Spatial distribution of grazers in Noord-Friesland Buitendijks

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Final thesis project

Picture front cover	Horses in Noord-Friesland Buitendijks, by Adriënne Verburg

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August, 2010

Preface

The last few months we carried out a research project for our bachelor thesis. During this period we worked with several people we want to thank.

In the first place Steffi Nolte, who supervised us the entire period. Steffi was willing to help, be patient and most importantly teach us. We gained a lot of knowledge from her, a couple examples are knowledge of salt marsh plants, working with GIS, using statistics and cooking a great variety of delicious dishes.

Secondly our supervisors from van Hall Larenstein, Peter Hofman and Arjen Strijkstra, need to be thanked for their support, comments and supervision.

Christa van der Weyde for helping us with our statistical problems.

Another word of thank will be given to Peter Esselink. At last we want to thank the Rijksuniversiteit Groningen, for giving us the opportunity to carry out our final thesis in Ferwert.

Last but not least, we want to thank our friends and family, which supported us during our study in Leeuwarden.

José de Jaeger and Adriënne Verburg, Ferwert 23th of August 2010.

Summary

The aim of this research was to describe paddock use of horses and cattle in different densities in the salt marshes of Noord-Friesland Buitendijks. This information is crucial for three PhD-students of the university of Groningen. In this report is also added the ongoing discussion about grazing in salt marshes in whole Europe and it might help understanding different outcomes in studies with different livestock (densities).

The research questions were:

1. What kind of vegetation composition, in relation to elevation, is preferred for grazing by cattle and horses in the salt marsh?
   1.1 What is the difference in preference between cattle and horses?
   1.2 What is the difference in preference between the different stocking rates of cattle and horses? (5 or 10 horses/ cows per eleven ha)
2. How does the fresh water supply influence the spatial distribution of cattle and horses?
3. Are dropping counts a suitable method to assess grazing pressure?

This research was done in a previously installed grazing experiment setting. The experiment was set up in a block design with three replicates. These three areas (blocks) were subdivided into paddocks of each about eleven ha. One block had six paddocks, of which five were used, and the other blocks had each five paddocks. Within a block, five different grazing regimes took place; varying grazing species and intensity of grazing species: 1) Grazed intensively by cattle (ten cows), 2) Grazed extensively by cattle (five cows), 3) Grazed intensively by horses (ten horses), 4) Grazed extensively by horses (five horses) and 5) Ungrazed.

Dispersal of the grazers in the paddocks was determined, in a direct way, by observations of the grazers and indirect by counting the droppings. In addition vegetation composition and elevation measurements were taken.
The behaviours which were looked at with the direct observations, were subdivided into five categories: grazing, resting, walking, social behaviour and drinking.

A significant interaction effect was found between vegetation and elevation in both cattle and horses. It was observed that horses disperse throughout the whole paddock whereas cows tend to stay closer towards the fresh water supply.
The grazers with higher stocking rates dispersed more throughout the whole paddock.
A grazing gradient is induced by the fresh water supply. In this research dropping counts turned out to be no reliable method to assess grazing pressure.

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1. Introduction

The introduction describes the salt marshes and the study site Noord-Friesland Buitendijks (NFB), where a large grazing experiment is taking place. The research aim and questions arise from the ongoing international discussion about the management of salt marshes, which is still lacking some knowledge about different grazing regimes.

1.1 Salt marshes: zonation

Salt marshes arise naturally on tidal flats that are enough elevated, protected from waves and current, and have a sufficient supply of sediment *(Dijkema, et al., 2007 and Bakker, et al., 1993).* Therefore they are found for example in lagoons and estuaries, but also on barrier islands and open shores with low wave energy *(Litlle, 2007 and Adam, 2002)*. Most marine and estuarine mudflats are covered with vegetation on the upper tidal level. In temperate zones this vegetation consists of salt-tolerant grasses and other herbaceous plants. *(Litlle, 2007)* Examples of salt-tolerant grasses are S*partina anglica* and *Elytrigia atherica.*

Salt marsh meadows are regularly flooded by seawater *(Pinet, 2006)* and because the tidal currents influence the area, saltwater drainage is important. The drainage is taken care of by a large (sometimes man-made) meandering network of tidal channels. *(Pinet, 2006)*

Salt marshes are generally divided into different zones (shown in figure 1), which are associated with the zonation of grasses; the first salt marsh zones are the intertidal mudflats and the pioneer zone. These are located below mean high tide and are flooded during high tides. The pioneer zone is defined as the area where pioneer vegetation cover ≤ 5% *(Wolff, 2009).*

The third zone is the lower salt marsh, which is partly flooded during high tides. The lower salt marsh is characterized by e.g. *Puccinellia maritima* and *Aster tripolium*. The middle salt marsh is the zone which extends from neap high tide to the level of the highest spring tide. This zone is only flooded during extremely high tides and during storms. *(Pinet, 2006)*

The high salt marsh is not described in figure 1, this zone can include different vegetation types, for example *Festuca rubra and Agrostis stolonifera.* Due to the relatively low salt impact in this area, even glycophitic plants are sometimes found. The high salt marsh is therefore a more terrestrial environment than the lower salt marsh. *(Pinet, 2006)*

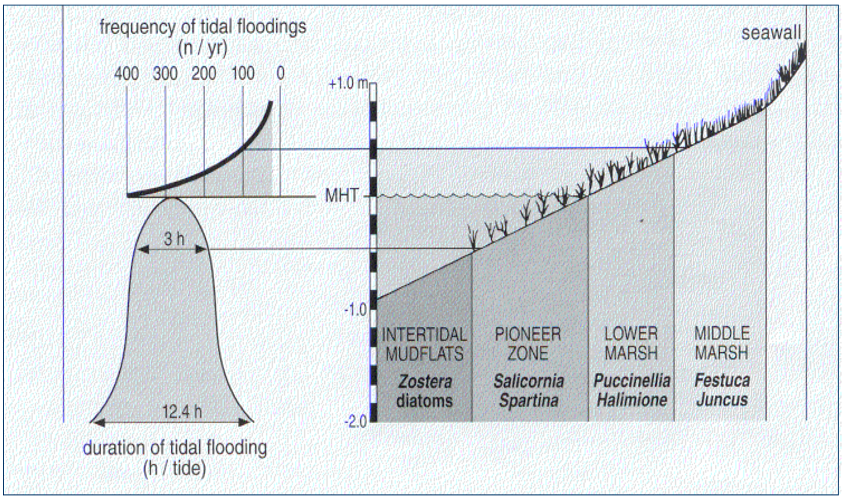

Figure 1. Zonation of artificial salt marshes in relation to duration and frequency of tidal flooding and marsh elevations for the western German Wadden Sea total number of flood tides is c. 700 each year *(Erchinger, 1985).*

1.2 Salt marshes: ecosystem

In spite of the physical conditions occurring in the salt marshes, these areas have a high productivity and therefore are recognized as one of the most productive natural environments on Earth *(Litlle, 2007 and Pinet, 2006).* Although diversity of coastal salt marshes in terms of numbers of species per unit area may be relatively low, coastal salt marshes are considered an irreplaceable habitat for a wide range of organisms. *(Esselink, 2000)*
Because of the high plant biomass, great numbers of phytophagous insects can be found. Salt marshes are important areas for the secondary production of estuaries. They provide feeding and sheltering grounds for juvenile organisms during floodings, such as fish using these areas as nursery grounds. *(Pinet, 2006)*

Furthermore the area houses moulting and wintering birds for at least 41 migratory waterbird species that use the East Atlantic flyway and originate from breeding populations as far away as northern Siberia or Northeast Canada. Up to 34 species are so numerous that the Wadden Sea is indispensable and often the main stepping stone during migration, or as their primary wintering or moulting habitat. *(Marencic, 2009)* Therefore the Wadden Sea is essential for the survival of these bird species. A severe deterioration of the Wadden Sea implies a biodiversity loss on a worldwide scale, *(Marencic, 2009)* also the biodiversity loss is prevented by appointing the area with Natura 2000.

1.3 Salt marshes: management

Management of the area is nowadays taken care of by It Fryske Gea.
It Fryske Gea is the provincial association for nature protection with circa 22.000 supporters. Their goal is protection, conservation and development of nature and natural landscapes in Friesland. Nowadays It Fryske Gea manages more than 50 different nature areas with a total surface of over 20.000 ha, spread through the whole province. *(It Fryske Gea, 2010)*

It Fryske Gea has the main responsibility of protecting and managing the area of Noord-Friesland Buitendijks *(It Fryske Gea, 2010),* since almost 90% of the area is owned by It Fryske Gea (about 3500 ha. of the 4000 ha.) *(Beintema, et al., 2007).*

Nowadays managers want to find the fitting management practice to reach previously set nature goals. *(Nolte, 2010)* One of the commonly used management practices in salt marshes such as Noord-Friesland Buitendijks is grazing. Although there is a lot of knowledge about the impact of grazing in general, this mainly covers the difference between no grazing and high intensity grazing, and often research is carried out only on cattle or sheep and without controls and replication. Thus one could say that there is not much knowledge about the impact of grazing on salt marshes. Furthermore, earlier researches often dealt with only a single aspect of the salt marsh ecosystem under grazing influence such as vegetation. There is still a lack of knowledge on the impact on birds and invertebrates and the interactions between the different groups in the ecosystem *(Nolte, 2010).*

Research about the effects of different livestock and different stocking rates, on the biodiversity of the salt marsh, regarding plants, birds and invertebrates, is done by three PhD-students of the Community and Conservation Ecology group (COCON) of the University of Groningen. They are supervised by Prof. Dr. Jan Bakker, Dr. Peter Esselink and Prof Dr. Han Olff, each PhD-student having their own focus on different subjects: invertebrates (Roel van Klink), birds (Freek Mandema) and plants (Steffi Nolte).

The grazing experiment at Noord-Friesland Buitendijks allows researchers to directly compare the impact of different cattle and horse grazing regimes on the salt marsh ecosystem in replicates. The project set-up with three PhD-students, each having their own subject, brings new possibilities to find out more about the interactions within the system *(Nolte, 2010).* The aim of the project is to improve the knowledge about how grazing effects the interactions between vegetation, birds and invertebrates and thereby give managers guidelines to decide what practices suits their aim/ target.
This goal of management is nowadays mainly maximizing biodiversity, which cannot be reached with one management practice, but should be achieved by varying management practices.

To understand the impact of grazing on a local scale, it is crucial to know more about the actual dispersal of the animals in the managed area. Previous studies concluded that a grazing regime of a given intermediate number of animals often leads to a grazing gradient.

The aim of this research will thus be to describe paddock use of horses and cattle in different densities in the salt marshes of Noord-Friesland Buitendijks, to make this crucial information available to the mentioned research project. It will also add to the ongoing discussion about grazing in salt marshes in whole Europe and might help understanding different outcomes in studies with different livestock. To allow a generalization of this study it is of importance to search for patterns in distribution of the animals and their possible explanation, such as preferred vegetation types and elevation.

1.4 Research questions

1. What kind of vegetation composition, in relation to elevation, is preferred for grazing by cattle and horses in the salt marsh?
   1.1. What is the difference in preference between cattle and horses?
   1.2. What is the difference in preference between the different stocking rates of cattle and horses? (5 or 10 horses/ cows per eleven ha)
2. How does the fresh water supply influence the spatial distribution of cattle and horses?
3. Are dropping counts a suitable method to assess grazing pressure?

1.5 Expectations / hypothesis

It is expected that cattle and horses prefer the more elevated parts of the salt marsh. Furthermore horses may be more inclined to spread out more evenly throughout the area than cattle. With a high stocking rate the animals may also distribute more evenly.
Another expectation is that for all regimes a grazing gradient will be induced by the fresh water supply. Then the hypothesis is that the dropping counts are a suitable method to asses grazing pressure when they are compared with the observations.

2. Material and Methods

This chapter will describe the study site, research design and data gathering methods, followed by a description of the data analysis.

2.1 Study site Noord-Friesland Buitendijks

The Dutch, German and Danish Wadden Sea is the biggest tidal area found in Europe, with a size of 900.00 ha. 40.000 ha of that area consist of salt marshes and 9.000 ha of these are located in the Dutch Wadden Sea. *(Dijkema, et al., 2007)* Noord-Friesland Buitendijks is an area located in the Dutch Wadden Sea in the province of Friesland (see figure 2).

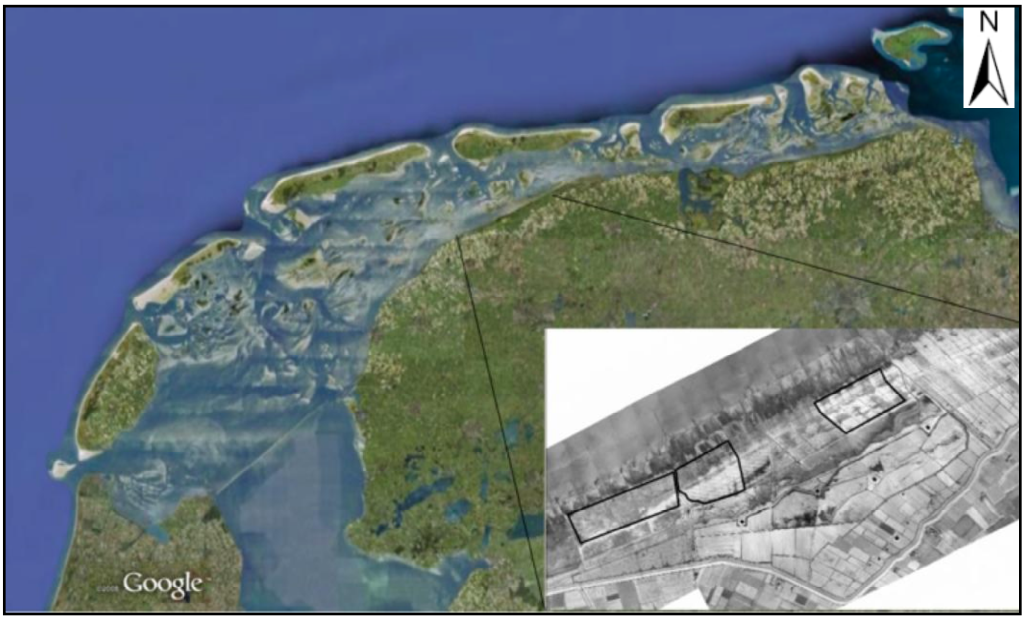

Figure 2. Overview of the Frisian coast (NL) and (small picture) the research area Noord-Friesland Buitendijks (Nolte, 2010).

2.1.1 Noord-Friesland Buitendijks: Natural history

Humans populated the salt marshes of Friesland and Groningen for the first time around six centuries BC. This was possible because the sea level was declining. *(Beintema, et al., 2007)* Three centuries later the sea level began to rise again and the sea reached further inland. This resulted in severe flooding during this time. *(Beintema, et al., 2007)*

The result of the flooding was the development of the Zuiderzee, the Dollard, the Middelzee and the Lauwerszee. During the Middle ages, people started to build dykes used for protection against the sea. This initialised parts of the salt marsh development. *(Beintema, et al., 2007)*

From the thirteenth century on, the whole Dutch coastline of the Wadden Sea was surrounded by dykes. The dykes were built parallel to the inlets and the inland seas. After that, people began to claim these inlets by damming in the salt marshes. *(Beintema, et al., 2007)* Between 1200 and 1500 much land reclamation took place. These polders are nowadays bordering the Noord- Friesland Buitendijks area. Noord-Friesland Buitendijks is now the largest contiguous salt marsh of the Wadden Sea. *(Beintema, et al., 2007)*

2.1.2 Noord-Friesland Buitendijks: Present situation

At the present time Noord-Friesland Buitendijks consists of salt marshes, polders and summer polders *(Beintema, et al., 2007)* and covers an area of 4000 ha. A large part of this area is less than 100 years old and the result of intensive land reclamation works, which took place in the 1930's. In fact this area consists of two land reclamation zones, which now are connected. *(Natuurinformatie, 2010)*

With the exception of some salt marshes that are located in sheltered bays, all mainland Wadden Sea salt marshes require artificial protection for wave energy to prevent erosion and to preserve their present extension. *(Esselink, 2000)* Land reclamations are not carried out anymore in Noord-Friesland

Buitendijks, although the structures like brushwood groynes are still maintained to prevent erosion. *(Nolte, 2010)*

The land reclamation method used in this area is called Schleswig-Holstein. This method is applied on areas that are 1 a 1,20 meters beneath mean high tide and where it is not yet possible for vegetation to grow. Squares of approximately 400 x 400m are formed by the construction of the so-called brushwood groynes *(Kley, van der, et al., 1969)*. These groynes consist out of two layers of poles, which are placed in the sediment. Between these poles brushwood is plaited. The tops of these dams are about 30 cm above the mean high water level. *(Beintema, et al., 2007)* This method is used for coastal protection and to capture the sediment. Therefore the salt marshes in these areas will elevate and be eventually not flooded by tides any more. *(Natuurinformatie, 2010)*

2.1.3 Noord-Friesland Buitendijks: Law and legislation

The salt marshes, located in the Netherlands, are of great international importance for conservation. This concerns different (breeding and over-wintering) bird species, for example the *Branta bernicla*, *Branta leucopsis*, *Falco peregrinus*, *Anas Penelope* and different waders are common *(Beintema, et al., 2007).* Salt marshes in general are also important for the conservation of (rare) plant species and other organisms *(Natuurinformatie, 2010).* Man-made marshes are a typical feature of the Wadden Sea. In recent years, increasing areas of man-made marshes have become nature reserves or parts of national parks *(Bakker, et al., 1997)*.

Noord-Friesland Buitendijks is receiving protection in different ways. These ways are listed below.

Nature conservation Act 1998 / European Bird and Habitat directive

In 1967 the Netherlands created their first Nature-protection law (Natuurbeschermingswet). This law made it possible to protect nature areas and species. But after 20 years this law was not sufficient anymore. In 1998 a new law was created which included the international and European agreements and a division was made in the new law. Only the areas were protected and in the new Flora- and fauna law the protection of species was organized.

In 2005 the law changed again and since then the criteria of the European Bird and Habitat directive are included.

Areas that are protected through the Nature-protection law are:

* Natura 2000 area's (Bird and Habitat directive area's)
* Protected nature monuments
* Wetlands *(Ministry of Agriculture, Nature and food quality, 2010)*

Flora and fauna law

Since 2002, the Netherlands introduced the Flora and fauna law. This law included the European regulation for the protection of species (bird and habitat directive) and the Cites agreement. The flora and fauna law is a "kaderwet" and is executed with a "no, unless" principle. It contains only general principles and responsibilities. *(Ministry of Agriculture, Nature and food quality, 2010)*

Goal of this law is the protection and the preservation of wild living plant and animal species.

The three main elements of this law are:

* List of protected species.
* Prohibition of killing, disturbance or damage of protected species and their holes, nests and eggs, and the prohibition of damaging or picking protected plants.
* The obligation to take sufficient care for wild animals and plants. *(natuurbeheer, 2010)*

Ecological Main Structure (EHS)

The EHS is a network of areas through the Netherlands where nature comes first. This network needs to prevent that plants and animals living in isolated areas get extinct and that nature areas lose their value. This network can be seen as the spine of the Dutch nature.

The EHS consists of:

* Existing nature areas, reserves, nature development areas and so-called robust connections.
* Agriculture areas which have the opportunity for agriculture nature management.
* Large waters (examples: the shore of the North Sea, the Ijsselmeer and the Wadden Sea).

The EHS is nowadays still developing and has to be ready in 2018. *(Minestry of Agriculture, Nature and food quality, 2010)*

Natura 2000
Natura 2000 is a network that connects protected nature areas throughout the European Union. The Netherlands nowadays has 162 areas in total included in the Natura 2000. Noord-Friesland Buitendijks is one of these areas. *(Ministry of Agriculture, Nature and food quality, 2010)*

Third Policy document Wadden Sea (PKB)
Since 1980 the Dutch Wadden Sea has been protected according to the PKB Third Policy Document of the Wadden Sea, which is a national physical planning decree defining the overall objectives of conservation, management and use of the Wadden Sea. The PKB is a specific integrated physical planning instrument of the Spatial Planning Act and its objectives and conditions are binding for all state, regional and local authorities. *(Marencic, 2009)*

UNESCO-world Heritage list
Since June 2009 the World Heritage Committee at its 33rd session, Seville, inscribed the Dutch German Wadden Sea on the World Heritage List under natural criteria: geomorphology, ecological and biological processes, and biological diversity. *(Marencic, 2009)*
The status World Heritage does not change anything in these protective measures; there are no new regulations. That this protected area has now become World Heritage, is primarily a crowning of years of efforts of many residents, organizations and governments in the region. *(Wadden Sea world Heritage, 2010)*

Ramsar Wetlands Convention
The Ramsar Wetlands Convention is an internationally recognized measure to identify wetlands of international importance. *(Marencic, 2009)* The Wadden Sea, which includes Noord-Friesland Buitendijks, includes eight Ramsar sites covering over 1.000.000 hectares. So it is also under the protection of the Ramsar Wetlands Convention. *(Bridgewater, 2003)*

2.1.4 Noord-Friesland Buitendijks: Current management

Horses and cattle are used to graze in Noord-Friesland Buitendijks as a management tool. Grazing takes place in Noord-Friesland Buitendijks from June till October *(Bakker, et al., 2000).* The exact dates can differ, depending on the level of the water and the weather. In winter there is a risk that these areas will be flooded by water, so there are no grazers present. During the time that the grazers are present in the area, there is no need for extra fertilising the land. *(Beintema, et al., 2007)*

2.2 Research design

This research was done in a previously installed grazing experiment setting. The experiment is set up in a block design with three replicates (West, Middle and East). These three areas were subdivided into paddocks. The West block had six paddocks, of which five were used, and the other blocks had each five paddocks (see figure 3). Each paddock covered an area of about 11 ha. The total research area was around 180 ha. Within a block, five different grazing regimes took place; varying grazing species and the number of animals:

1) Grazed intensively by cattle, which means with ten cows per paddock.
2) Grazed extensively by cattle, which means with five cows per paddock.
3) Grazed intensively by horses, which means with ten horses per paddock.
4) Grazed extensively by horses, which means with five horses per paddock.
5) No grazing took place.

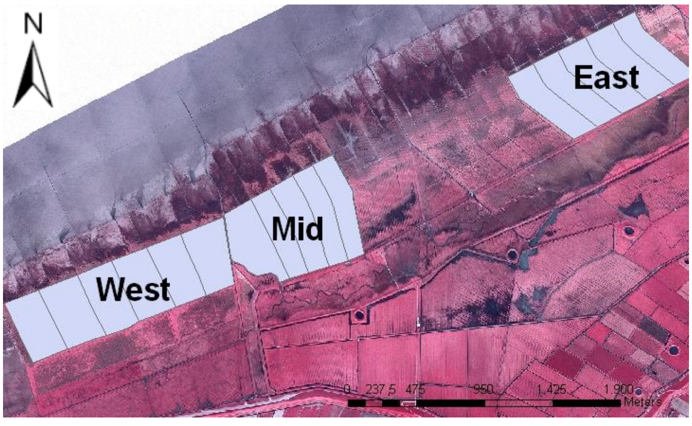

Figure 3. Overview of the study site, showing the West, Middle and East blocks. The Wadden Sea is situated at the northern part of the area, whereas the summer dike lies on the southern part. (Which animals are in which paddock is described/ shown in the results chapter).

During this project the decision to use cattle and horses instead of e.g. sheep, was based on the fact that these animals were used for traditional grazing in the area of Noord-Friesland Buitendijks. The extensively grazed paddocks had a stocking rate of 0.45 livestock per ha, and the intensively grazed paddocks had a stocking rate of 0.9 livestock per ha. According to Kleyer, et al 2003, intermediate-stocking rates would be 0.6 livestock units per ha and 1.3 livestock units per ha would be a high stocking rate.

2.3 Data gathering methods

In this paragraph the methods used for the data gathering are described.

2.3.1 Observations

Each paddock, of eleven ha, was divided into 24 gird cells. Each of these were approximately 6800m². The observations took place between 14 June 2010 and 30 July 2010, and were done from observation towers.
In order to be able to recognize the exact location of the grazer during the observations, maps were used. These maps, created with ArcGIS 9.3.1 by ESRI 2009, were showing each paddock with the grid cells. Fence poles were marked with colour to be used as a reference point during the observations. On the maps the paddocks, painted fence poles and fresh water tanks were indicated. .

The observation was started 5-10 minutes after the arrival at the observation tower, in order to minimize interference with the behaviour of the grazers. Each observation session had a length of twenty minutes; every ten minutes an observation was done.

Two observers carried out the observations. One of these was using a binocular to count the behaviours and determinate where the grazers were located, the other observer was writing and using the map to determine the actual grid cell(s).
To note locations, an observation form was used, an example is enclosed in appendix I.
Each paddock was observed at different times of the day to include daily behavioural patterns of the grazers.

The behaviours of the animals were defined in five categories: 1) Grazing, 2) Resting, 3) Walking, 4) Social behaviour, and 5) Drinking. In table 1 the definitions of these behaviours are described.

Table 1. Definitions of behaviour for horses and cattle.

Behaviour	Horses	Cattle
Grazing	Vegetation intake with no more than three steps between the bites.	Vegetation intake with no more than three steps between the bites.
Resting	Any stationary, non-feeding activity engaged in by the herd (e.g., standing, lying, ruminating, sleeping) *(Senft, et al., 1985).*	Any stationary, non-feeding activity engaged in by the herd (e.g., standing, lying, ruminating, sleeping) *(Senft, et al., 1985).*
Walking	Taking more than three steps without grazing.	Taking more than three steps without grazing.
Social behaviour	Any behaviour which is taking place between members of the same species (example given: establishment of the picking order and communicating)	Any behaviour which is taking place between members of the same species (example given: establishment of the picking order and communicating)
Drinking	Water intake	Water intake

2.3.2 Dropping counts

Droppings were counted once a week in four different plots per paddock. These different plots, each representing one grid cell, were chosen randomly. In ArcGIS the X and Y coordinates of the middle point of the grid cells were calculated for these grid cells. A GARMIN eTrex ® H Global Positioning System (GPS) was used to find the points in the field. As stated earlier, each paddock had four different plots, with a circular form for specific experimental use. The plots had a radius of 11 m, and covered a surface of about 400m^2 within the approximately 6800m^2 grid cell. Metal pins were put into the ground, to mark the exact location of the dropping count points. A metal detector was used to relocate these later.

During the measurements, a stick with measuring tape was used, with which the distance to the centre point of the plot was measured and noted. All the new droppings per plot were counted and marked with paint. An example of the observation form for the dropping counts can be found in appendix II.

2.3.3 Elevation measurements

The elevation was measured in a subset of paddocks because of time restrictions: the middle paddocks 1-4 and the eastern paddocks 3 and 5. These paddocks were chosen because of the large amount of observations available from those paddocks.

The elevation measurements were done using a Spectra Precision® Laser LL500 and Spectra Precision® Laser HR500 receiver by Trimble. The laser was placed at one of the observation towers. The laser receiver was attached to a measuring stick.
To calculate the elevation in reference to Normaal Amsterdam’s Peil (NAP) a fixed point with a known elevation is needed. In this case previously installed Sedimentation Erosion Bar (SEB) poles, placed during an earlier study by Esselink, P., were used.
The SEB poles have a crosscut of 7,5 cm and a length of 160cm. After drilling 1m deep, they were placed in the ground and fixed into the ground in the sand layer (with an average mean of 125cm deep). *(Duin, van, et al, 2007)*

In each grid cell ten measurements were randomly taken. The ditches in the grid cells were avoided, as they were not representative for the grid cells. The elevation measurement form can be found in appendix III.

2.3.4 Vegetation composition

The vegetation composition was recorded by noting the four most dominant species in order of abundance, per grid cell.

2.4 Data analysis

In this paragraph the data analysis will be described.

2.4.1 Data processing observations

The data from the observation form were transported to an Excel file. Using this Excel file, the total amount of animals observed per grid cell was readable. It was done per five horses or cows and horses or cows in total. Next there was made a difference between the different behaviours. This was later calculated into percentages.

2.4.2 Elevation measurements

The elevation data was transported into Excel. A calculation was made to measure the height to NAP. The A represents the measurements at the SEB poles, whereas B represents the measurements taken in the grid cells (see equation underneath).

$$\text{NAP point} = \overbrace{(\text{fixed point NAP} + \text{measurement FP})}^{A} - \overbrace{(\text{fixed stick - measurement})}^{B}$$

The equation above is corresponding to figure 4. The NAP point is measured by first calculating;
(The fixed point NAP (in the figure nr.1) + the measurement of the fixed point (in the figure nr. 2)) – (The fixed stick length (in the figure nr.3) – measurement (in the figure nr. 4))

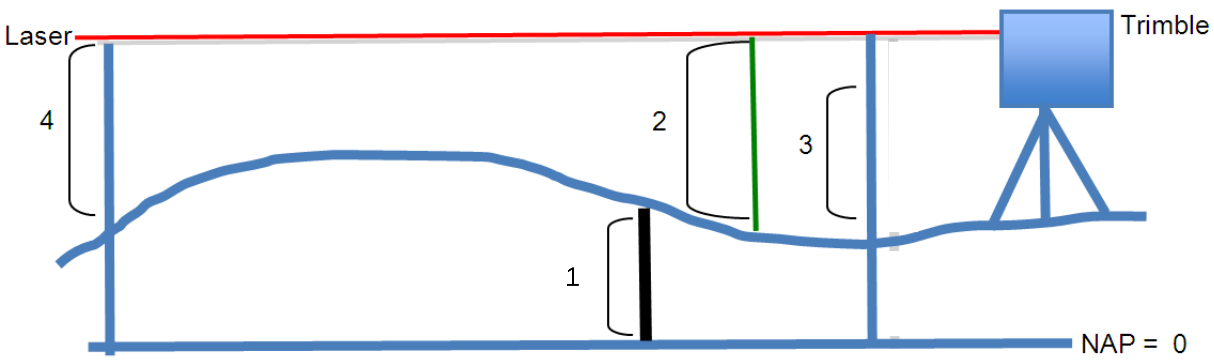

Figure 4. Model of the set-up during the elevation measurements.

After this calculation the results were set into a relation to the Mean High Tide (MHT). As there is no measuring station for the water level in Noord-Friesland Buitendijks, the data from the closest stations (Harlingen and Holwerd) were used. A mean of these was calculated to estimate the MHT in Noord-Friesland Buitendijks.
The elevation means were included into the ArcGIS map.

2.4.3 Vegetation

The vegetation composition was used to classify the grid cells into eight different vegetation classes (see table 2).
The classes 1 – 5 are the vegetation classes that are seen on the high marsh, whereas classes 6 – 8 are found on the low marsh. The vegetation classes were imported into the ArcGIS map.

Table 2. Vegetation classes

1	*Agrostis stolonifera – Cirsium spec.*
2	*Agrostis stolonifera – Glaux maritima*
3	*Agrostis stolonifera – Puccinellia maritima – Aster tripolium*
4	*Agrostis stolonifera – Puccinellia maritima*
5	*Agrostis stolonifera – Suaeda maritima*
6	*Puccinellia maritima – Glaux maritime – Aster tripolium*
7	*Puccinellia maritima – Plantago maritimum*
8	*Puccinellia maritima – Suaeda maritima – Salicornia europea*

3. Results

Chapter three will show the results of the analysed data.

3.1 Research question 1: What kind of vegetation composition, in relation to elevation, is preferred to be grazed by cattle and horses in the salt marsh?

This research question is subdivided into two questions. The following two sub-paragraphs will describe these questions and the outcomes of these questions.

3.1.1 What is the difference in preference between cattle and horses?

In figure 5 the dispersal of grazing cattle and horses per vegetation class is shown. In the graph can be seen that horses were grazing more frequently in the low marsh than cows.

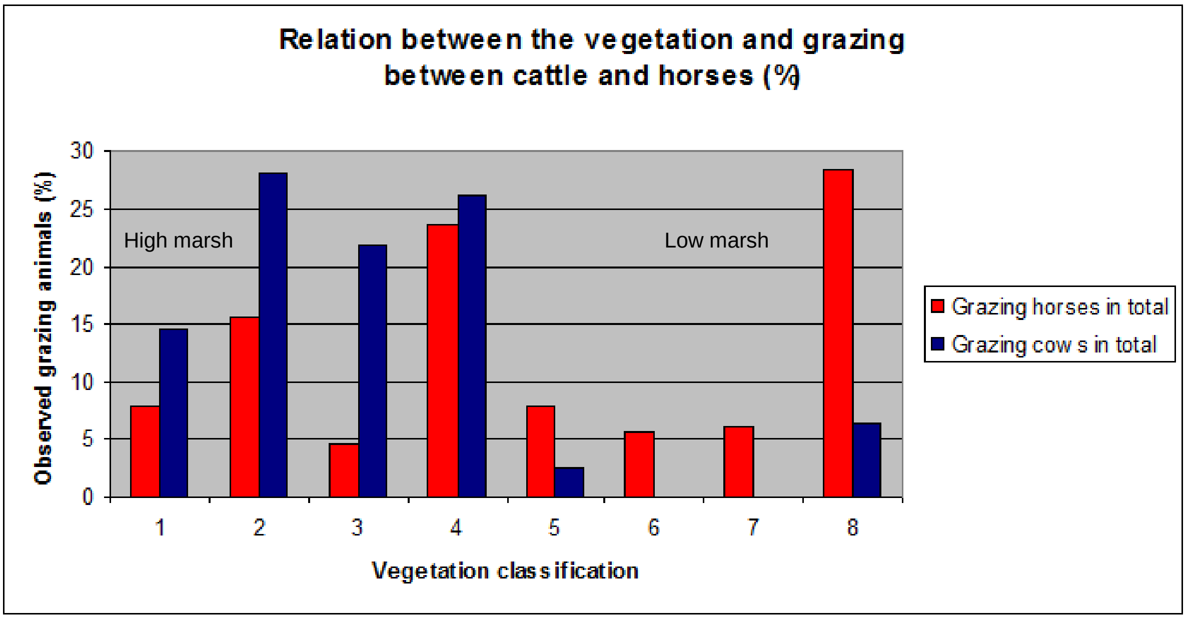

Figure 5. Dispersal of grazing cattle and horses per vegetation class.
The blue bars represent the percentages observed grazing cows. The red bars represent the percentages observed grazing horses. The species names of the vegetation classifications are: *1 - Agrostis Stolonifera – Cirsium spec.2 - Agrostis stolonifera – Glaux maritima 3 - Agrostis stolonifera – Puccinellia maritima – Aster tripolium 4 - Agrostis stolonifera – Puccinellia maritima 5 - Agrostis stolonifera – Suaeda maritima 6 - Puccinellia maritima – Glaux maritime – Aster tripolium 7 - Puccinellia maritima – Plantago maritimum 8 - Puccinellia maritima – Suaeda maritima – Salicornia europea.* The vegetation classifications are subdivided into high salt marsh species (left) and low salt marsh species (right). The boundary is situated between vegetation classification 5 and 6.

Not only graphs were used to describe the results, also the results are statistical disproved:
The data did not follow the normal distribution. The assumption of normal distribution was still not met after transformation.

The data from both horses and cattle followed a Poisson distribution, so loglinear regression was used.
The dependent variable was log transformed to allow estimation of the model.
Number of observed animals was included in the model as the dependent variable. Elevation was included as a covariate and vegetation type as a factor. Further the interaction between vegetation and elevation was also taken into account.

The regression model explained the variation in observed horses (intercept: X^2=12,062 df=1; p= 0,001, regression coefficient vegetation:X^2= 20,917; df=7;p-0,004, regression coefficient elevation: X^2=6,151;df=1;p=0,013 regression coefficient vegetation * elevation: X^2=19,982; df=7;p=0,006; N= 93).

The regression model did not explained the variation in observed cows (intercept: X^2=0,309 df=1; p= 0,578 regression coefficient vegetation:X^2= 35,229; df=5;p <0,0005, regression coefficient elevation:

X^2=1,299 ;df=1;p=0,254 regression coefficient vegetation * elevation: X^2=33,879; df=5;p<0,0005; N= 48).

In both cattle and horses there appeared to be a significant interaction effect between vegetation and elevation.

On the next four pages, four different ArcGIS maps are shown. These pages are rotated to have a better overview of the maps.
In figures 6 and 8 the percentages of observed grazing cattle and horses are shown in relation with the different elevations in the middle and east blocks. These maps are showing that both horses and cattle were grazing more intensely on the higher parts of the salt marsh.
In figures 7 and 9 the percentages of observed grazing cattle and horses are shown in relation with the different vegetation classifications. In the map of the middle block, (see figure 7) can be seen that vegetation classification number 8 is more common close by the Wadden Sea than in the rest of the paddocks. Generally the grazing pressure is higher in the parts further away from the Wadden Sea.
In the map of the eastern block, (see figure 9) the vegetation classification is more various throughout the two paddocks. In the paddock with the ten horses grazing was mostly observed on vegetation classification 4.

Also other behaviours than grazing were observed. The results of these observations are shown in appendix IV.

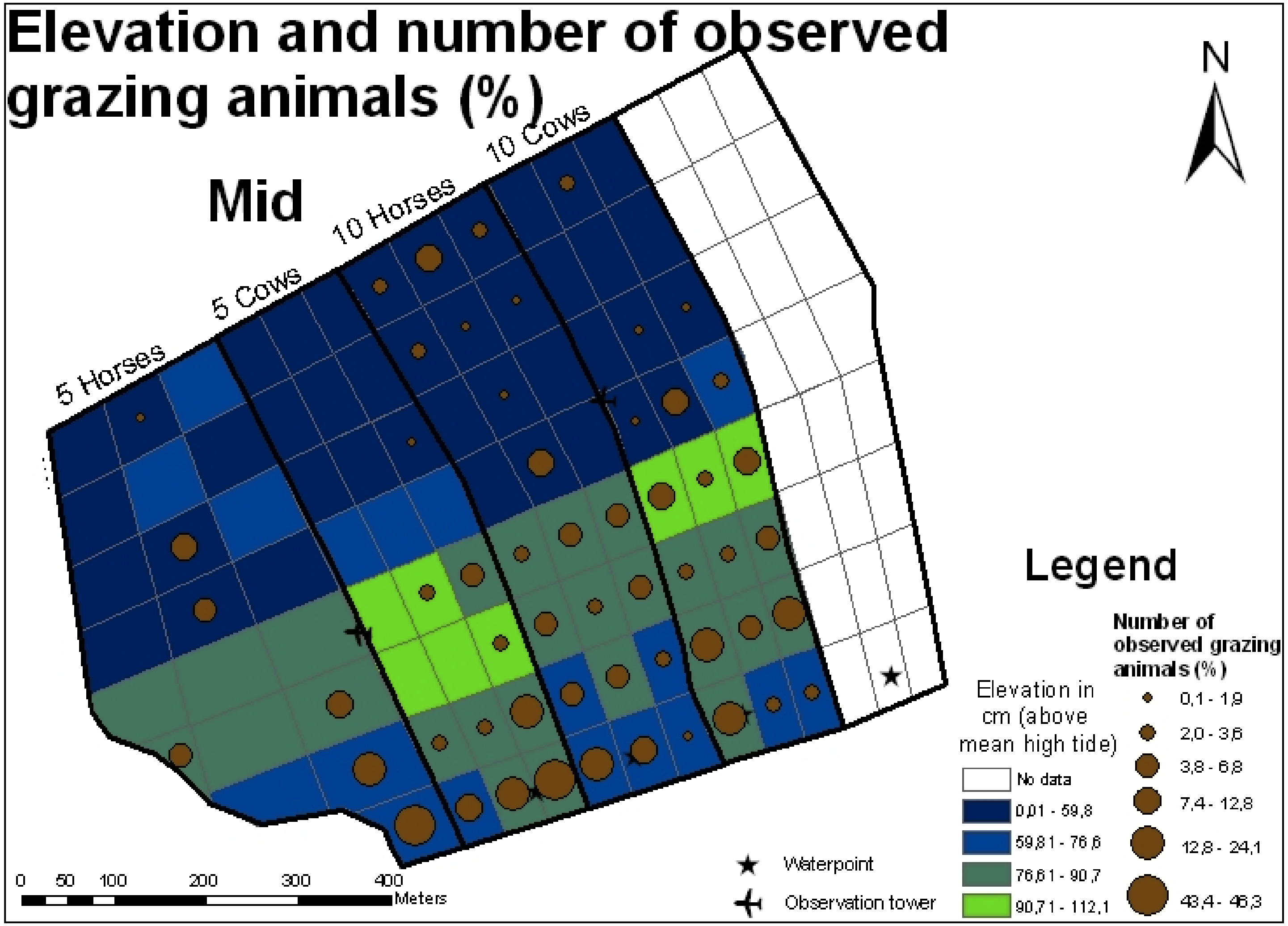

Figure 6. Elevation and the percentage of the number of observed grazing animals in the middle block.
The Wadden Sea is located in the north. In the first (left to right) paddock, five horses were grazing, in the second paddockfive cows were grazing, in the third paddock ten horses were grazing, in the fourth paddock ten cows were grazing and in the fifth paddock no grazers wee in. The background colours are the different elevations above mean high tide, in cm. See the legend for the differert heights. The brown circles are representing the number of observed animals, in percentages. The airplane symbols are representing the observation towers and the stars are rφresenting the water supplies

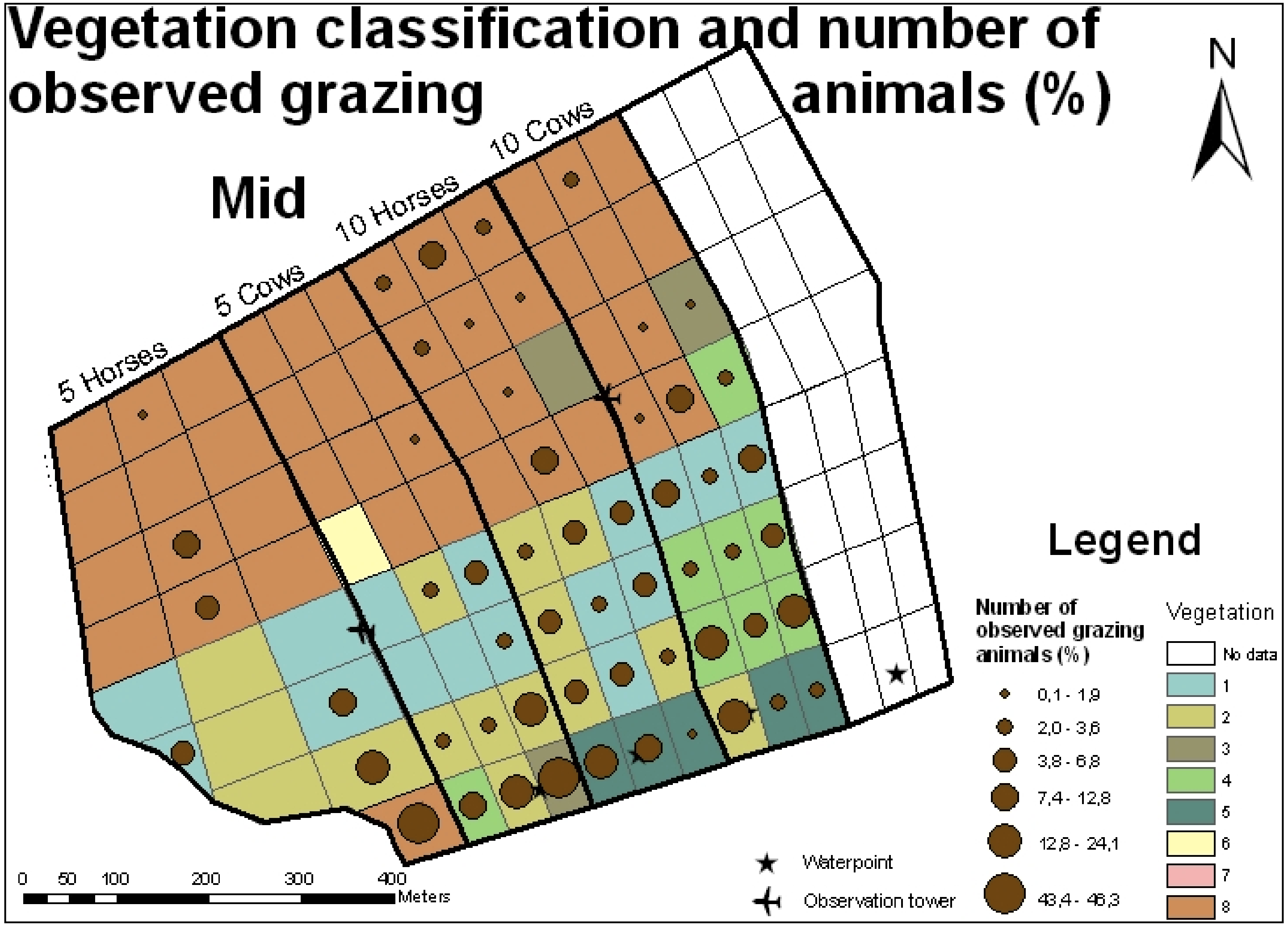

Figure 7. Vegetation and the percentage of the number of observed grazing animals in the middle block.
The Wadden Sea is located in the north. In the first (left to right) paddock, five horses were grazing, in the second paddockfive cows were grazing, in the third paddock ten horses were grazing, in the fourth paddock ten cows were grazing and in the fifth paddock no grazers were in. The backgroundcolours are the different vegetation classifications*: 1 - Agrostis Stolonifera – Cirsium spec.2 - Agrostis stolonifera – Glaux maritima 3 - Agrostis stolonifera – Puccinellia maritima – Aster tripolium 4 - Agrostis stolonifera – Puccinellia maritima 5 - Agrostis stolonifera – Suaeda maritima 6 - Puccinellia maritima – Glaux maritime – Aster tripolium 7 - Puccinellia maritima – Plantago maritimum 8 - Puccinellia maritima – Suaeda maritima – Salicornia europea.* The brown circles are representing the number of observed animals, in percentages. The airplane symbols are representing the observation towersand the stars are representing the water supplies.

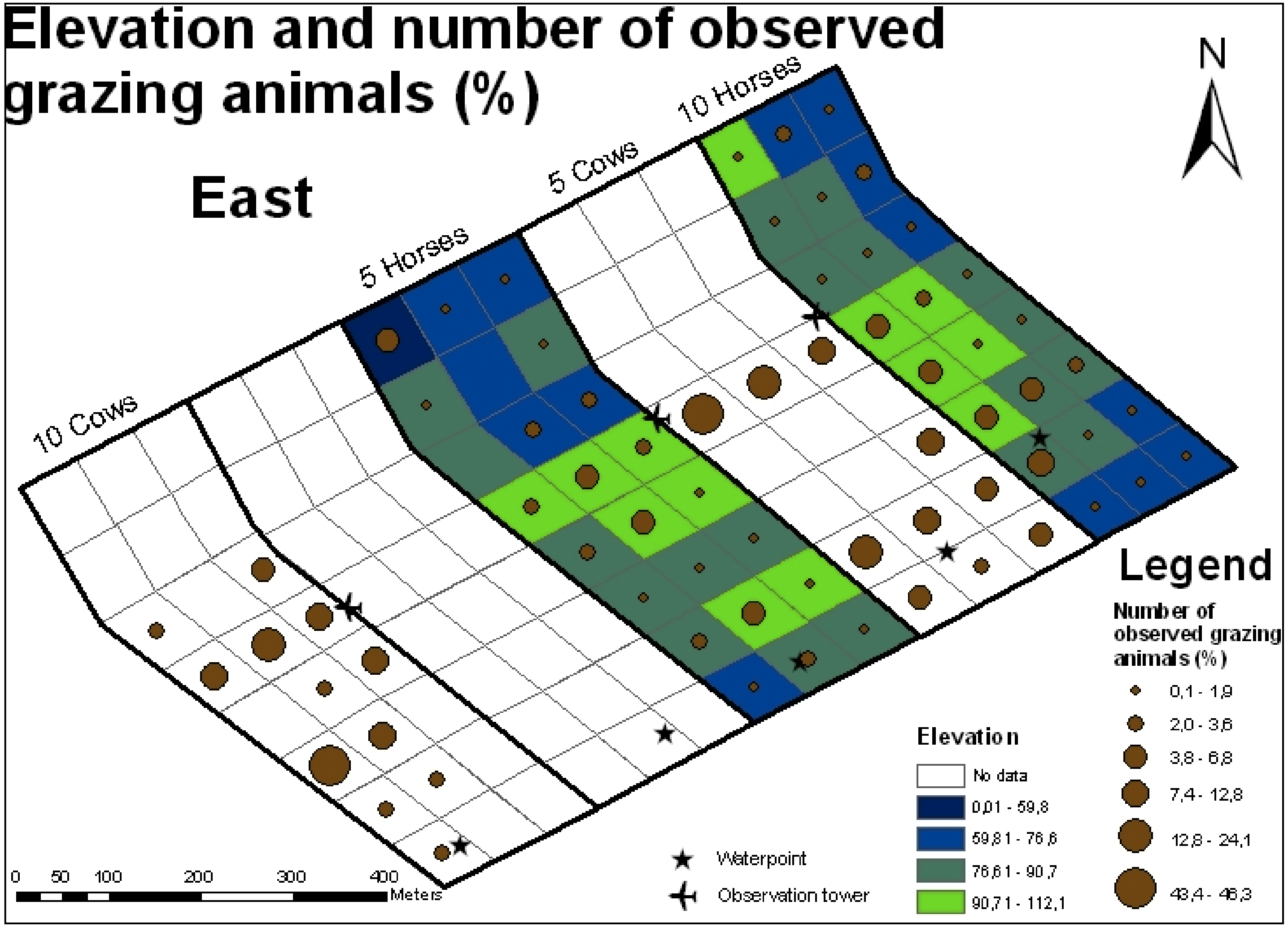

Figure 8. Elevation and the percentage of the number of observed grazing animals in the east block.
The Wadden Sea is located in the north. In the first (left to right) paddock, ten cows were grazing, in the second paddock no grazers were in, in the third paddock five horses were grazing, in the fourth paddock five cows were grazing and in the fifth paddock ten horses were grazing. The background colours are the different elevations above mean high tide, in cm. See the legend for the different heights. The brown circles are representing the number of observed animals, in percentages. The airplane symbols are representing the observation towers and the stars are representing the water supplies.

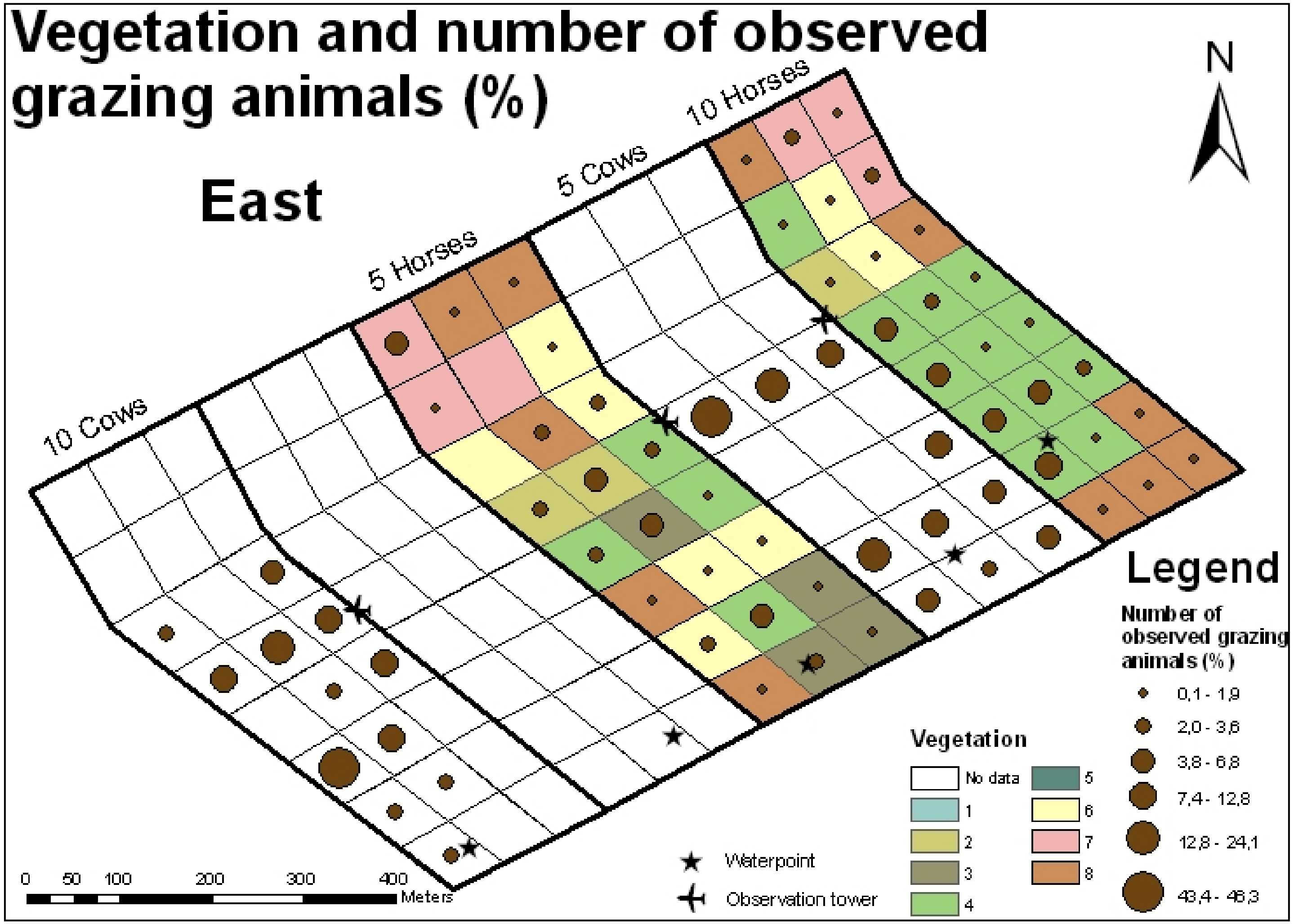

Figure 9. Vegetation and the percentage of the number of observed grazing animals in the east block.
The Wadden Sea is located in the north. In the first (left to right) paddock, ten cows were grazing, in the second paddock no grazers were in, in the third paddock five horses were grazing, in the fourth paddock five cows were grazing and in the fifth paddock ten horses were grazing. The background colours are the different vegetation classifications: *1 - Agrostis Stolonifera – Cirsium spec.2 - Agrostis stolonifera – Glaux maritima 3 - Agrostis stolonifera – Puccinellia maritima – Aster tripolium 4 - Agrostis stolonifera – Puccinellia maritima 5 - Agrostis stolonifera – Suaeda maritima 6 - Puccinellia maritima – Glaux maritime – Aster tripolium 7 - Puccinellia maritima – Plantago maritimum 8 - Puccinellia maritima – Suaeda maritima – Salicornia europea.* The brown circles are representing the number of observed animals, in percentages. The airplane symbols are representing the observation towers and the stars are representing the water supplies.

3.1.2 What is the difference in preference between the different stocking rates of cattle and horses?

For this question a figure is made (see figure 10). It shows the dispersal of the different stocking rates of grazing cattle and horses per vegetation classification.

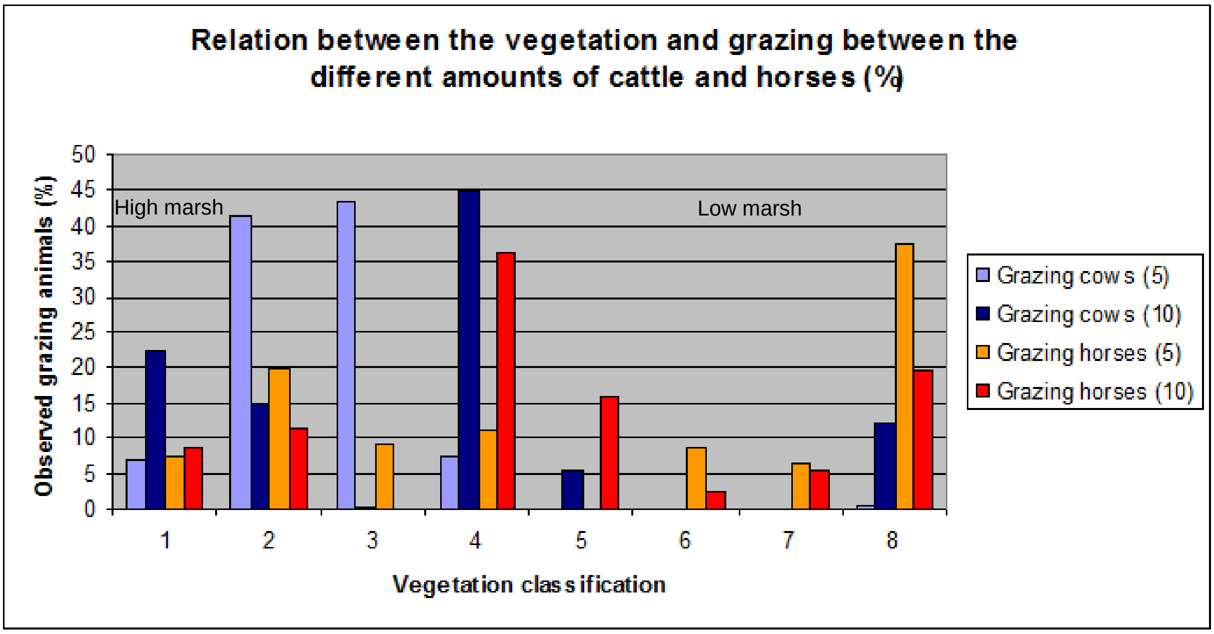

Figure 10. Dispersal of the different stocking rates of grazing cattle and horses, per vegetation class. Red bars represent the percentages observed grazing cows, 10 per paddock. Orange bars represent the percentages observed grazing cows, 5 per paddock. Dark blue bars represent the percentages observed grazing horses, 10 per paddock. Light blue bars represent the percentages observed grazing horses, 5 per paddock. The species names of the vegetation classifications are: *1 - Agrostis Stolonifera – Cirsium spec.2 - Agrostis stolonifera – Glaux maritima 3 - Agrostis stolonifera – Puccinellia maritima – Aster tripolium 4 - Agrostis stolonifera – Puccinellia maritima 5 - Agrostis stolonifera – Suaeda maritima 6 - Puccinellia maritima – Glaux maritime – Aster tripolium 7 - Puccinellia maritima – Plantago maritimum 8 - Puccinellia maritima – Suaeda maritima – Salicornia europea.* The vegetation classifications are subdivided into high salt marsh species (left) and low salt marsh species (right). The boundary is situated between vegetation classification 5 and 6.

Cows that have a stocking rate of five, are observed in the vegetation types 2 and 3 frequently. Whereas the cows with a stocking rate of 10 are mostly observed in vegetation type 4.

Horses are observed mostly in vegetation class 8 during stocking rates of 5 animals, but whit a stocking rate of 10 they were observed in vegetation type 4.

3.2 Research question 2: How does the fresh water supply influence the spatial distribution of cattle and horses throughout the area?

To answer this question there are made two scatterplots; one for the horses (see figure 11) and one for the cows (see figure 12).

In figure 11 a graph is shown which represents the relation between the distance to the water supply and the number of observed horses. In this graph can be seen that close by the water supply the percentage of the observed horses was a little bit higher than further away from the water supply.

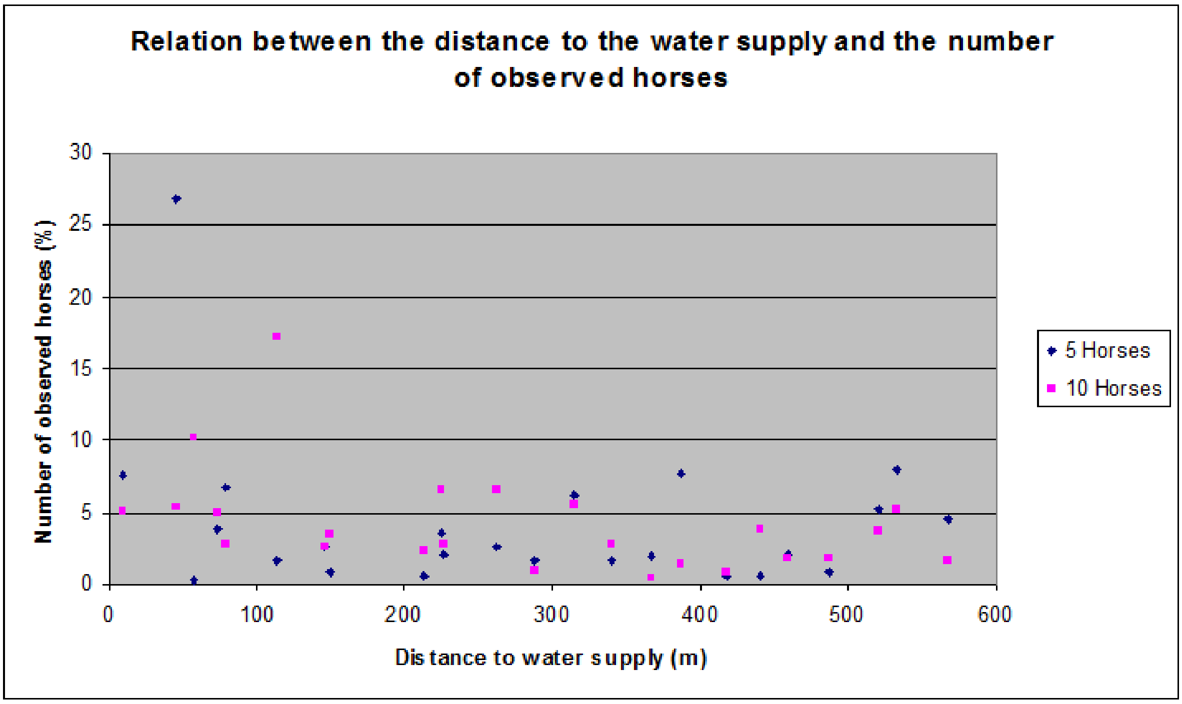

Figure 11. Relation between the distance to water supply and the number of observed horses
The pink dots represent the percentages of observed horses, with a stocking rate of 10. Whereas the blue dots represent the percentage of observed horses, with a stocking rate of 5.

This data is also statistical disproved:
The data did not follow the normal distribution. The assumption of normal distribution was still not met after transformation.

The data followed a Poisson distribution so the decision was made to use loglinear regression. This was done with Generalized Linear Model.
The dependent variable is number of animals observed in percentage. The covariate is the distance to water.

The dependent variable was log transformed to allow estimation of the model.
When the distance from the water increased, the percentage of observed horses declined significantly.
Intercept 2,216; X^2 = 697,674; df 1; $p < 0,0005$
Regression coefficient -0,003; X^2=88,661;df 1;$p <0,0005$; N= 93

In figure 12 a graph is shown which represents the relation between the distance to the water supply and the number of observed cows. In this graph can be seen that close by the water supply the percentage of the observed cows was a higher than further away from the water supply.

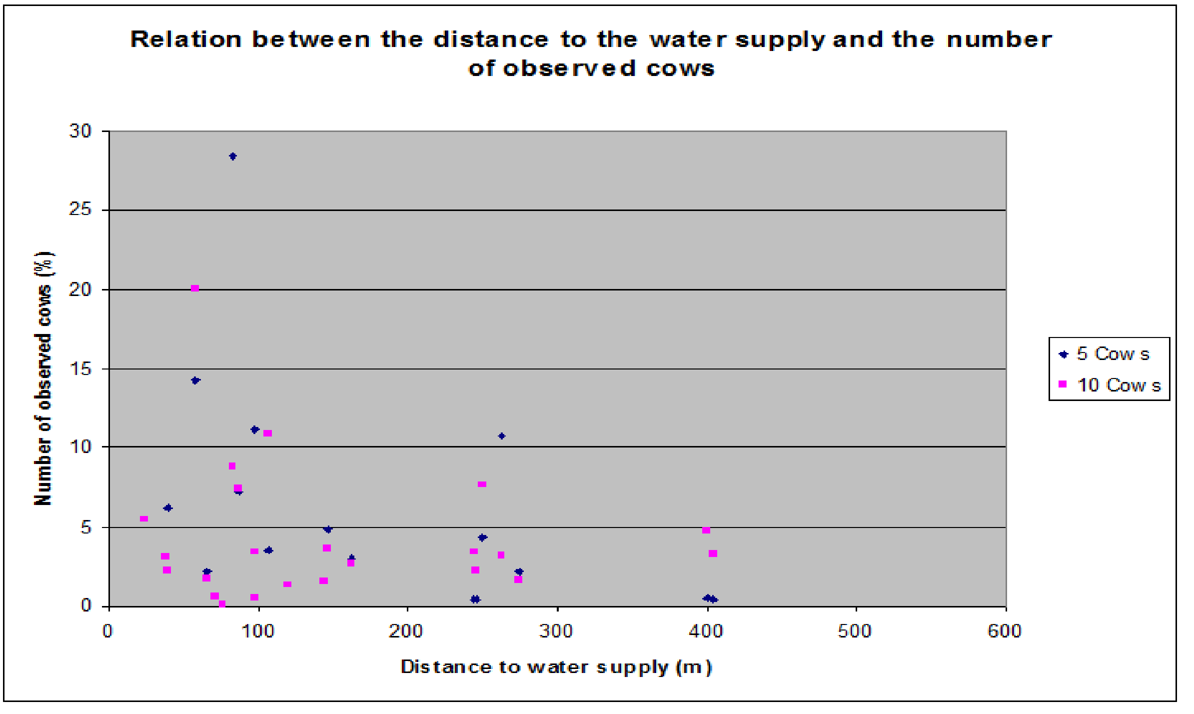

Figure 12. Relation between the distance to water supply and the number of observed cows
The pink dots represent the percentages of observed horses, with a stocking rate of 10. Whereas the blue dots represent the percentage of observed horses, with a stocking rate of 5.

This data is also statistical disproved:
The data did not follow the normal distribution. The assumption of normal distribution was still not met after transformation.

The data followed a Poisson distribution so the decision was made to use loglinear regression. This was done with Generalized Linear Model.
The dependent variable is number of animals observed in percentage. The covariate is the distance to water.

The depended variable was log transformed to allow estimation of the model.
When the distance increased from the water, the percentage of observed cows declined significantly.
Intercept: 2,556; X^2= 1519,198; df 1;p<0,0005
Regression coefficient –0,006; X2=621,768; df 1;p<0,0005; N= 144

In figures 13,14 and 15 the spatial distribution of the observed animals (in percentage) for each paddock per grid cell are shown. Most of the red grid cells are close by the water supplies. So in these figures can be seen that more animals were observed in the grid cells close by the water supply, as was earlier disproved statistically.

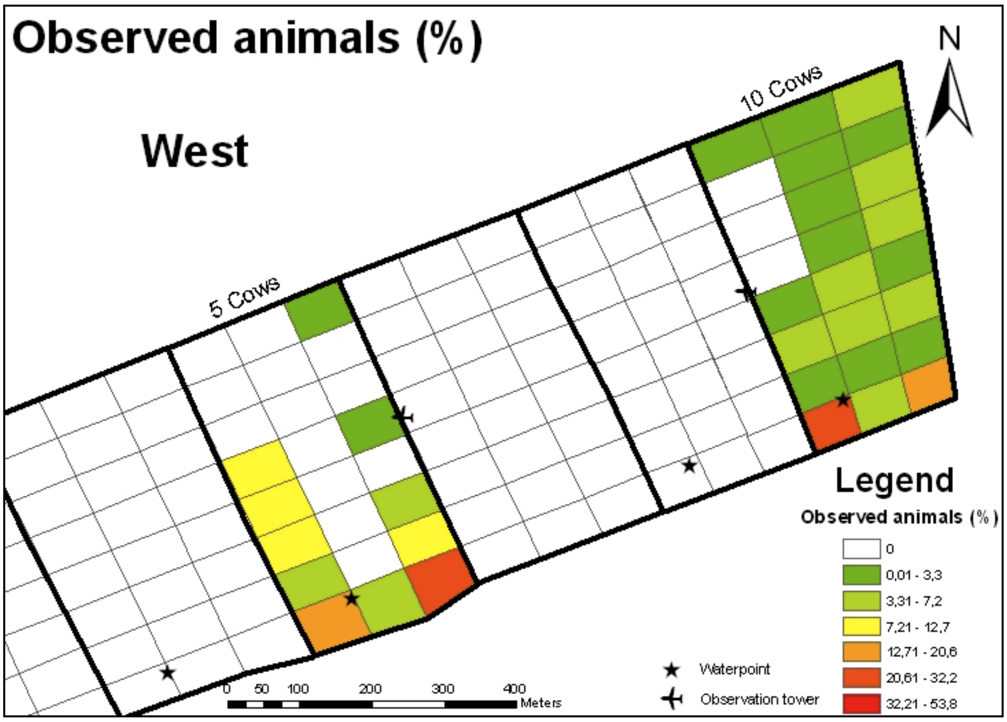

Figure 13. Number of observed animals, in percentage, in the west block.
The Wadden Sea is located in the north. In the first two (left to right) paddocks, no grazers were in, in the third paddock five cows were grazing, in the fourth paddock no grazers were in and in the fifth paddock ten cows were grazing. The airplane symbols are representing the observation towers and the stars are representing the water supplies. The background colours are representing the percentages of the numbers of observed animals. Whereas green is representing a few observed percentage of animals and red for a lot of observed animals in percentages. See the legend for the different amounts of observing in percentages.

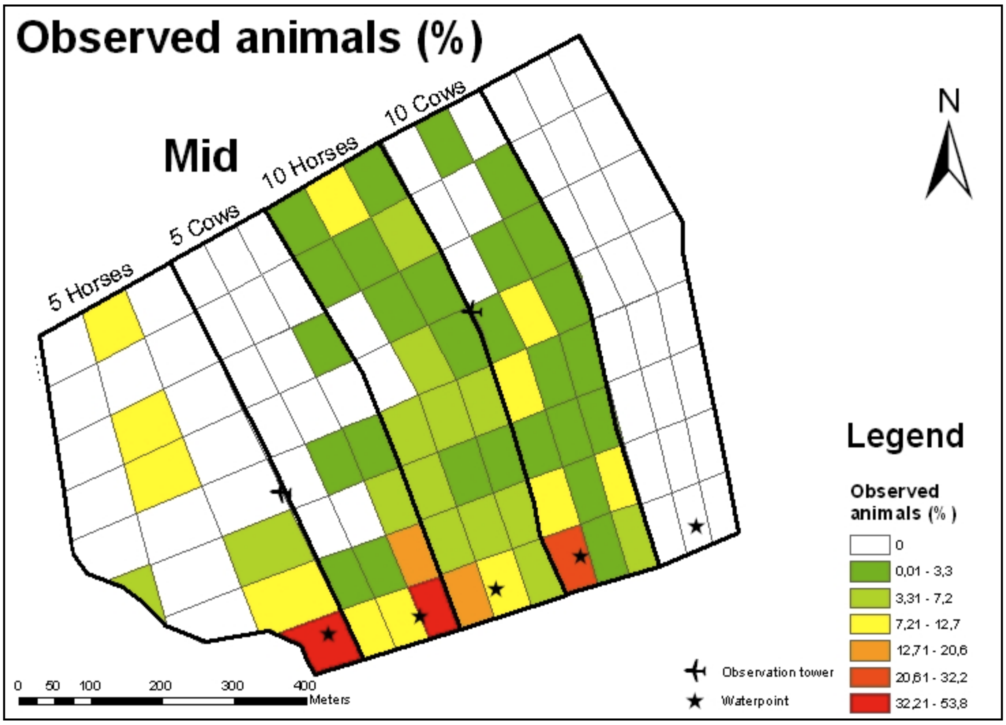

Figure 14. Number of observed animals, in percentage, in the middle block.
The Wadden Sea is located in the north. In the first (left to right) paddock, five horses were grazing, in the second paddock five cows were grazing, in the third paddock ten horses were grazing, in the fourth paddock ten cows were grazing and in the fifth paddock no grazers were in. The airplane symbols are representing the observation towers and the stars are representing the water supplies. The background colours are representing the percentages of the numbers of observed animals. Whereas green is representing a few observed percentage of animals and red for a lot of observed animals in percentages. See the legend for the different amounts of observing in percentages.

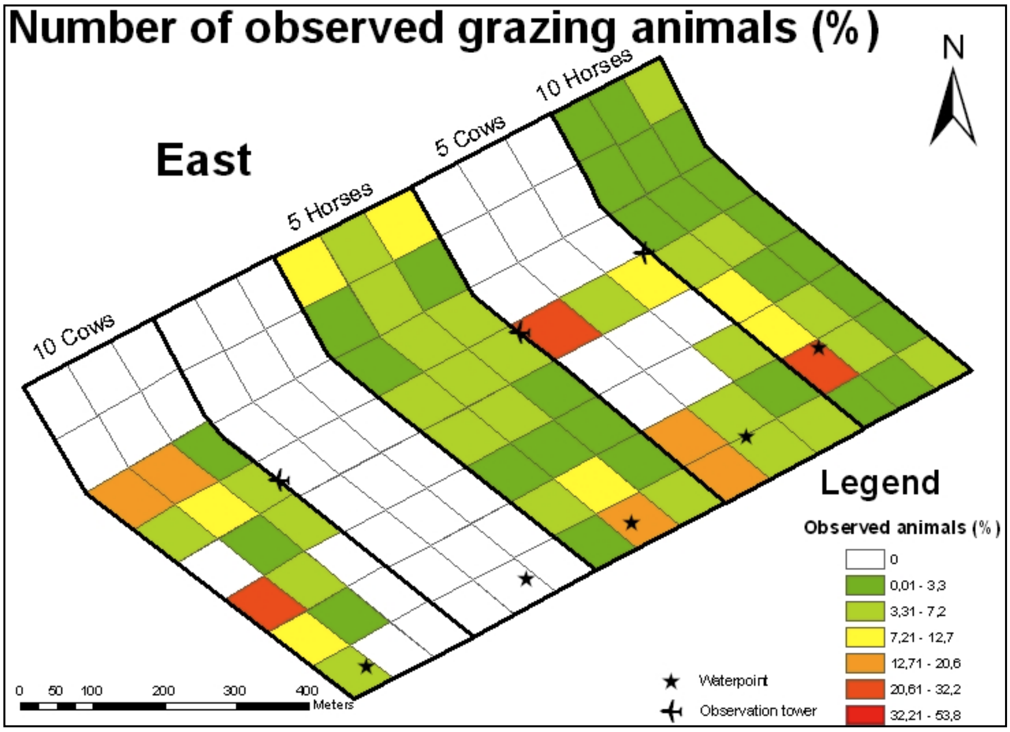

Figure 15. Number of observed animals, in percentage, in the east block.
The Wadden Sea is located in the north. In the first (left to right) paddock, ten cows were grazing, in the second paddock no grazers were in, in the third paddock five horses were grazing, in the fourth paddock five cows were grazing and in the fifth paddock ten horses were grazing. The airplane symbols are representing the observation towers and the stars are representing the water supplies. The background colours are representing the percentages of the numbers of observed animals. Whereas green is representing a few observed percentage of animals and red for a lot of observed animals in percentages. See the legend for the different amounts of observing in percentages.

3.3 Research question 3: Are dropping counts a suitable method to assess grazing pressure?

To answer this third question, there are made two scatterplots; one for the horses (see figure 16) and one for the cows (see figure 17).

In figure 16 a graph is shown which represents the relation between the number of observed horses (in percentage) and the number of droppings per horse.
For example in a paddock with ten horses; when 4,5% of the horses were observed, 5 droppings were counted per horse.

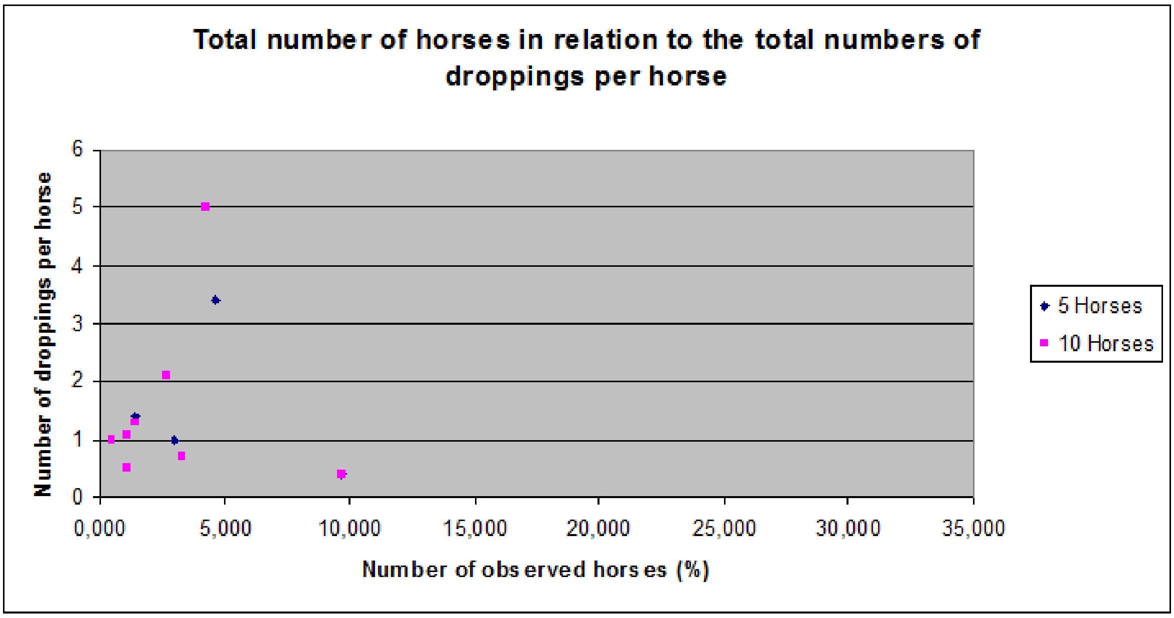

Figure 16. Relation between the number of observed horses and the number of droppings per horse.
Pink dots represent the number of droppings per horse in relation with the percentage of observed horses where 10 horses were in one paddock. Blue dots represent the number of droppings per horse in relation with the percentage of observed horses where 5 horses were in one paddock.

The data of the horses did not follow the normal distribution and transformation did not help to meet the assumption of normal distribution.
In order to assess whether dropping counts are a suitable method, a spearman's rank order correlation coefficient was used, to assess the relationship between the number of observed horses and the number of droppings observed.

Spearman's rank order correlation coefficient: -0,459; N = 12 p=0,134
Figure 16 shows that there is no significant relation between the number of droppings per horse and the number of observed horses. The pink dots represent the number of droppings per horse in relation with the percentage of paddocks with 10 observed horses. The Blue dots represent the number of dropping per horse in relation with the percentage of paddocks with 5 observed horses.

In figure 17 a graph is shown which represents the relation between the number of observed cows (in percentage) and the number of droppings per cow.
For example in a paddock with five cows; when 23% of the cows were observed, 3,5 droppings were counted per cow.

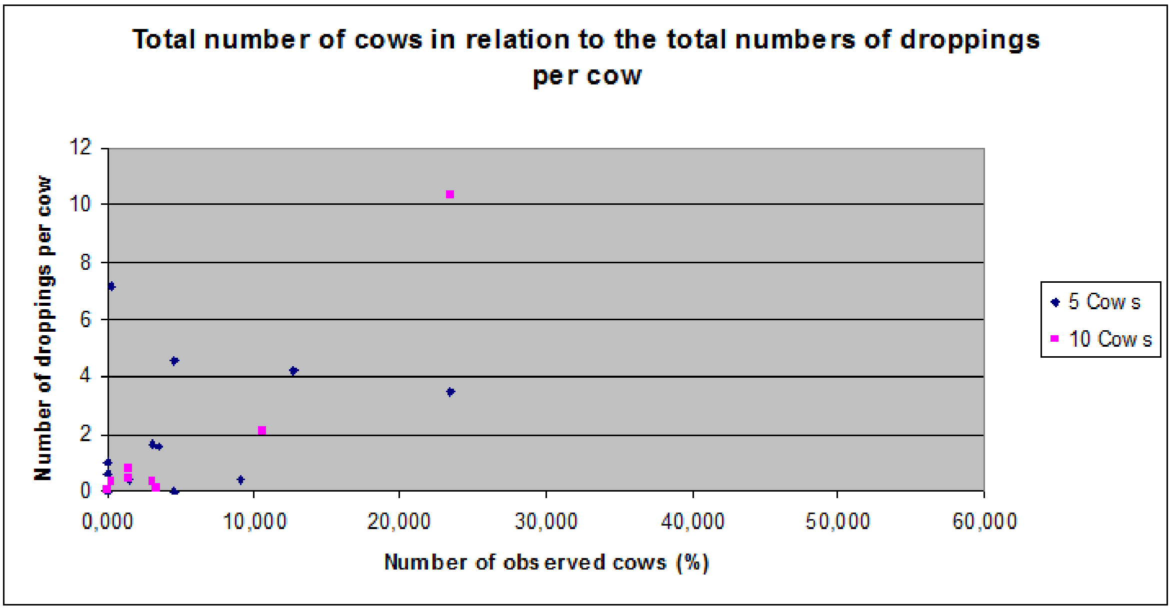

Figure 17. Relation between the number of observed cow and the number of droppings per cow.
Pink dots represent the number of droppings per cow in relation with the percentage of observed cows where 10 cows were in one paddock. Blue dots represent the number of droppings per cow in relation with the percentage of observed cows where 5 cows were in one paddock.

The data of the cows did not follow the normal distribution and transformation did not help to meet the assumption of normal distribution.
In order to assess whether dropping counts are a suitable method, a spearman's rank order correlation coefficient was used, to assess the relationship between the number of observed cows and the number of droppings observed.

Spearman's rank order correlation coefficient: 0,387; N= 20 p= 0,092
Figure 17 shows that there is no significant relation between the number of droppings per cow and the number of observed cows. The pink dots represent the number of droppings per horse in relation with the percentage of paddocks with 10 observed cows. The Blue dots represent the number of dropping per horse in relation with the percentage of paddocks with 5 observed cows.

The relation between the droppings per animal and the distance to the water supply are also put in a graph. One for the horses and one for the cows. These two graphs can be found in appendix V.

4. Discussion

This chapter deals with describing the discussion points encountered during this research. Possible effects for the results will also be defined.

4.1 Number of observations

There is not the same number of observations per paddock, because the paddocks were not in use at the same time. This was partly because the fence was not completed in time. Adding to this, animals had to be removed during a flooding. This led to a very uneven number of observations with a difference up to 70 observations. Also the paddocks had sometimes not the right numbers of animals in it, for example 11 instead of 10. This complicated the data-analysis.

4.2 Number of grid cells

Due to the uneven shape of the paddocks, one of them (the first paddock of the Middle block) was divided into 21 grid cells instead of 24. This might have biased the data.

4.3 Fresh water supply

Due to practical reasons, the water supply was always located close to the summer dike in the south of the paddock, in either the grid cell 1, 2 or 3. It was found that the grazing gradient is caused by the distance of fresh water supply. This is extra pronounced from the hot days, with temperature rising to +30 °C. During these warm days the animals were expected to need more water, than during cooler days. Thus the fresh water supply might have influenced the dispersal of both cattle and horses and which vegetation/ elevation they pick.

To exclude the effect of the water supply in a next research, more water tanks can be realised located in different vegetation/ elevation types. But then a grazing gradient is not found, which might be wanted. Second, for practical reasons, it is quite hard to realize these fresh water supplies throughout the area.

4.4 Disturbance

During the observations, other researchers were present in the area. They might have influenced the outcome of the observations by altering the animals behaviour. It sometimes happened that a researcher was in the paddock that was observed at that time. The effect of disturbance by other researches probably diminished over the season, because the animals got used to their presence.

In order to do the dropping counts, the animals sometimes needed to be chased away. But while the horses were running away from the dropping count spot, it was observed that they defecate very often. It could have been that they wanted to defecate anyway. This might have had an effect on the dropping count observations.

Another disturbance factor were the other cows and horses that were placed on the adjacent summer polders. In the beginning the animals often sought contact with each other. This could also be a reason for the animals to be more present closer to the summer dike.

4.5 Elevation and vegetation measurements

The elevation and vegetation measurements were done in the paddocks of the middle 1, 2, 3, and 4 and eastern paddocks 3 and 5. The measured paddocks were the ones that were grazed from the beginning. For the data it was better if the measurements would have been done in all of the grazed paddocks, but due to time constrains, this was not possible.
Another factor is that some of the vegetation classes are not present in each paddock. Some vegetation classes were are more abundant than others, so there was a difference in availability of certain vegetation classes. This might affected the data.

5. Conclusions and recommendations

As expected an interaction effect was found between vegetation and elevation in both cattle and horses. As it is not possible to separate vegetation and elevation one should be careful to interpret the effect of vegetation and elevation separately. So no conclusion could be drawn about which variable explains the variation in numbers observed.

Horses disperse throughout the whole paddock and make use of most vegetation classes. Cows however tend to stay closer towards the fresh water supply and therefore they make use of the vegetation/ elevation present nearby the water supply.

As expected the grazers with higher stocking rates dispersed more throughout the whole paddock.

There is a significant relation between water supply and both observed horses and cows. The fresh water supply induces a grazing gradient.
According to the ArcGIS map horses are making more use of their whole paddock than cows. Cows tend to stay close to the fresh water supply.

There is no significant relation between the number of droppings and the observed animals, for both horses and cows.
Concluding that dropping counts-method is not a suitable method to asses grazing pressure during this research.

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Overview Appendixes

Appendix I

Observation form

Name observer Date Time Weather Other
Paddock: Cattle/ horses
1= grazing 2= resting 3= walking
4= social behaviour 5= drinking
Observation:

Observation number	Observed cattle or horses per grid cell and their behaviour Grid cell number																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1																								
2																								
3																								

Name observer Date Time Weather Other
Paddock: Cattle/horses
1= grazing 2= resting 3= walking
4= social behaviour 5= drinking
Observation:

Observation number	Observed cattle or horses per grid cell and their behaviour Grid cell number																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1																								
2																								
3																								

Appendix II

Dropping count form

Name observer Date Time
Weather Other

Paddock	Number of droppings
W1	
W1.1	
W1.2	
W1.3	
W1.4	
W2	
W2.1	
W2.2	
W2.3	
W2.4	
W3	
W3.1	
W3.2	
W3.3	
W3.4	
W4	
W4.1	
W4.2	
W4.3	
W4.4	
W5	
W5.1	
W5.2	
W5.3	
W5.4	
W6	
W6.1	
W6.2	
W6.3	
W6.4	

Paddock	Number of droppings
M1	
M1.1	
M1.2	
M1.3	
M1.4	
M2	
M2.1	
M2.2	
M2.3	
M2.4	
M3	
M3.1	
M3.2	
M3.3	
M3.4	
M4	
M4.1	
M4.2	
M4.3	
M4.4	
M5	
M5.1	
M5.2	
M5.3	
M5.4	

Paddock	Number of droppings
E1	
E1.1	
E1.2	
E1.3	
E1.4	
E2	
E2.1	
E2.2	
E2.3	
E2.4	
E3	
E3.1	
E3.2	
E3.3	
E3.4	
E4	
E4.1	
E4.2	
E4.3	
E4.4	
E5	
E5.1	
E5.2	
E5.3	
E5.4	

Appendix III

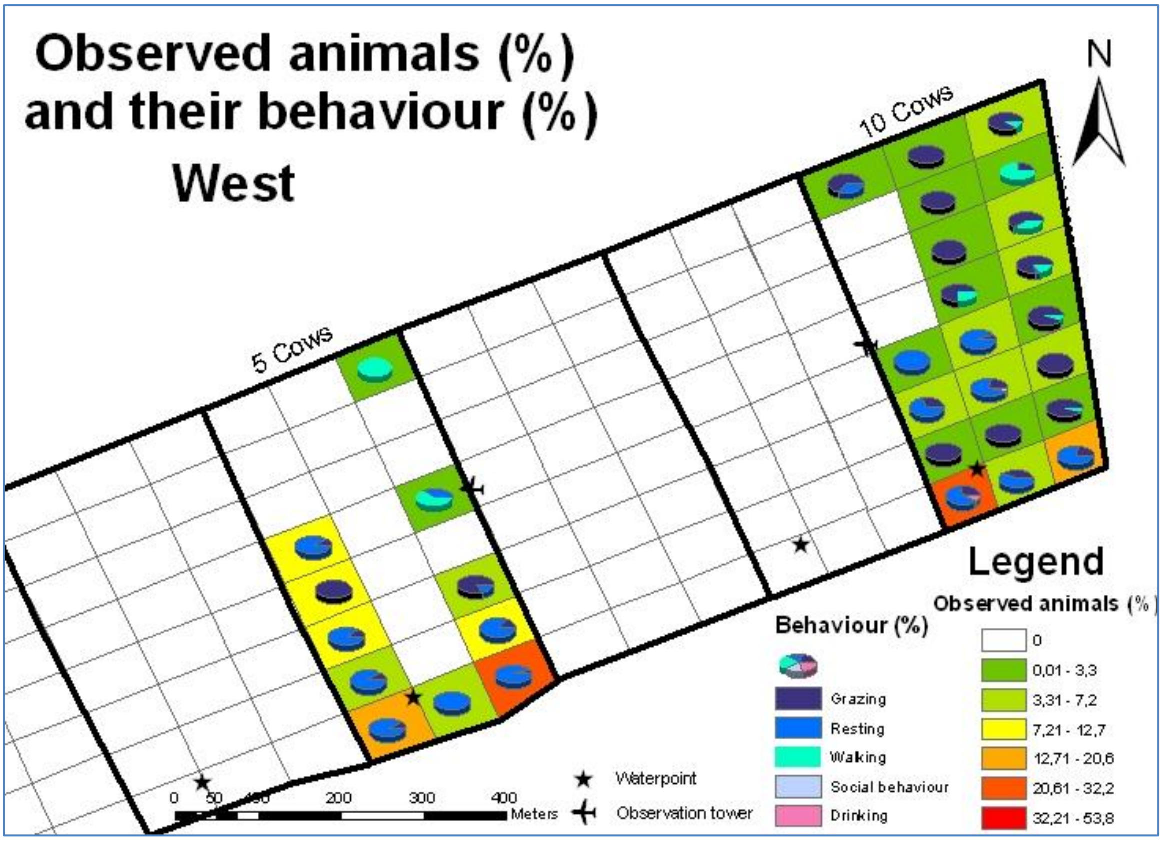
Elevation measurement form

Date:

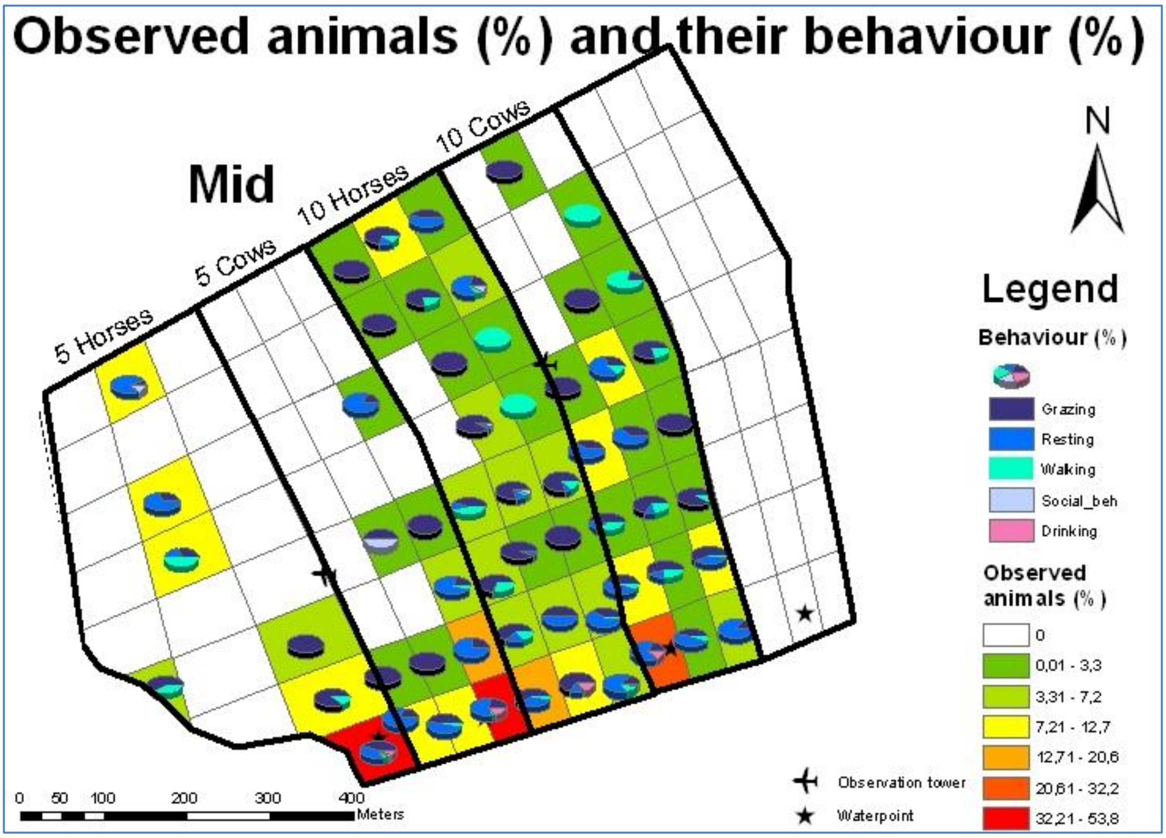
Fixed stick length: Elevation fixed point:

Plot	1	2	3	4	5	6	7	8	9	10	Plant1	Plant 2	Plant 3	Plant 4

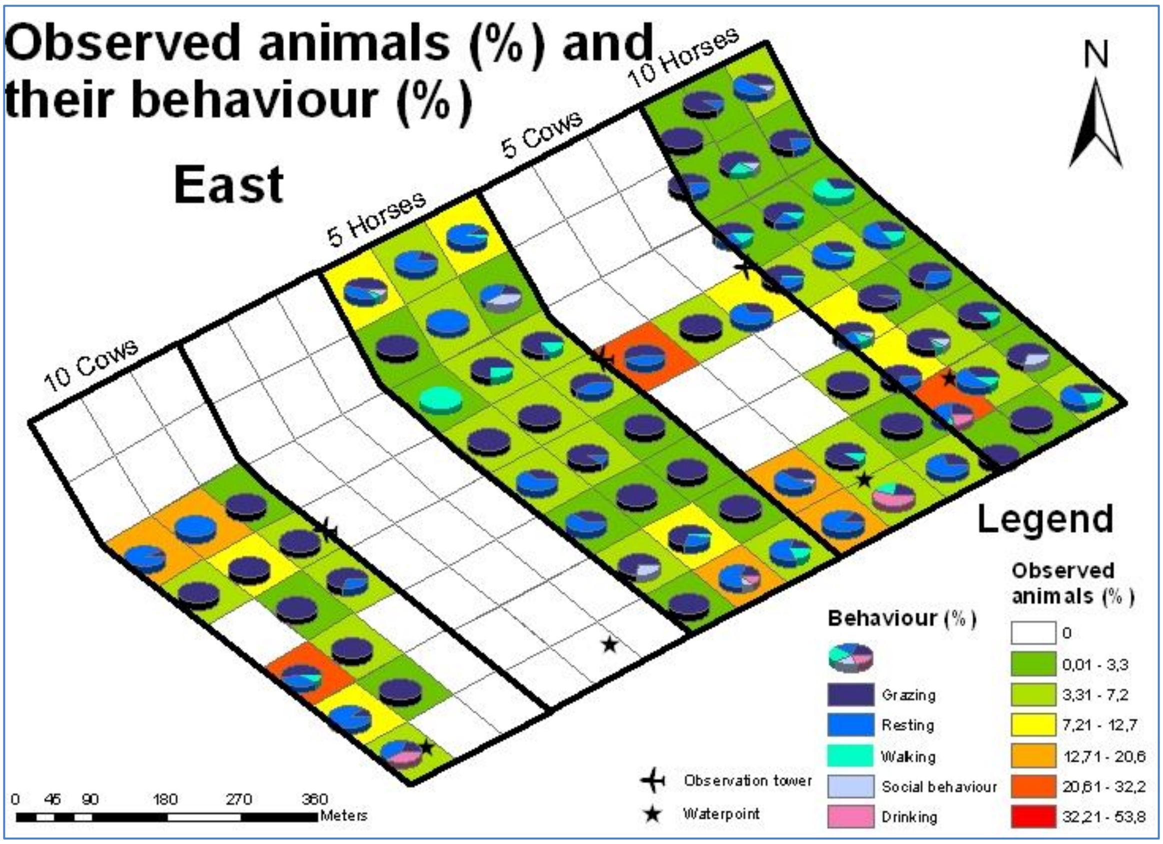
Appendix IV - ArcGIS maps observed animals (%) and their observed behaviour (%)



Number of observed animals and their behaviour, both in percentage, in the west block.
The Wadden Sea is located in the north. In the first two (left to right) paddocks, no grazers were in, in the third paddock five cows were grazing, in the fourth paddock no grazers were in and in the fifth paddock ten cows were grazing. The airplane symbols are representing the observation towers and the stars are representing the water supplies. The background colours are representing the percentages of the numbers of observed animals. Whereas green is representing a few observed percentage of animals and red for a lot of observed animals in percentages. See the legend for the different amounts of observing in percentages. The pie charts are representing the different behaviours (in percentages) which were observed in the grid cell. See the legend for the different behaviours.

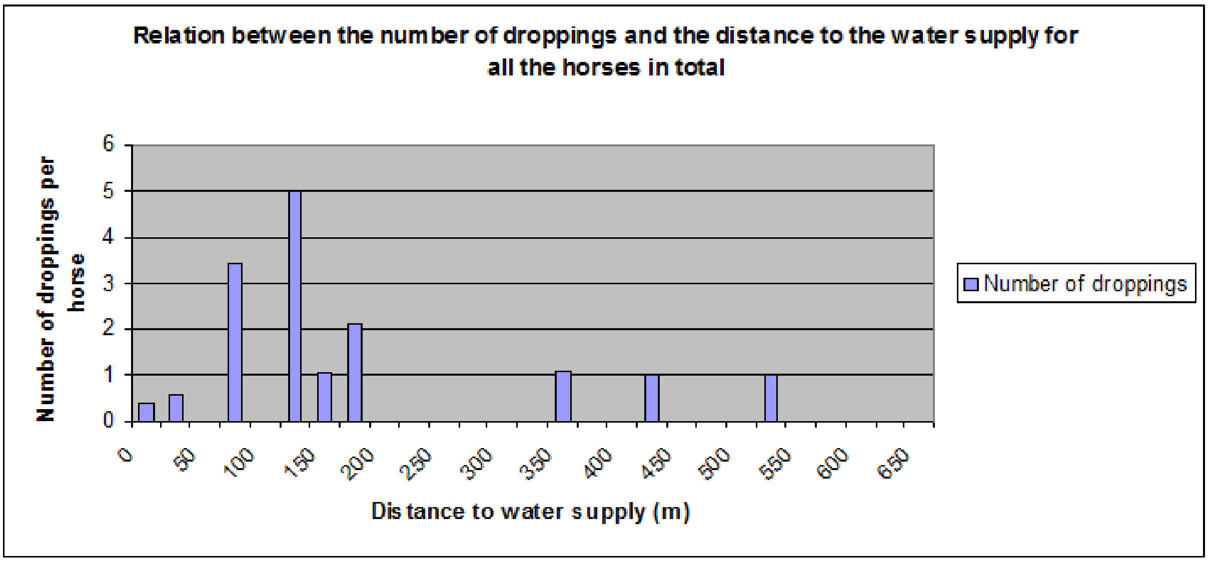


Number of observed animals and their behaviour, both in percentage, in the middle block.
The Wadden Sea is located in the north. In the first (left to right) paddock, five horses were grazing, in the second paddock five cows were grazing, in the third paddock ten horses were grazing, in the fourth paddock ten cows were grazing and in the fifth paddock no grazers were in. The airplane symbols are representing the observation towers and the stars are representing the water supplies. The background colours are representing the percentages of the numbers of observed animals. Whereas green is representing a few observed percentage of animals and red for a lot of observed animals in percentages. See the legend for the different amounts of observing in percentages. The pie charts are representing the different behaviours (in percentages) which were observed in the grid cell. See the legend for the different behaviours.

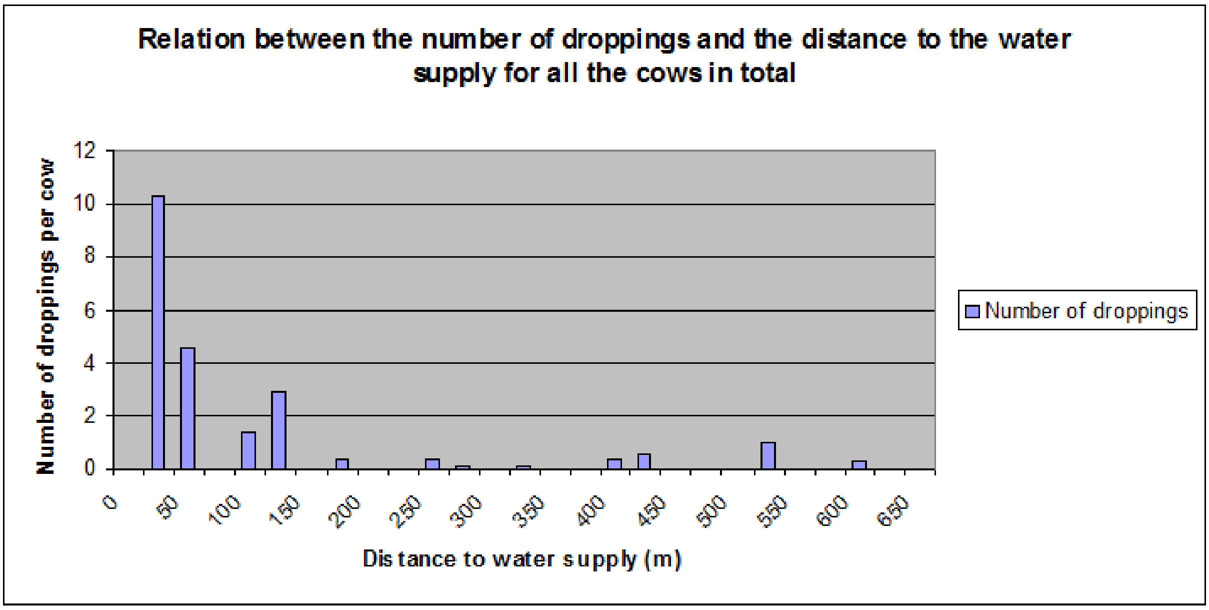


Number of observed animals and their behaviour, both in percentage, in the east block.
The Wadden Sea is located in the north. In the first (left to right) paddock, ten cows were grazing, in the second paddock no grazers were in, in the third paddock five horses were grazing, in the fourth paddock five cows were grazing and in the fifth paddock ten horses were grazing. The airplane symbols are representing the observation towers and the stars are representing the water supplies. The background colours are representing the percentages of the numbers of observed animals. Whereas green is representing a few observed percentage of animals and red for a lot of observed animals in percentages. See the legend for the different amounts of observing in percentages. The pie charts are representing the different behaviours (in percentages) which were observed in the grid cell. See the legend for the different behaviours.

Appendix V
Number of droppings and the distance to the water supply



Relation between the number of droppings and the distance to the water supply for the horses.
The bars represent the number of droppings per horse that are counted for each distance to the water supply.



Relation between the number of droppings and the distance to the water supply for the cows.
The bars represent the number of droppings per cow that are counted for each distance to the water supply.

These figures show that there is a trend with distance to water and numbers of droppings. It shows that the bigger distance to the water supply, the less number of droppings are found. As well for cows as for horses.