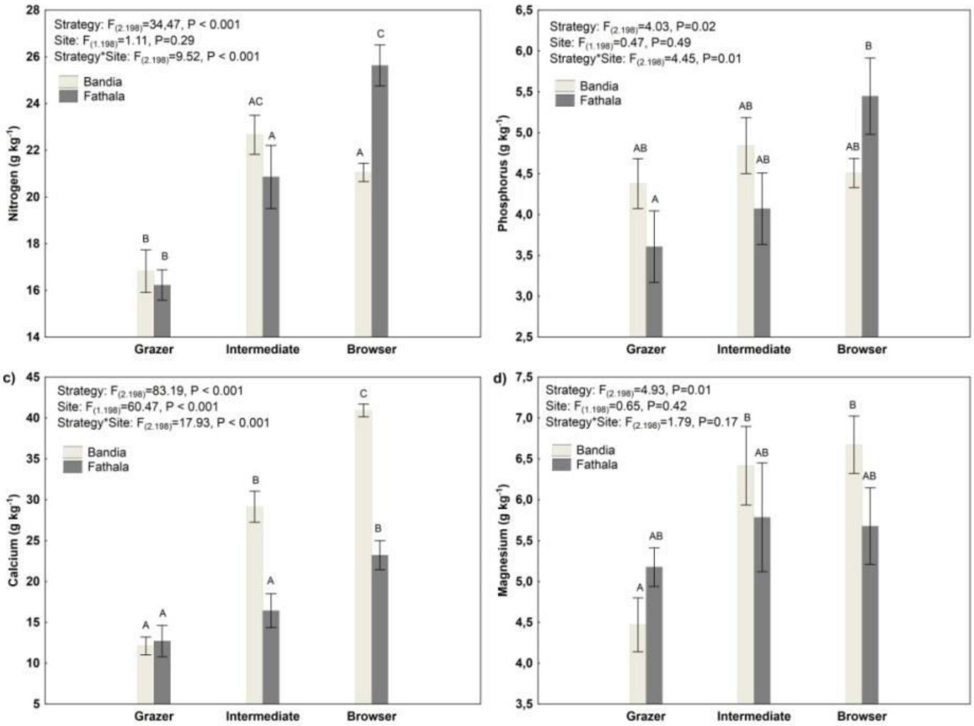

Fig 15 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in all season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Site

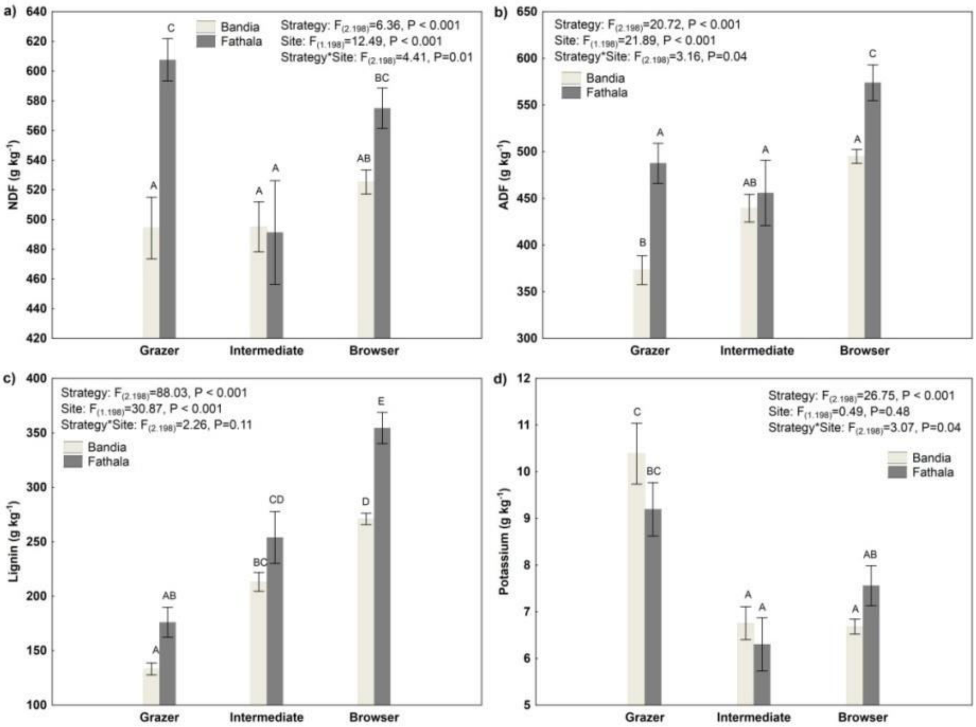

Fig 16 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in all season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Site

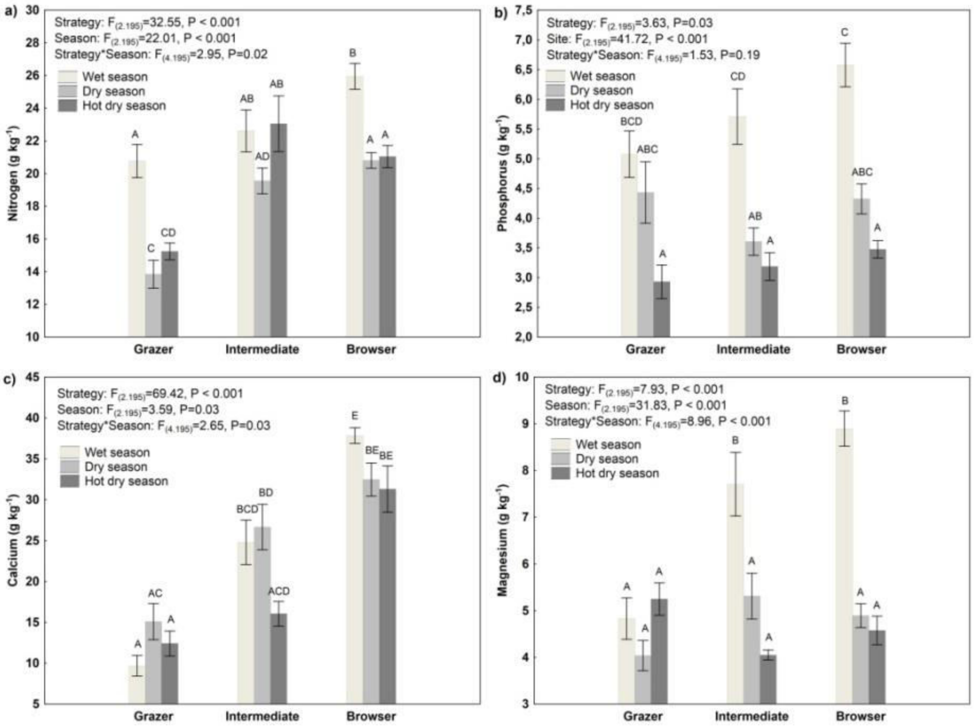

Fig 17 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in all seasons in two reserves. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Season

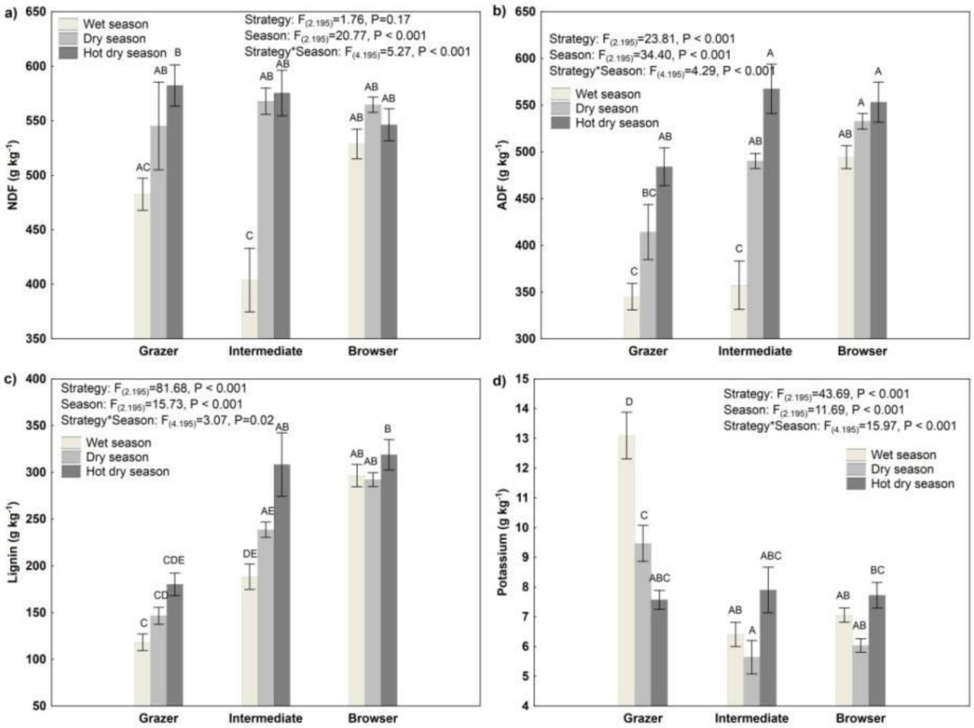

Fig 18 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in all seasons in two reserves. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Season

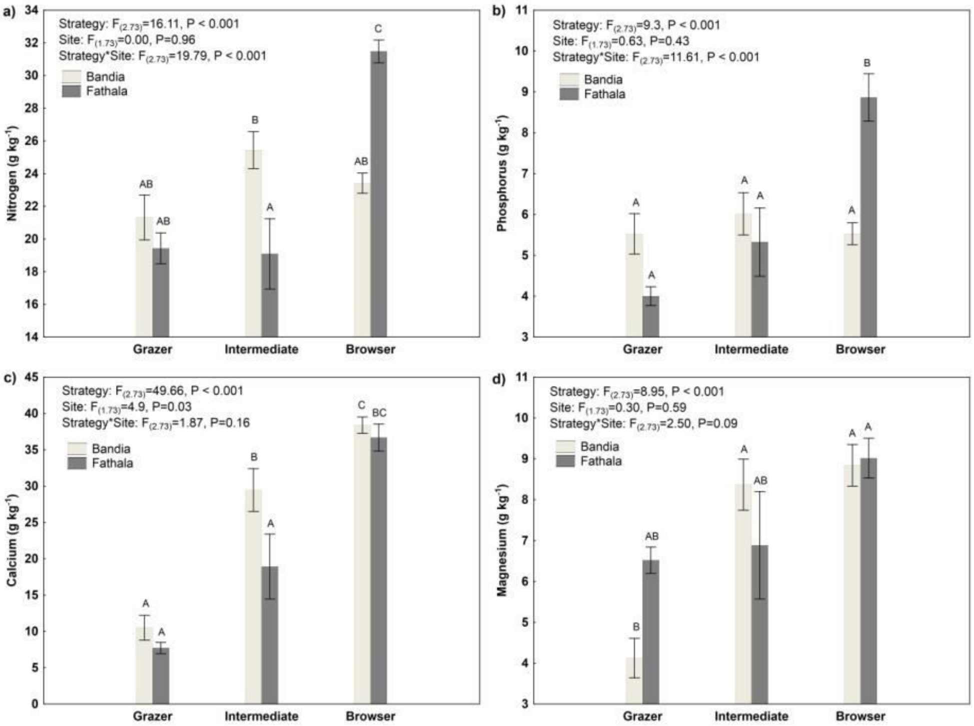

Fig 19 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in wet season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Site

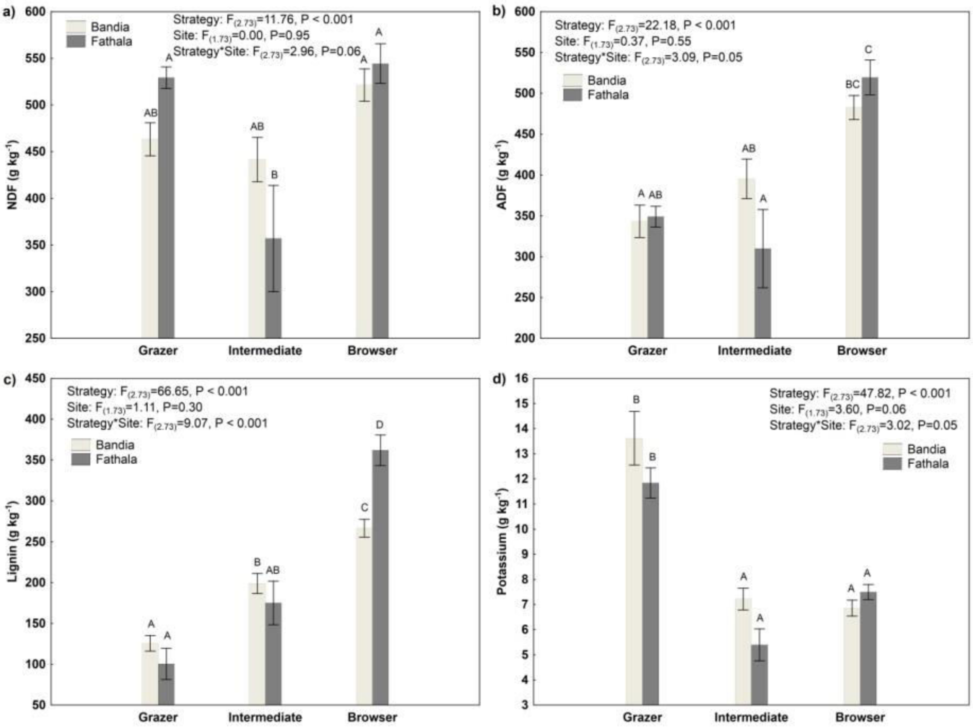

Fig 20 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in wet season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Site

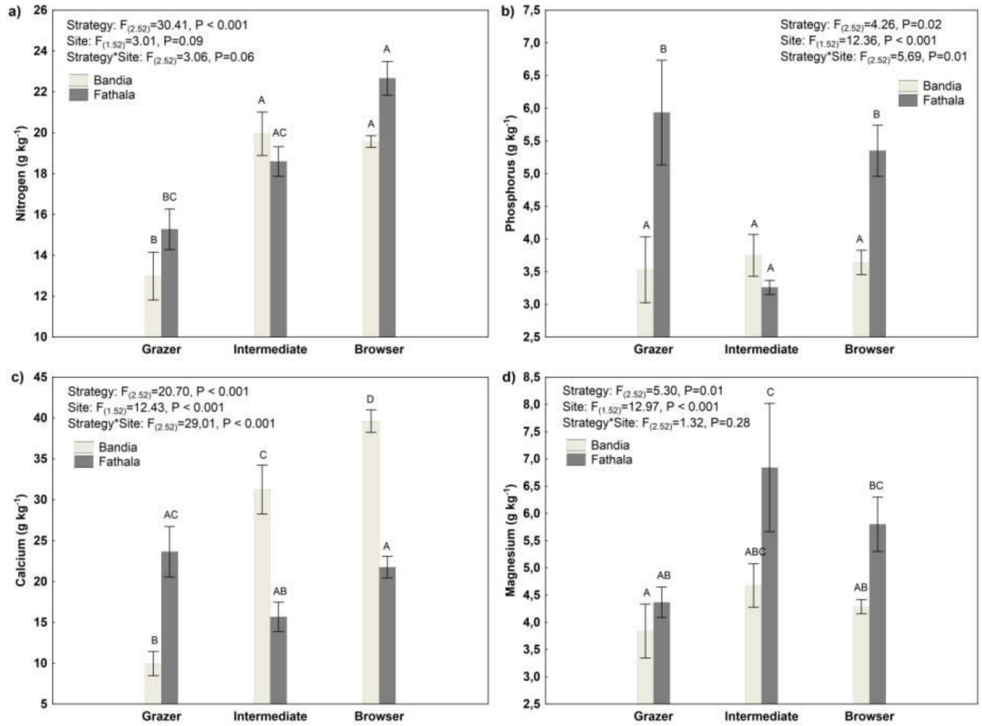

Fig 21 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Site

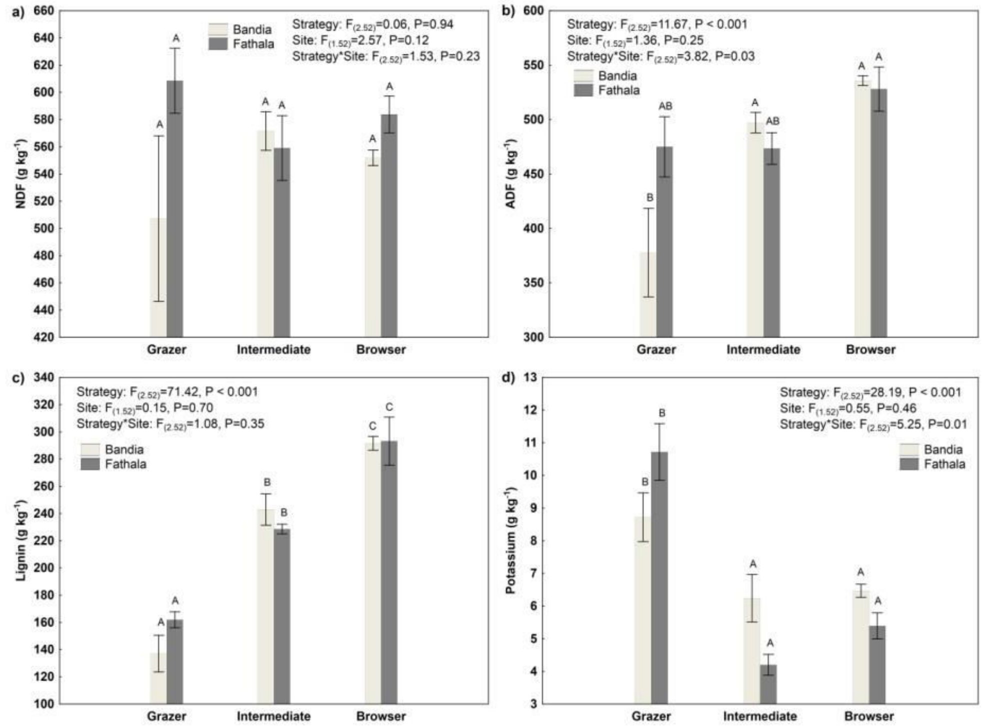

Fig 22 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Site

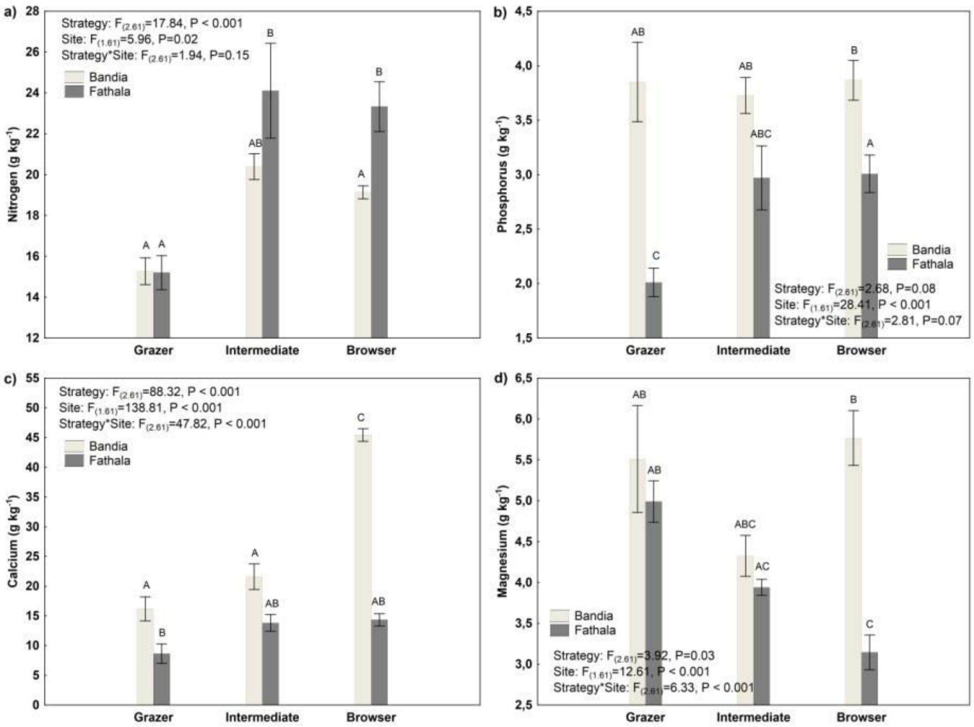

Fig 23 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in hot dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Site

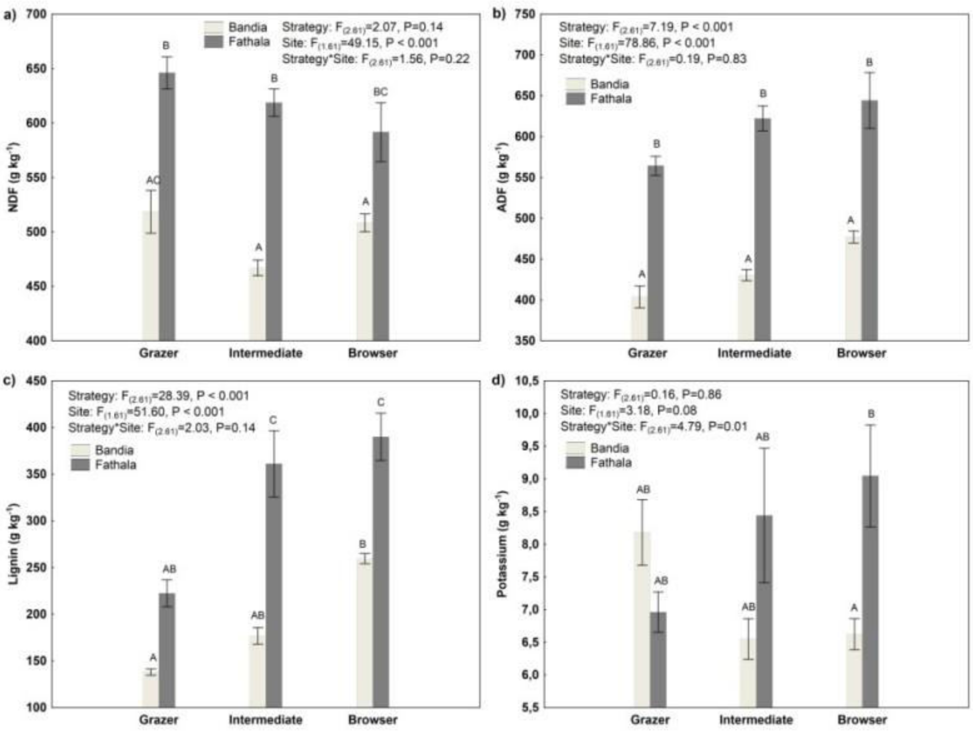

Fig 24 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in hot dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Site

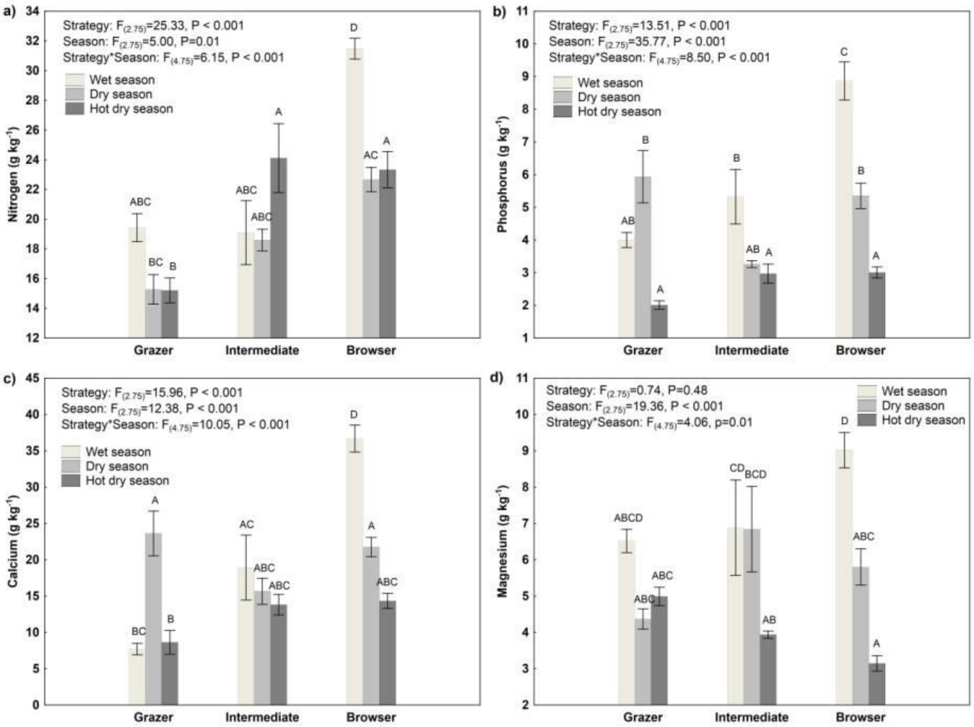

Fig 25 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in all seasons in Fathala. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Season

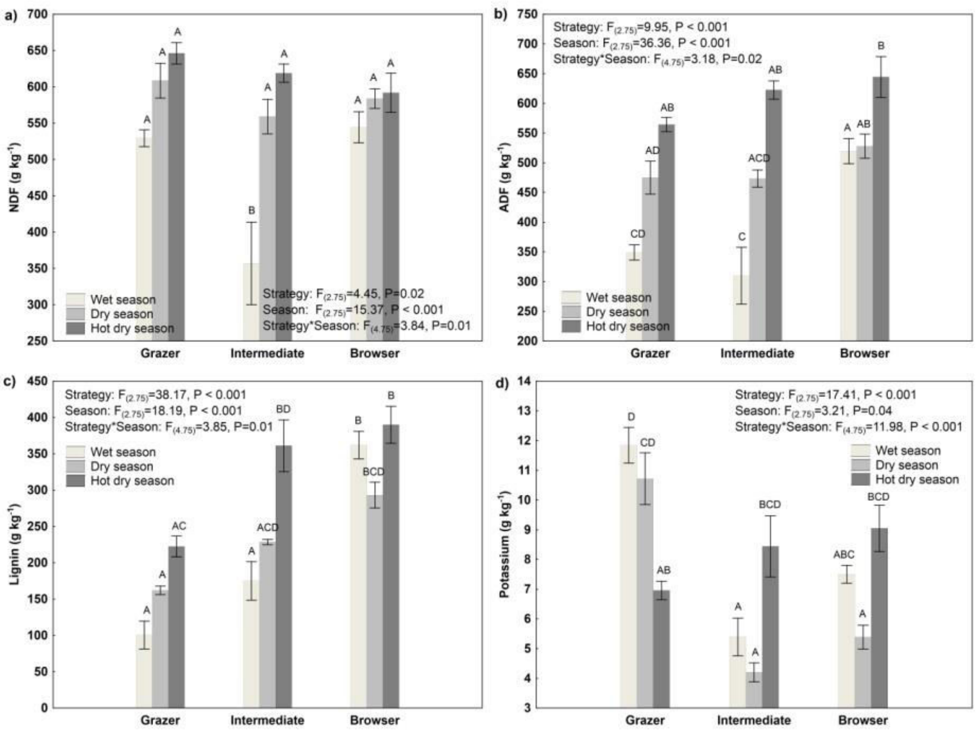

Fig 26 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in all seasons in Fathala. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Season

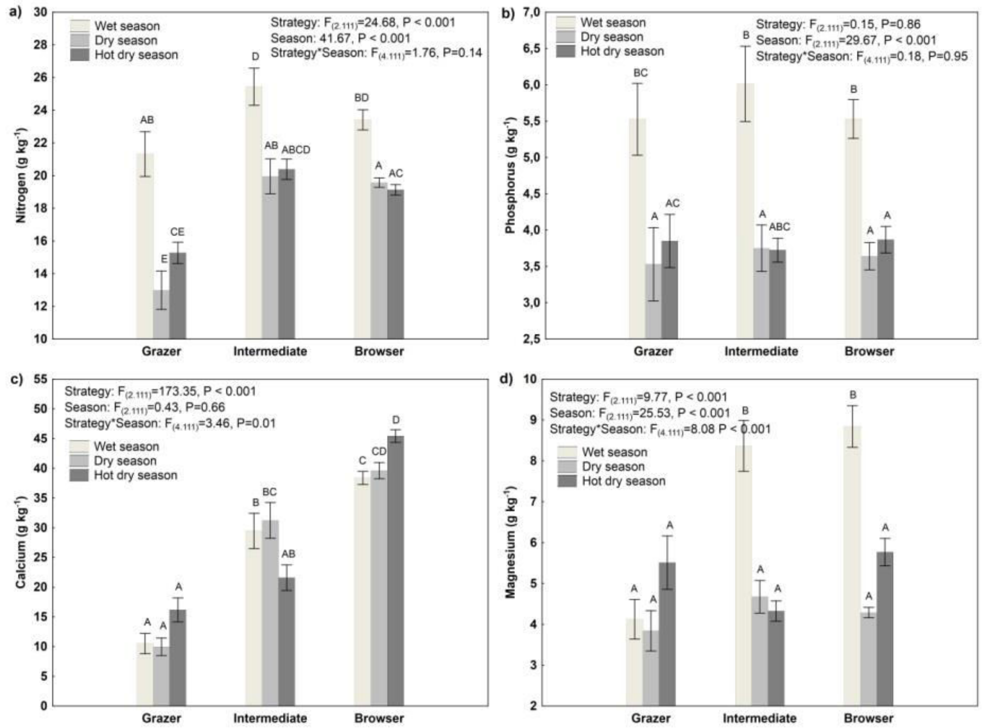

Fig 27 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in all seasons in Bandia. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Season

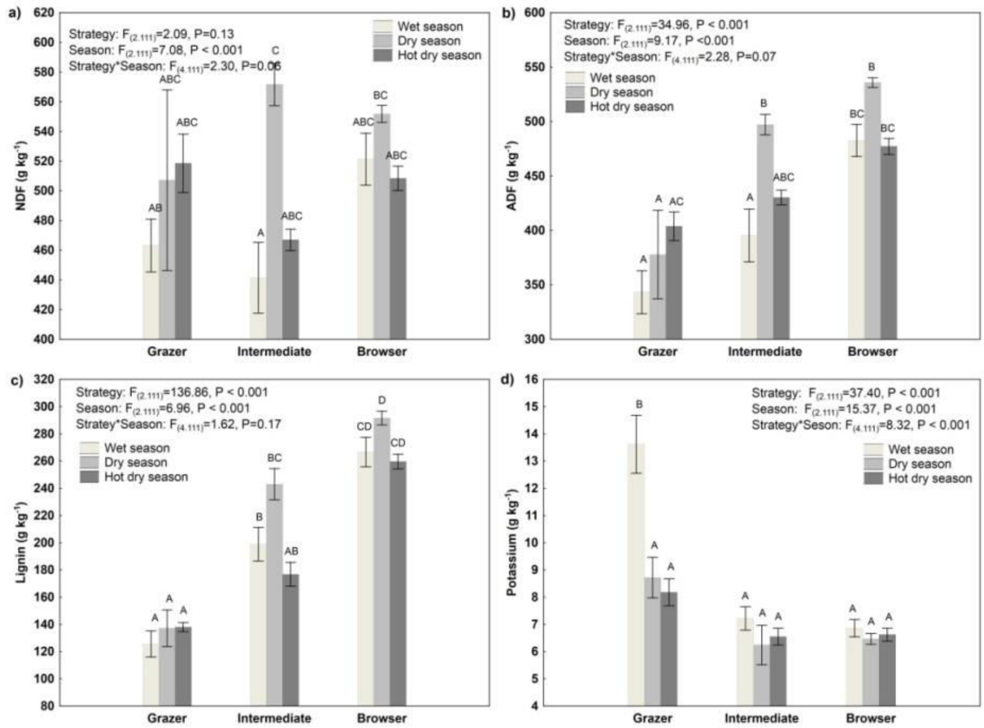

Fig 28 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in all seasons in Bandia. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Strategy*Season

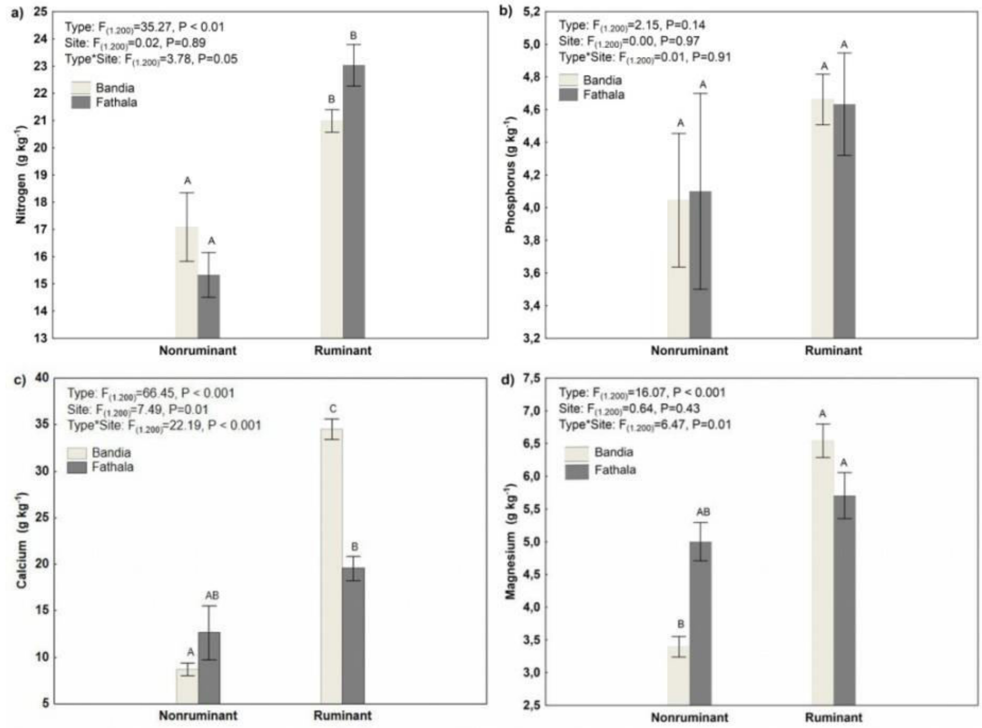

Fig 29 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in all seasons. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Site

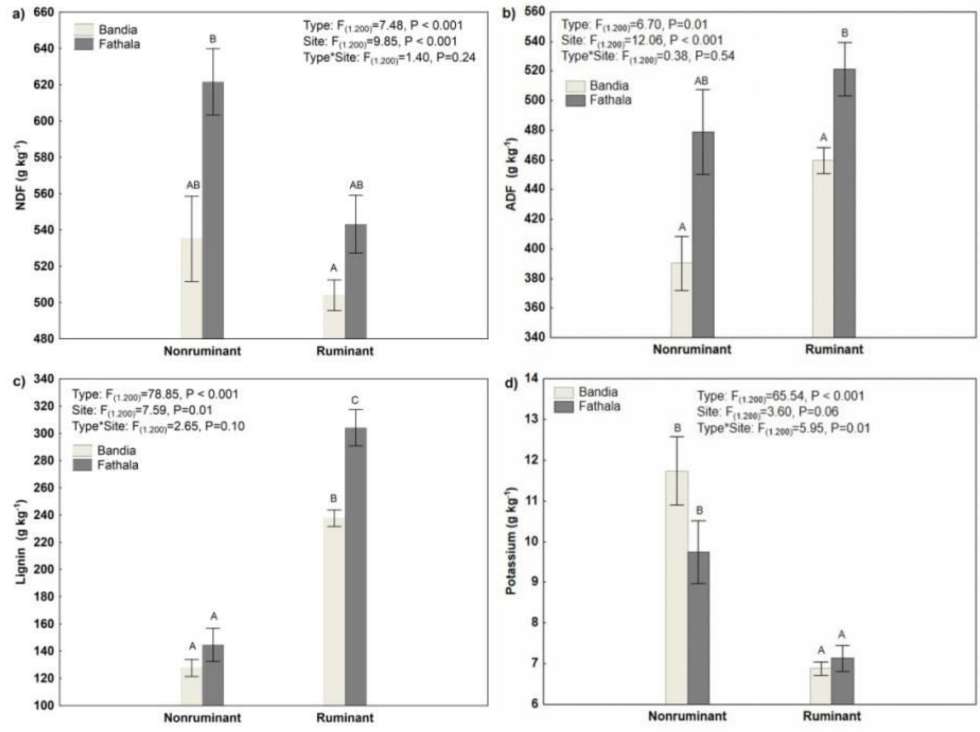

Fig 30 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in all seasons. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Site

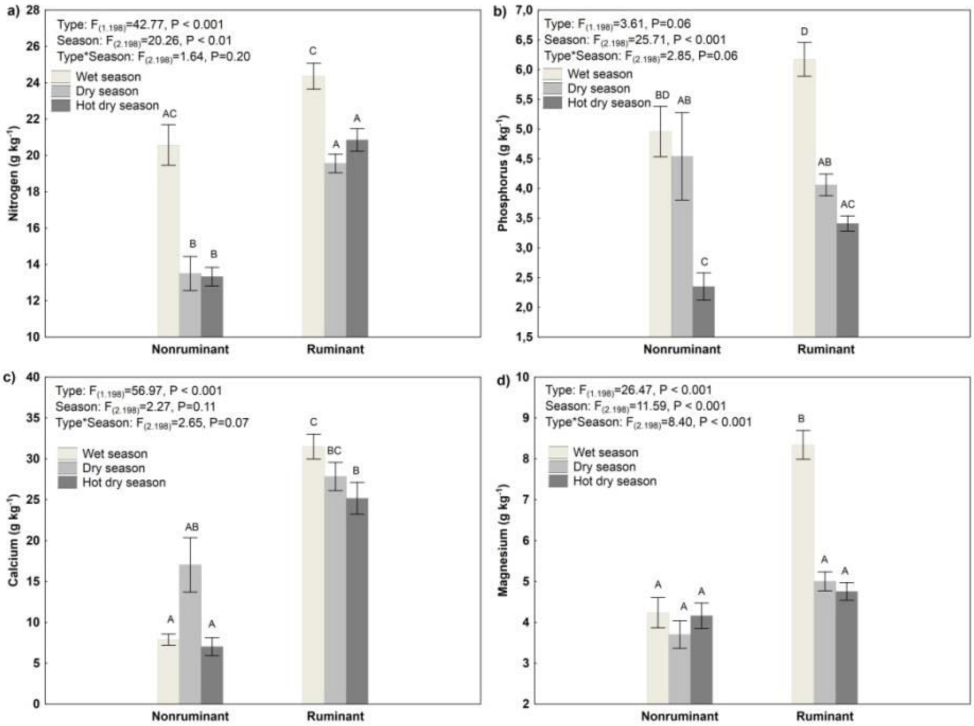

Fig 31 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in all seasons in two reserves. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Season

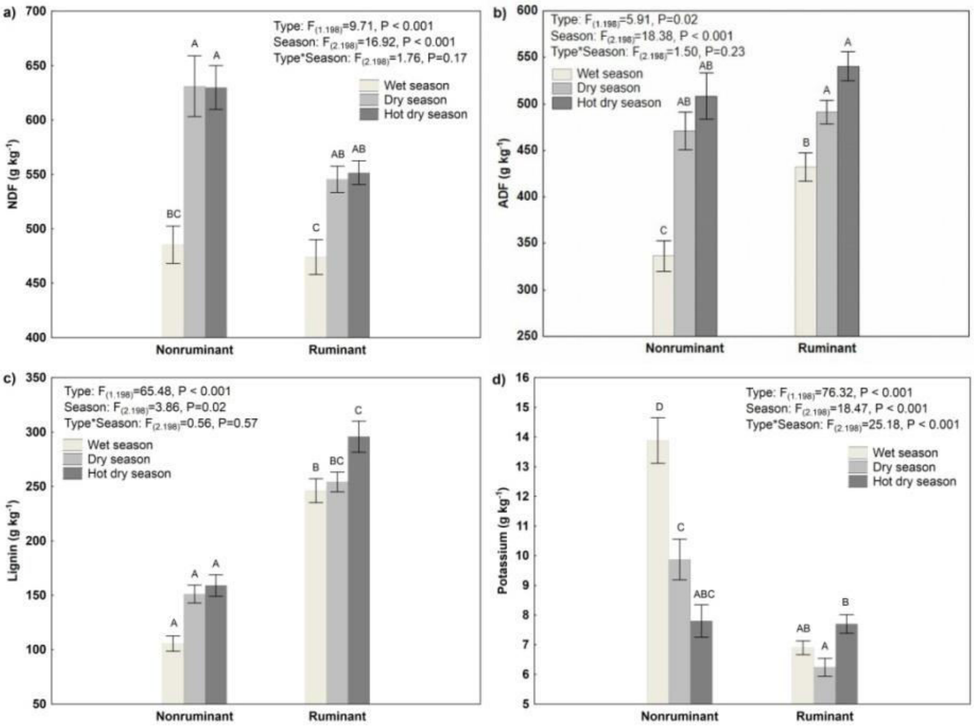

Fig 32 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in all seasons in two reserves. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Season

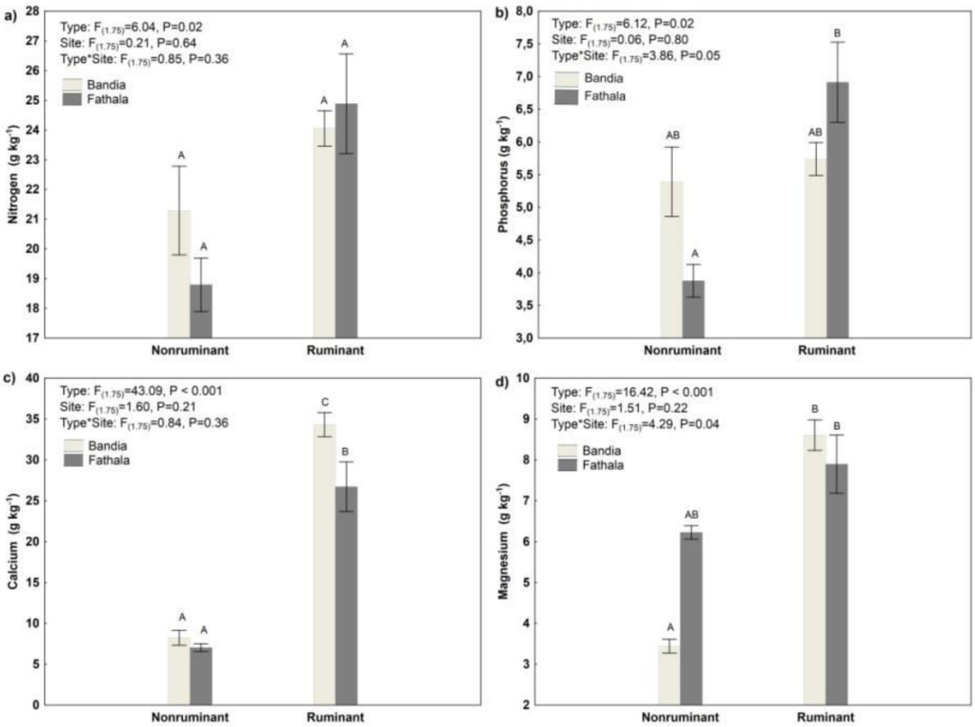

Fig 33 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in wet season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Site

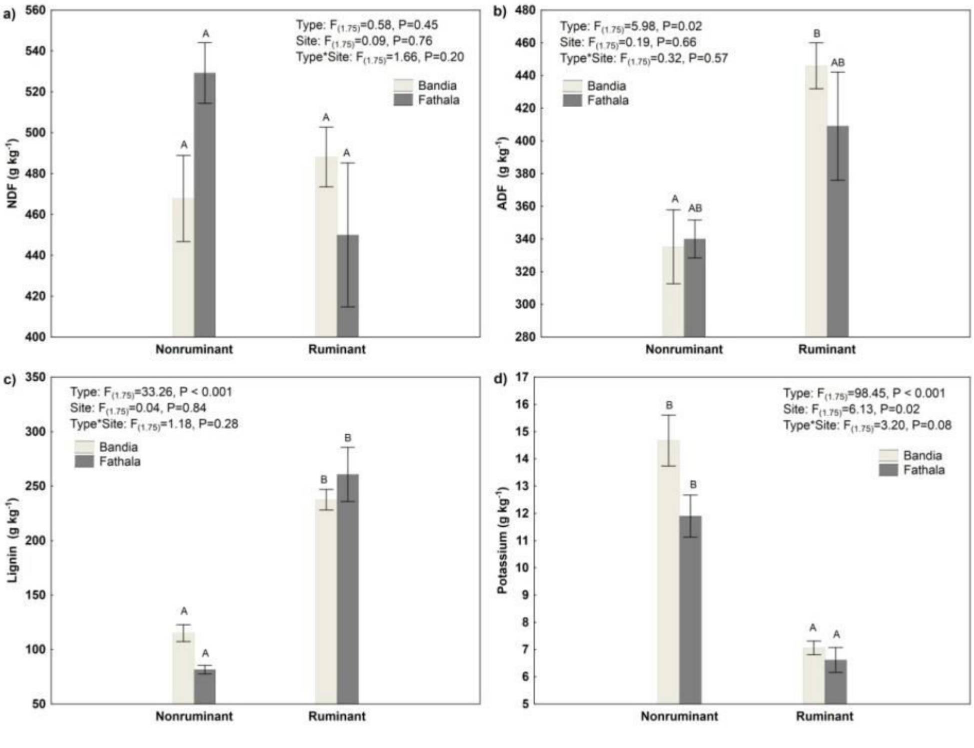

Fig 34 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in wet season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Site

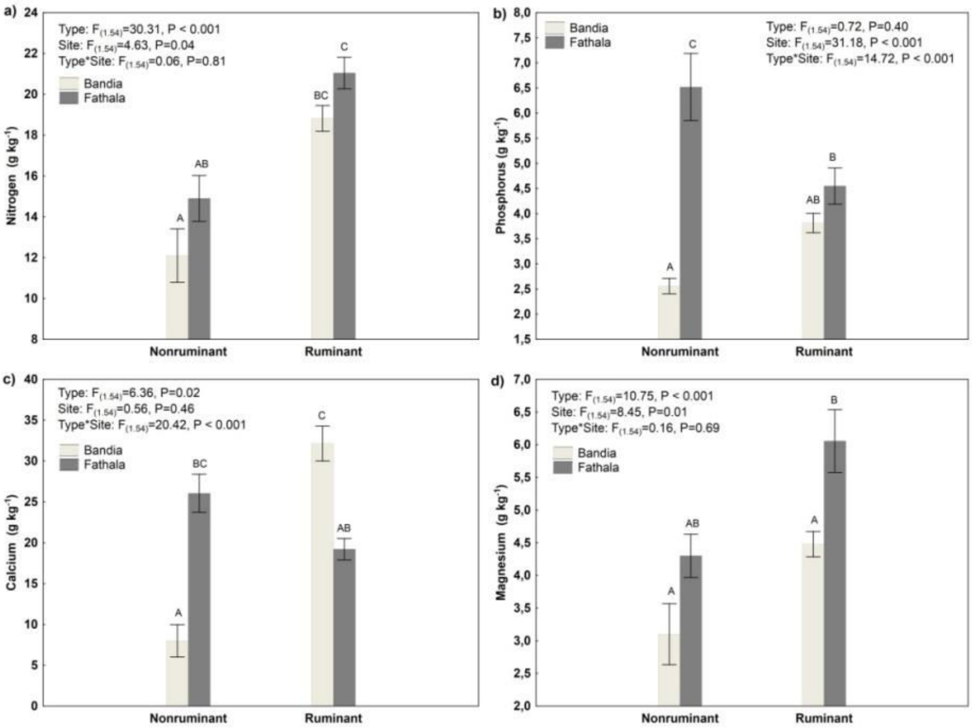

Fig 35 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Site

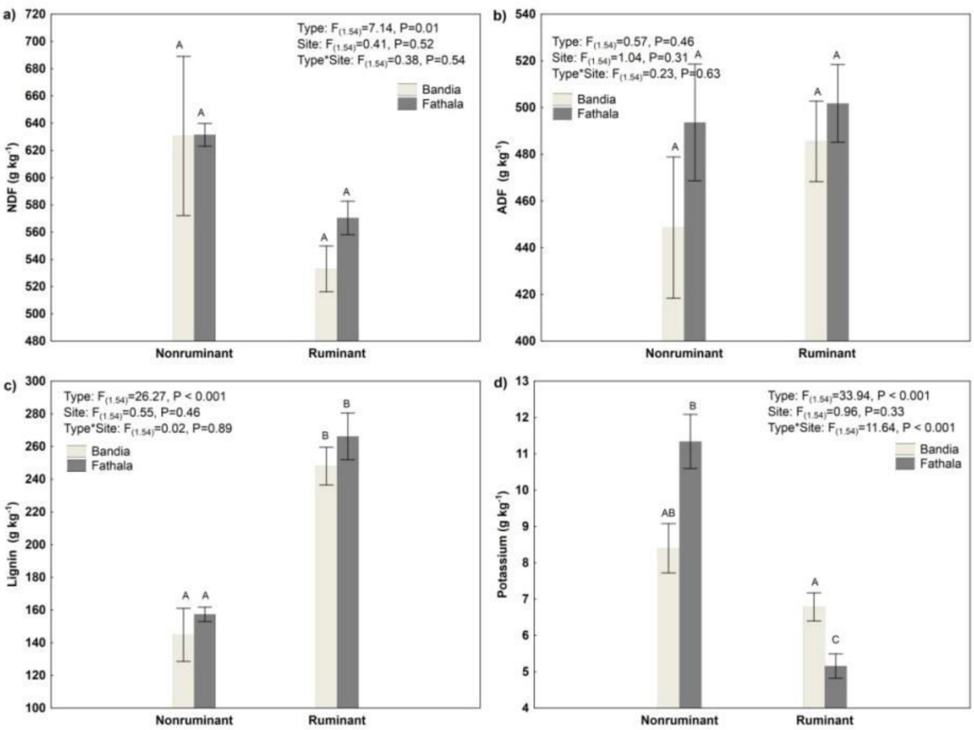

Fig 36 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Site

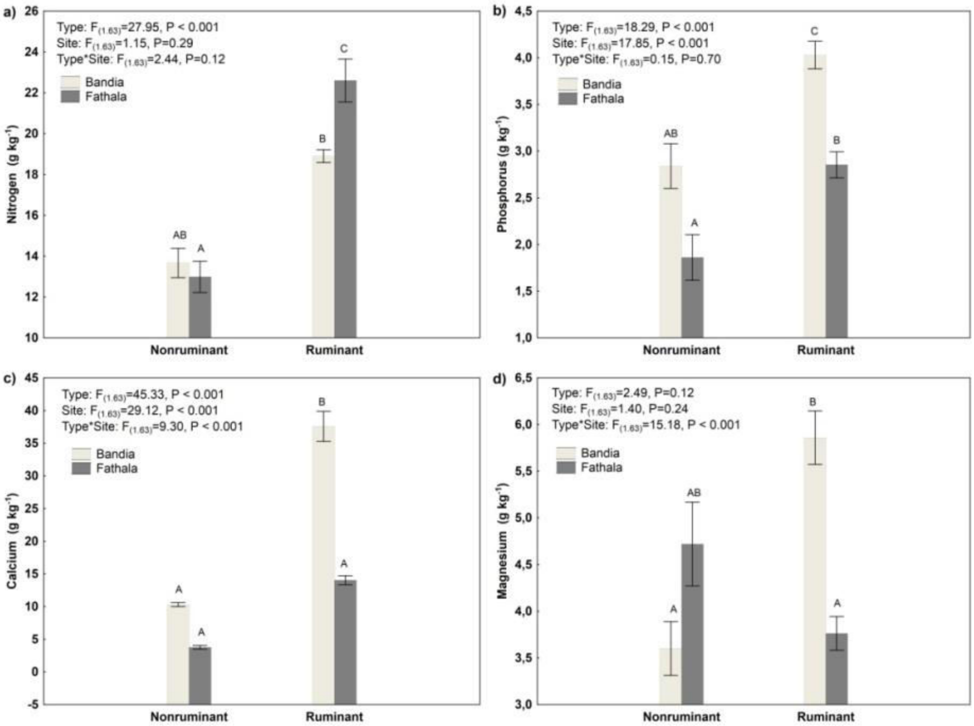

Fig 37 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in two reserves in hot dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Site

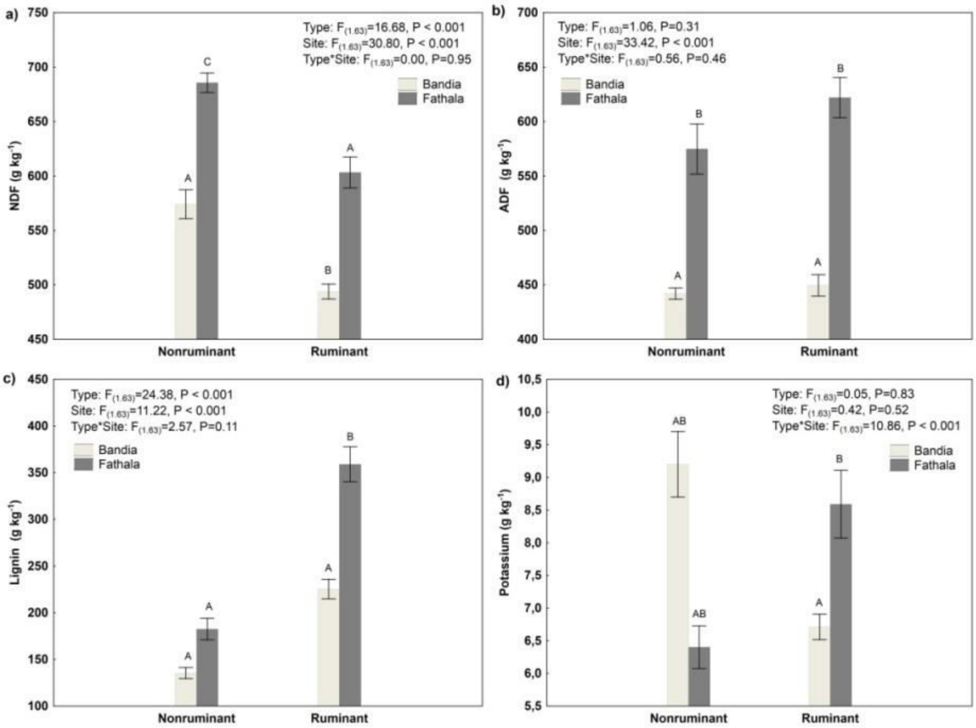

Fig 38 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in two reserves in hot dry season. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Site

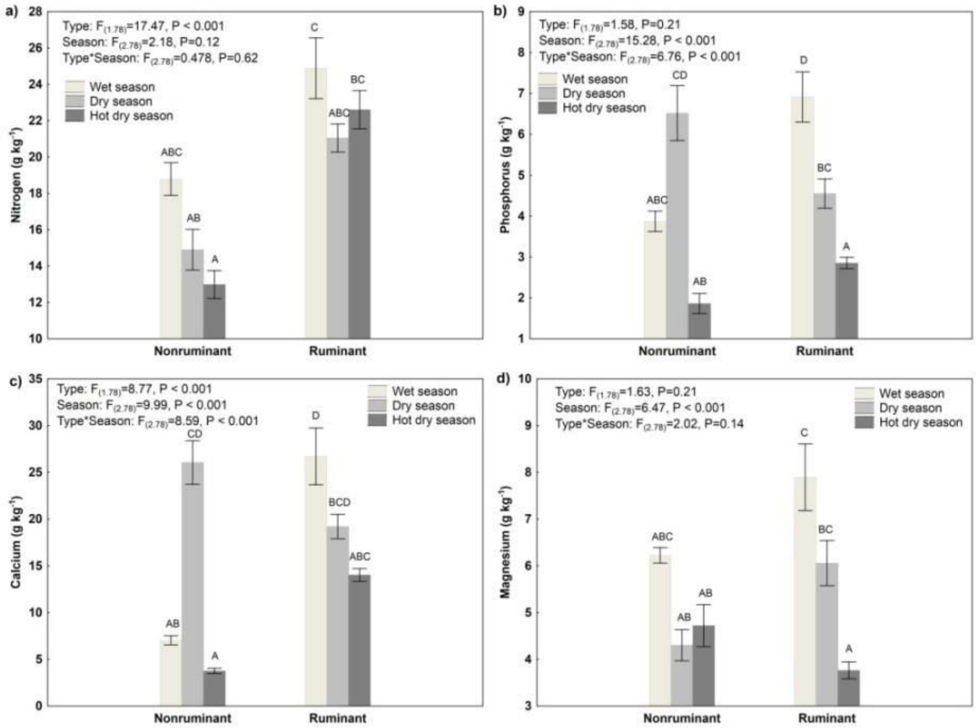

Fig 39 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in all seasons in Fathala. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Season

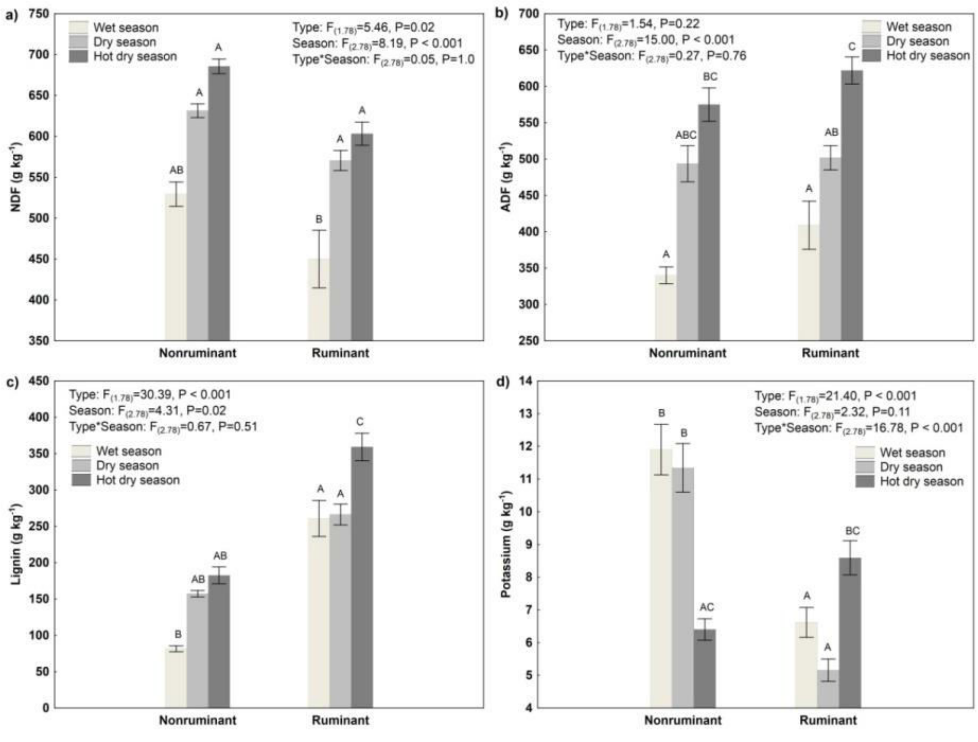

Fig 40 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in all seasons in Fathala. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Season

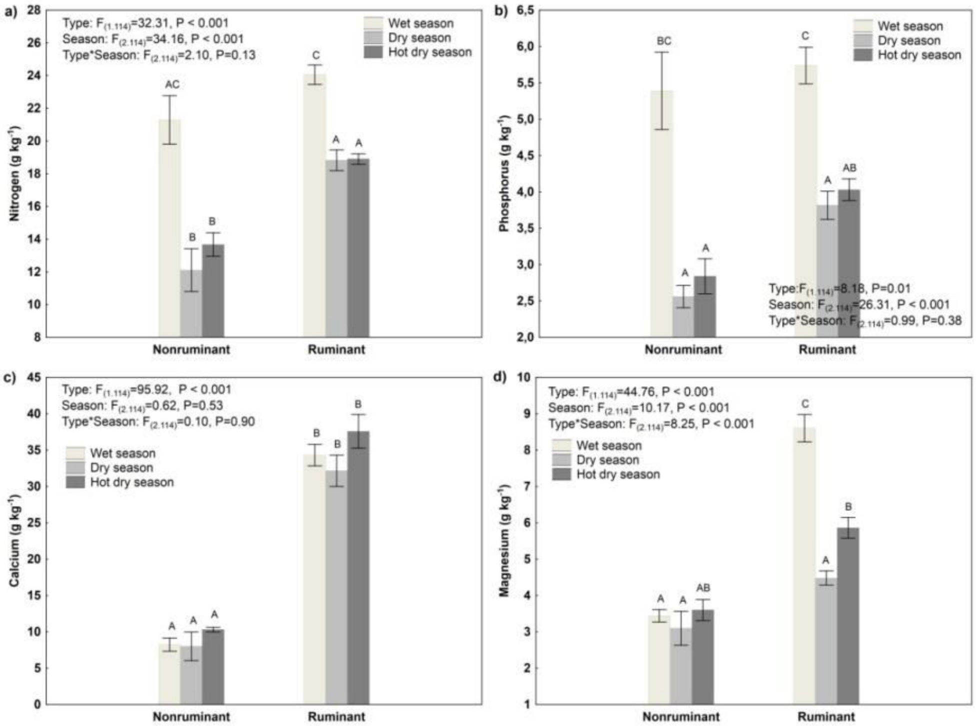

Fig 41 Concentrations of a)N; b)P; c)Ca; d)Mg in faeces of large herbivores in all seasons in Bandia. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Season

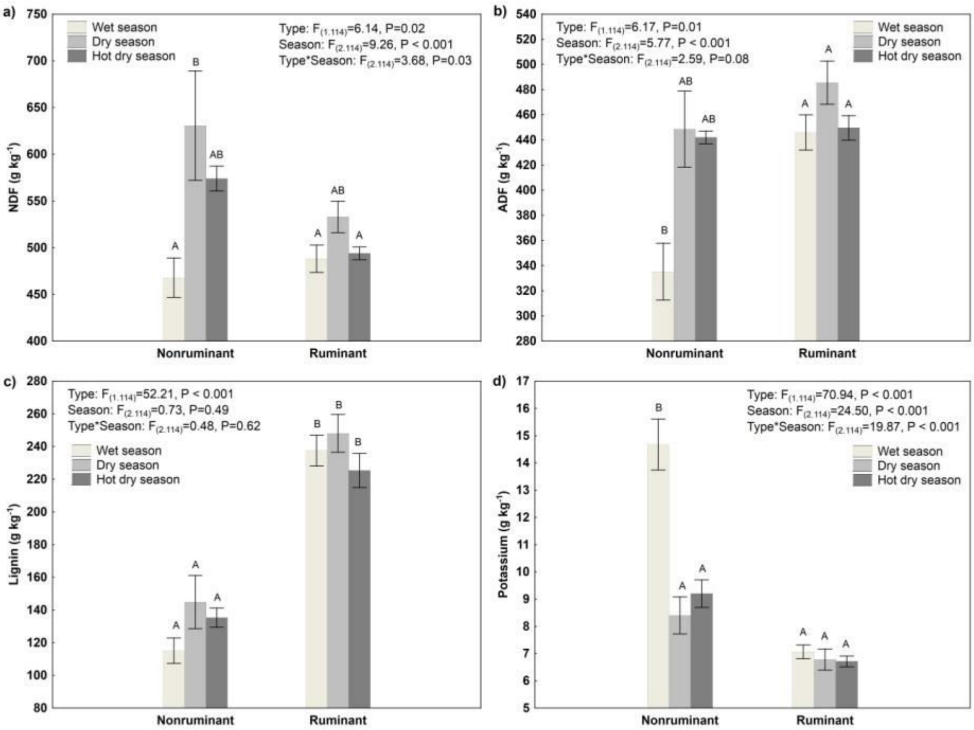

Fig 42 Concentrations of a)NDF; b)ADF; c)Lignin; d)K in faeces of large herbivores in all seasons in Bandia. Vertical bars indicate SE/standard error of the mean. Letters indicate results of post-hoc HSD Tukey test of significant test of interaction Type*Season

Fig 43 Map of Senegal with hihglited reserves Bandia, Fathala and national park Nikolo Koba (Nežerková *et al*, 2004)

Fig 44 Bandia vegetation with woody savannah and grasses savannah (Nežerková *et al*, 2004)

Fig 45 Fathala vegetation with grassy and woody cover (Nežerková *et al*, 2004)

Fig 46 Roan antelope *Hippotragus equinus* (Nežerková *et al*, 2004)

Fig 47 West african buffalo *Syncerus caffer brachyceros* (Nežerková *et al*, 2004)

Fig 48 Western Derby eland *Taurotragus derbianus* (Nežerková *et al*, 2004)

Fig 49 Plains zebra *Equus burchelli* (Wildscreen Arkive is a Wildscreen initiative, 2009)

Fig 50 Common eland *Taurotragus oryx* (Wildscreen Arkive is a Wildscreen initiative, 2009)