Monitoring Habitat Change and Its Relation to Sand Lizard Population Dynamics with Multi Temporal Remote Sensing
A Case Study of Terschelling and Vlieland, The Netherlands

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A Case Study of Terschelling and Vlieland, The Netherlands

by

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Disclaimer

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Abstract

Habitat change is one of the prime causes of decline in biodiversity. Both human induced and natural causes are responsible for habitat change. Sand lizard (*Lacerta agilis*) is an endangered species in northwest Europe. The study was aimed at monitoring habitat change and finding out whether there was any relation between habitat change and sand lizard population dynamics. The study was based on Terschelling and Vlieland, two northern islands of the Netherlands. The study area is characterized by sand dunes along the coast. 288 SPOT Vegetation 10 days composite NDVI images from April 1998 to March 2006 were used in the study. SPOT NDVI images of the study area were classified in five classes using ISODATA clustering algorithm. Mean NDVI of those classes over 288 decades (10 days) were used to monitor habitat change.

Vegetation, sandy open patches and south or south west aspect are three important environmental parameters of sand lizard habitat. Among these parameters vegetation is most susceptible to change. Extensive grass or bush encroachment in dunes can result in decline in sandy open patches thus having negative impact on sand lizard habitat.

Terschelling and Vlieland are inhabited by a very small size of sand lizard population. Particularly sand lizard population in Terschelling is alarmingly low. Unlike Terschelling sand lizard population in Vlieland has increased in recent years.

It appeared from NDVI time series analysis that there was no significant change in vegetation in Terschelling and Vlieland during 1998 to 2005. The analysis did not indicate extensive grass or shrub encroachment in dunes which could cause habitat degradation. It was found that habitat change had no or very little influence on sand lizard population in the area.

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1. Introduction

1.1 Background

Habitat change is one of the prime causes of decline in biodiversity (Goode *et al.*, 2005). Both human induced and natural causes such as timber management, tourist activities, land management projects and forest fire are responsible for habitat change (Goode *et al.*, 2005). Habitat change is often manifested in the form of habitat loss or habitat disturbance. Habitat loss or habitat disturbance tends to speed up extinction rate of different species thus having negative impact on species abundance (Osborne *et al.*, 2001).

It has been well documented that European reptiles are declining quite rapidly. One of the reasons of decline in reptile population is their vulnerability to habitat change (Benayas *et al.*, 2006; Brooks *et al.*, 2002; Jellinek *et al.*, 2004). Most of the reptiles are characterized by small home range and little ability to migrate in the face of danger arising from habitat loss or alteration. In addition to this, conservation of reptiles is overlooked in many cases (Omolo, 2006).

Sand lizard (*Lacerta agilis*) is one of the reptile species found in the Netherlands and many other places in Europe. Sand lizard is an endangered species in northwest Europe. Sand lizard habitat is protected in EU region under habitat directive (Bird and Edgar, 2005). Inappropriate conservation management is mostly responsible for decline in sand lizard population in northwest Europe (Bird and Edgar, 2005).

Habitat monitoring is an integral part of biodiversity conservation. Continuous monitoring is essential to ensure effective habitat management. Application of remote sensing has added new dimension to habitat monitoring. High spatial and temporal resolution imageries are now available which facilitate habitat monitoring with increasing efficiency and accuracy.

The focus of this research is habitat change and its relation to sand lizard population dynamics in the Netherlands. The study is aimed at finding out change in sand lizard habitat and whether this change is influencing population size of the species. Remote sensing techniques have high potential in habitat study thus increasingly being used in biodiversity management. This study will also explore the potentiality of multi temporal remote sensing in habitat study.

1.2 Sand lizard

The sand lizard, *Lacerta agilis*, is one of the most widely distributed reptile species in the world. It occurs from Spain to China and from Sweden south to Greece (Bird and Edgar, 2005). The range of sand lizard in the Netherlands includes sandy heath lands in the centre, east and south east of the country; dune system along the coast on most of the Wadden islands and on the Frisian islands of Vlieland, Terschelling and Schiermonnikoog (Bird and Edgar, 2005).

Figure 1: ***Lacerta agilis***

Source (http://en.wikipedia.org/wiki/Image:Jaszczurka_zwinka.jpg)

Lacerta agilis is a short legged, medium sized lizard of the family Lacertidae. Sand lizard normally reaches a total length of 18 cm. Male sand lizards are slightly smaller than females. There are many variations in colour and pattern of this species. Usually male sand lizards turn bright green in breeding season which fades before hibernation. Female sand lizards hold light brown or greyish ground colour all year. Both male and female have vertebral band made up of brown or black markings along with various white spots or lines.

Active period of sand lizards in the Netherlands lasts from the beginning of April to the end of September. During spring (April, May) lizards come out of hibernation and it is their mating season. Female lizards lay their eggs in summer (June, July) and in autumn (August, September) juvenile lizards prepare for their first winter. A female sand lizard lays 4-14 eggs in a season. During active period sand lizards require minimum morning temperature of 18° C for basking (Spellerberg, 1988). In spring and autumn sand lizards need basking for longer time but in summer it is necessary for few hours. Usually male sand lizards have home range of few hundred meters and those of females are even smaller (Nicholson and Spellerberg, 1989). Sand lizards are primarily insectivorous. It consumes a range of spiders and insects like orthopterans , bugs and beetles.

1.3 Monitoring habitat change with multi temporal remote sensing

Habitat can be defined as a place where a species lives either actually or potentially (Corsi *et al.,* 2000). For many species, vegetation is the most important component of their habitats. Change in vegetation can be detrimental to habitat quality. Therefore habitat monitoring mainly involves monitoring change in vegetation.

Multi temporal remote sensing data are quite useful for monitoring vegetation change. Historical archive remote sensing imageries such as Landsat, NOAA AVHRR and SPOT facilitate monitoring change over long period of time. Landsat TM imageries at 30 meter resolution have been used for monitoring vegetation change at both local and regional scale. In two sites of southern Kalahari Desert, direction and magnitude of change in grassland was identified using Landsat TM images (Palmer and Van Rooyen, 1998). Example of Landsat application at regional scale includes estimation of the rate of tropical deforestation in the Amazon (Skidmore, 2002). Although Landsat TM is a high resolution image, availability of it at frequent interval and cost involved are some of the uncertainties of this data.

NDVI time series have been widely used for monitoring vegetation change. NDVI is derived by combining red and near infrared spectral region in a ratio. Chlorophyll in growing vegetation absorbs red radiation and cell wall structure of green leaves reflects near infrared radiation. Lower reflectance of red radiation and higher reflectance of NIR radiation indicates high photosynthetic activities. This is why red and NIR regions of electromagnetic spectrum are mainly used in vegetation study. Both SPOT and NOAA AVHRR NDVI time series are available for monitoring vegetation. In Saudi Arabia impact of grazing on rangelands was assessed using NOAA AVHRR NDVI data (Weiss and Marsh, 2001). A number of researches were carried out previously where NOAA AVHRR NDVI had been used to monitor vegetation change (Fuller, 1998; Kennedy, 1989; Maselli *et al.*, 1992; Prince, 1991;

Prince and Tucker, 1986; Sannier *et al.*, 1998; Tucker *et al.*, 1986). NOAA AVHRR data is available since 1980 onwards at lower resolution (7.5 km global scale). AVHRR NDVI data are useful in large scale vegetation monitoring where consistent data over long period of time is necessary. The use of such low resolution NDVI data complicates vegetation monitoring at smaller scale. It is very difficult to detect small and sparse vegetation with low spatial resolution data (Tucker *et al.*, 1994). SPOT Vegetation program provides NDVI data at 1 km² resolution. SPOT NDVI time series data were used to assess the trends of vegetation changes in West China (Xu *et al.*, 2004). SPOT NDVI is available in the form of 10 days composite since 1998, which allows monitoring seasonal and annual change in vegetation. In recent years SPOT NDVI images are increasingly being used in vegetation study (Pettorelli, 2005).

1.4 Problem statement and justification

Sand lizard is an endangered species in the Netherlands (Hom *et al.*, 1996). It has been documented that heathland populations in the Netherlands are under serious threat (Bergmans and Zuiderwijk, 1986). Loss or destruction of habitat due to inappropriate conservation management has been primarily responsible for the situation (Bird and Edgar, 2005; Strijbosch, 2002; Stumpel, 2004) In order to protect the endangered species it is important to have knowledge about habitat change and population dynamics of the species.

Habitat monitoring requires consistent data over a long period of time. Multi temporal remote sensing imageries and state of the art image analysis techniques can be very useful in this regard. In spite of the potentiality, no research was done on *Lacerta agilis* habitat monitoring in the Frisian islands of the Netherlands using multi temporal remote sensing imageries. In this research multi temporal remote sensing images have been used to monitor habitat change. The research will provide information regarding change in habitat and sand lizard population dynamics in the Frisian islands of Terschelling and Vlieland. It will also reveal whether habitat change has had any influence on sand lizard population dynamics. It is expected that the outcome of the research will be helpful for the conservation of the species in Terschelling and Vlieland.

1.5 Objectives

In order to accomplish the research following three objectives were proposed.

1. Investigate change in sand lizard habitat in Terschelling and Vlieland.
2. Analyze sand lizard population dynamics in the study area.
3. Determine whether there is any relation between habitat change and sand lizard population dynamics.

1.6 Research questions

Four research questions were formulated in line with three objectives of the research.

1. Which environmental parameters are important for sand lizard habitat?
2. Has there been any change in those parameters, if yes which ones?
3. What is the pattern of change in sand lizard population?
4. Is there any relation between change in environmental parameters and sand lizard population

2. Methods and materials

2.1 Study area

The study is based on Terschelling and Vlieland, two northern islands of the Netherlands. The study area extends from 53°12'25.41"N & 4°51'3.73"E to 53°26'30.18"N & 5°33'17.29"E. Terschelling is about 30 km long and 4 km wide and Vlieland is about 20 km long and 2.5 km wide. Both Terschelling and Vlieland are characterized by mostly sand dunes along the coast, small urban areas and agricultural field. Sand dunes are preserved in these islands. Dunes in the area are geologically younger. Most of the dunes have developed since approximately 900 AD (Kros *et al.*, 1994). The area has undulating topography with an average elevation of 0 to 40 meters. The study area is shown below.

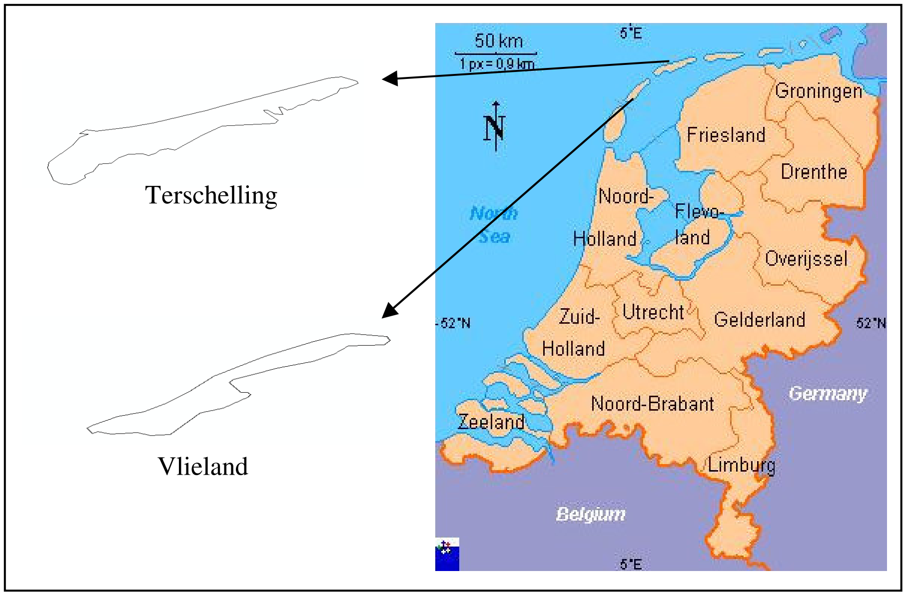

Figure 2: Study Area

Vegetation of the area is characterized by dune grass, heather, deciduous and coniferous forest and shrubs. Marram grass (*Ammophila arenaria*) is the most common among different types of dune grass found in the area.

2.2 Materials

SPOT Vegetation

SPOT 4 vegetation 10 days composite NDVI images (S10 product) at 1 km² resolution were used in the study. Detail information about SPOT 4 vegetation S10 product is available on www.VGT.vito.be. All NDVI images were geo referenced and declouded. Declouded means pixels with good radiometric quality for band 2(red) and band 3(near IR) and pixels without cloud or shadow were kept (removed pixels were labelled as 'missing') (Skidmore *et al.*, 2006). NDVI values were converted to a digital number in the range of 0 to 255 ($DN = (NDVI+0.1)/0.004$). 288 ten days composite NDVI images from April 1998 to March 2006 were used to monitor vegetation change. All NDVI images were obtained from 'Biodiversity and carbon sequestration monitoring in fragmented landscapes using advanced remote sensing techniques and GIS modelling' (BIOFRAG) project in International Institute for Geo Information Science and Earth Observation.

ASTER

ASTER image acquired in July 2006 was used to prepare land cover map of the study area. ASTER sensor provides multi spectral images with 14 bands, 3 of them in the visible and near infrared (VNIR), 6 of them in short wave infrared (SWIR) and 5 of them in thermal infrared (TIR). Spatial resolution for bands in VNIR is 15 m, for bands in SWIR 30m and for bands in TIR 90 m. VNIR and one SWIR (3N) were used for land cover classification.

SRTM DEM

The digital elevation model (DEM) from Shuttle Radar Topography Mission (SRTM) was used in the study. Slope and aspect were calculated from the DEM.

Sand lizard population data

Sand lizard occurrence and population data were obtained from Foundation for Reptile, Amphibian and Fish Research in the Netherlands (RAVON). Sand lizard population data collected during 1998 to 2005 were used in the research. Data collection took place from the end of March to the end of September. Sand lizard population data were collected along thirteen transects in the study area. Each year on an average 16 observations were made by volunteers in each transect.

2.3 Data collection

In order to prepare land cover map 150 samples were collected in the month of September 2006 from the study area. Those samples covered major land cover classes in the area.

2.4 Method

2.4.1 Identification of environmental parameters

Literature survey and expert knowledge

Literature survey (Bird and Edgar, 2005; Corbett & Moulton, 1999; Corbett & Tamarind, 1979; Glandt, 1991;House & Spellerberg, 1983) was carried out to find out environmental parameters relevant to sand lizard habitat. Expert opinion (Zuiderwijk, 2006) was also taken in this regard.

Maxent model

Maxent model was applied to predict sand lizard distribution and identify important environmental parameters relevant to sand lizard distribution. The model approximates unknown probability distribution satisfying maximum entropy principle (Phillips *et al.*, 2006). It is to be noted that the model uses only presence data. Maxent model uses Jackknife method to analyze variables importance. Jackknife excludes each variable and predicts the distribution with the remaining variables. It also predicts distribution using single variable in isolation(Phillips *et al.*, 2006). The user-specified parameters were set as default (regularization multiplier = 1, maximum iterations = 500, convergence threshold = 10, maximum number of background points = 10000, and use of linear, quadratic, product, threshold and hinge features). Four environmental layers were used in the model; land cover, slope, aspect and altitude.

2.4.2 Pre processing of ASTER and land cover classification

All VNIR and SWIR bands of the ASTER image were resampled to a spatial resolution of 15 m. The image was atmospherically corrected and geo referenced. Maximum likelihood classifier (MLC) was used to do the land cover classification.

It is the most widely used classifier which unlike others takes into account spectral variability within each class and the overlap that may occur among different classes(Campbell, 2002).The image was classified in eight land cover classes namely dune grass; heath; dune grass and bare sand mixed; heath, dune grass and shrub mixed; water; forest; agricultural and grazing land. In the mixed class of dune grass and bare sand, proportion of dune grass and bare sand are around 60% and 40% respectively. In the mixed class of heath, dune grass and shrub; proportion of heath, dune grass and shrub are around 40%, 30% and 30% respectively. In the land cover classification emphasis was given on vegetation as they are relevant to sand lizard habitat. Due to complex vegetation characteristics of the study area, two mixed classes were included in the classification. Urban areas were excluded in the classification. Erdas-Imagine software was used to do the classification. 75 samples collected from field were used as training areas and the remaining 75 samples were used for accuracy assessment. Overall accuracy and Kappa statistics were calculated in order to assess the accuracy of the land cover map.

2.4.3 SPOT NDVI processing and vegetation change analysis

288 SPOT NDVI 10 days composite images were stacked in a single image. The resulting image had 288 bands each representing one single decade. For example, band one represents first decade which is first ten days of April 1998. The areas of Terschelling and Vlieland were clipped separately from the stacked image. Stacked images of Terschelling and Vlieland were classified in unsupervised way using ISODATA clustering algorithm of Erdas-Imagine software. The maximum number of iterations was set to 50 and the convergence threshold was set to 1.0. ISODATA clustering algorithm involves assigning pixels to classes based on class means (Campbell, 2002). It is possible to make clusters of pixels or classes by applying the algorithm on stacked images. Mean NDVI of those clusters of pixels or classes over 288 decades can be obtained from signatures of those classes. NDVI profiles obtained from those signatures can be used for monitoring vegetation. Another advantage of ISODATA classifier is that no prior knowledge of the area is required to perform the classification. Stacked images of Terschelling and Vlieland were classified in 5 to 10 classes separately to find out number of best separable classes. Signature separability of each classified image was assessed using Euclidean spectral distances between their means. Signature separability is a means to compute the statistical distance between signatures (ERDAS, 2003). This distance can be used to determine how distinct signatures are from one another (ERDAS, 2003). Images with five classes showed the highest signature separability (see appendix 1). Considering

the signature separability, relatively small size of the study area and coarse resolution NDVI data, images classified in five classes were taken for analysis. Mean NDVI of five classes of Terschelling and Vlieland in 288 decades were derived from signatures of those classes. Mean NDVI of five classes of Terschelling and Vlieland were plotted on graphs. NDVI profiles showed seasonal and annual variation in NDVI of each class. Change in habitat was assessed based on those NDVI profiles. In order to get proportion of different land cover types in each NDVI class, land cover maps were overlaid on classified NDVI images using union overlay function of ARC GIS.

2.5 Research approach

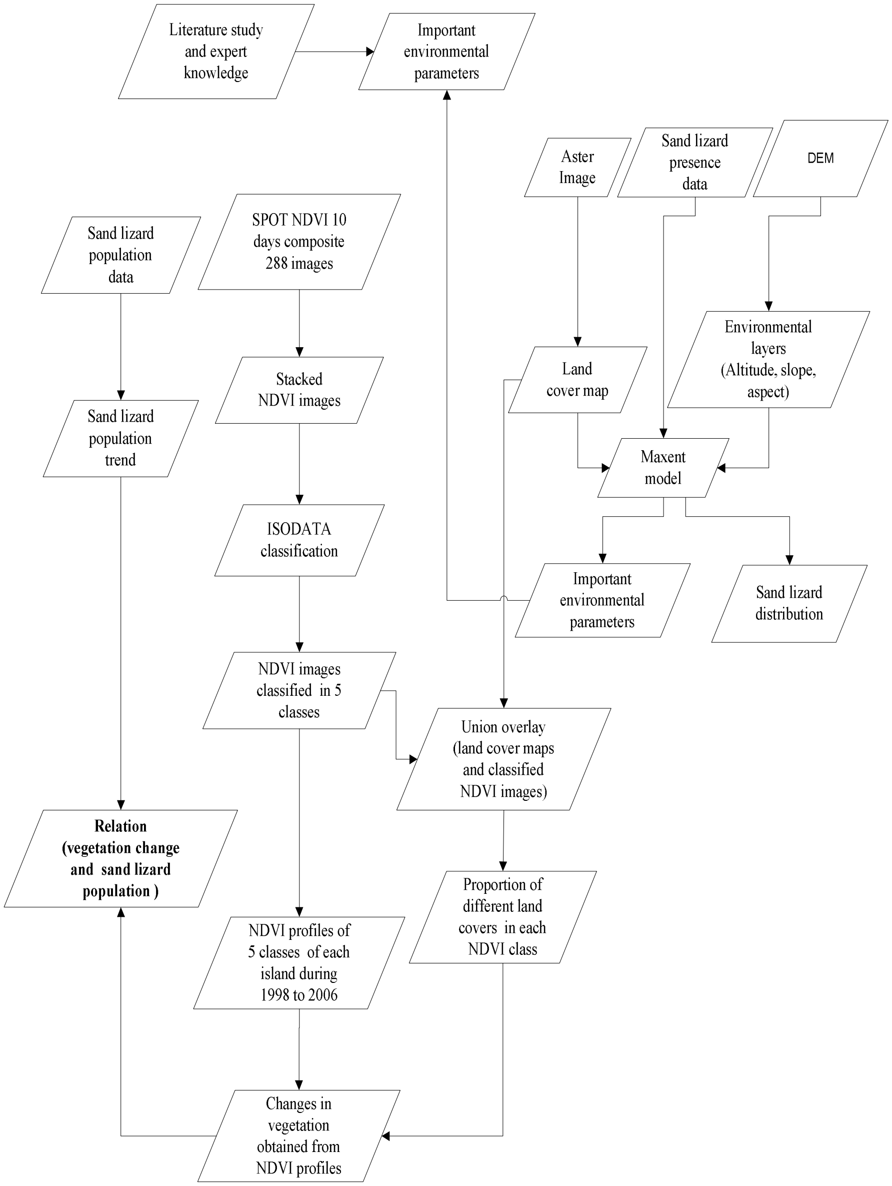

Figure 3: Research approach

3 Results

3.1 Land cover map

Land cover maps of Terschelling and Vlieland derived from classification of ASTER image are shown in figure 4 and 5.

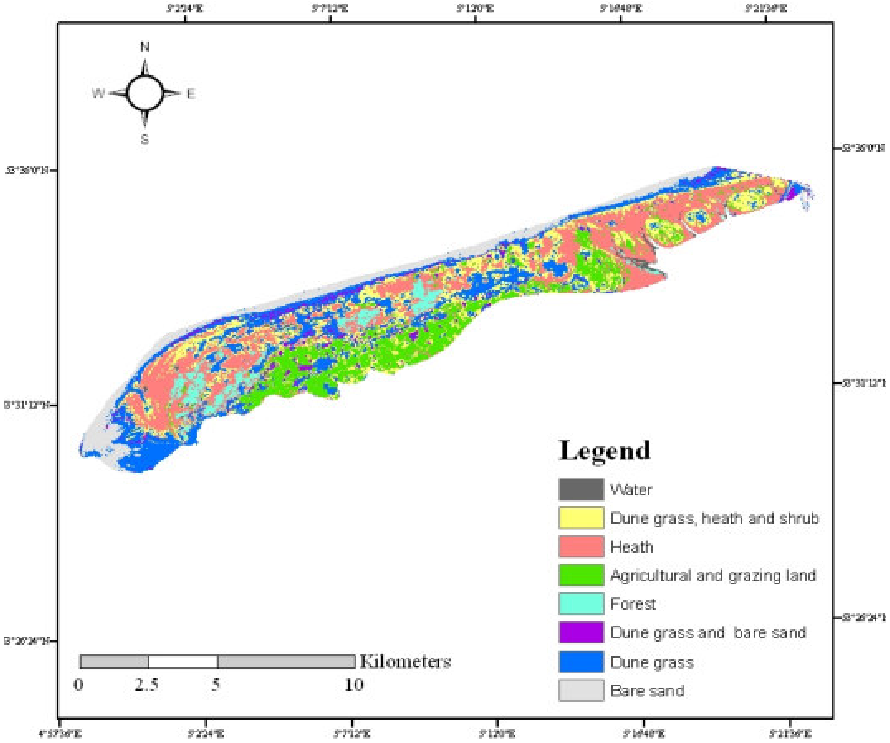

Figure 4: Land cover map of Terschelling

It appeared that heath and dune grass are dominant land cover classes in Terschelling in terms of area of coverage (see appendix 2).

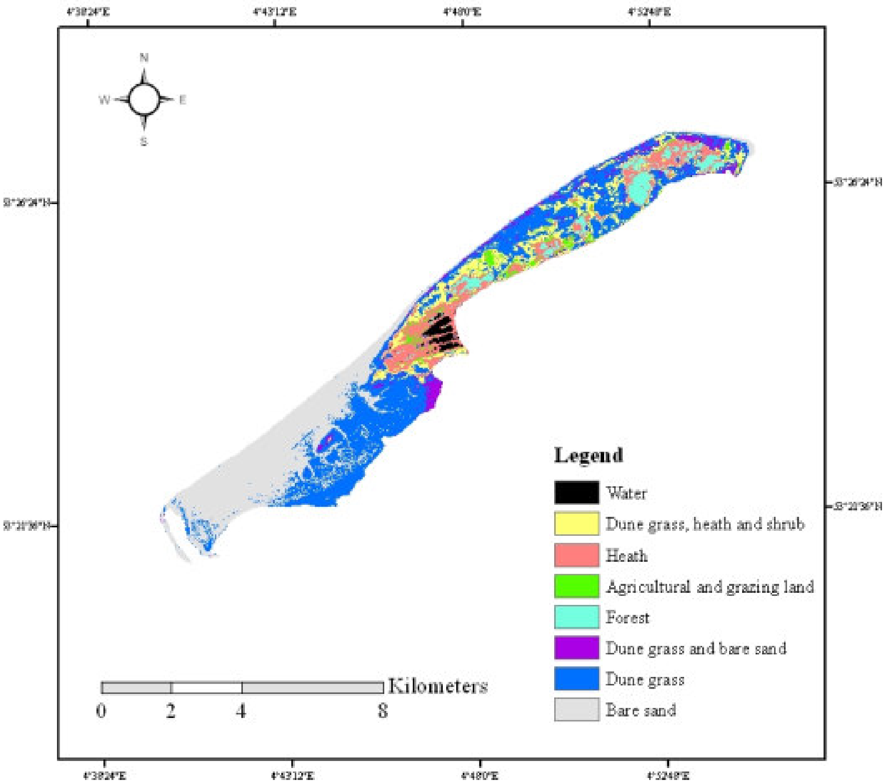

Figure 5: Land cover map of Vlieland

It appeared that dune grass and bare sand are dominant land cover classes in Vlieland in terms of area of coverage (see appendix 2).

Overall accuracy and Kappa statistics of the classification are 73% and 0.72 respectively.

3.2 Environmental parameters relevant to sand lizard habitat

Sand lizards can be found in a variety of habitats (Bird and Edgar, 2005). In northwest Europe sand lizards are mostly confined to sandy habitats such as lowland heathland and sand dunes (Corbett & Moulton, 1999). Sandy habitats are preferred by the species because it needs sandy patches for basking and hatching eggs. Sand lizard habitats in northwest Europe are also characterized by south or southwest facing aspect and diverse vegetation structure (Corbett & Tamarind, 1979; House & Spellerberg, 1983). South or southwest aspect provides minimum shadow and diverse vegetation structure provides shelter against predators. In low heathland sites sand lizards are mostly found in later successional stage of dry heath (Corbett & Moulton, 1999; Glandt, 1991). Areas with ground layer of bryophytes and lichens and dwarf gorses grown amongst heather are also favored by sand lizard (Bird and Edgar, 2005).

It is evident from literature study that sandy open patches, vegetation and south or south west aspect are three crucial elements of sand lizard habitat in northwest Europe. Expert opinion was also taken about sand lizard habitat in Terschelling and Vlieland. In Terschelling and Vlieland sand lizard habitats are mostly characterized by the presence of dune grass and sandy patches with south or soutwest aspect (Zuiderwijk, 2006). Sand lizards are rarely found in heathland in Terschelling and Vlieland (Zuiderwijk, 2006).

Based on literature study and expert opinion it appeared that vegetation, soil type and aspect are three important environmental parameters relevant to sand lizard habitat.

3.3 Important environmental parameters in predicting sand lizard distribution

Maxent model was used to find out which environmental parameter(s) is/are important in the prediction of sand lizard distribution. Maxent model uses Jackknife method to identify important variables for the prediction of potential distribution of any species. The result of Jackknife analysis is given below. It is to be noted that land cover, aspect, altitude and slope were used in the model. Soil was not used due to unavailability of soil map of the area at smaller scale. Jackknife of test gain and AUC and sand lizard potential distribution maps are shown in the appendix.

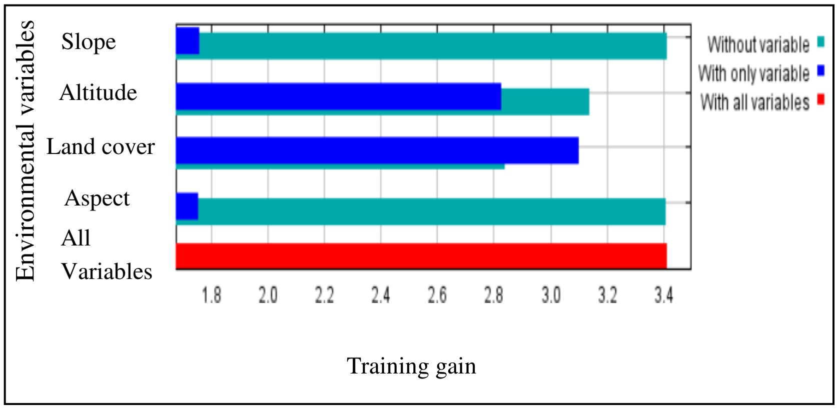

Figure 6: Jackknife of training gain

In figure 6, gain indicates contribution of each variable in the prediction of species distribution. From Jackknife analysis it is evident that land cover and altitude are two variables which have influenced the prediction of sand lizard distribution to a great extent. Compared to land cover and altitude, slope and aspect have insignificant contribution to the prediction of the species distribution.

It can be observed that land cover has the most useful information by itself which is not present in other environmental variables. When it is omitted it reduces the gain the most. So land cover is the most important environmental parameter for predicting sand lizard distribution in the area.

3.4 Change in environmental parameters

Three important environmental parameters identified for sand lizard habitat are vegetation cover, aspect and soil. The study is concerned about change in environmental parameters during 1998 to 2005. It is unlikely that within this short span of time aspect and soil of the area have experienced noticeable change. No evidence of change in soil type or aspect of the area in the last decade was found in relevant literature. Among these parameters vegetation is most susceptible to change. Vegetation change can take place in dunes due to many reasons such as vegetation succession, grazing, trampling by increased tourism and bush fire. In recent past decline in lichen cover and increase in marram grass (*Ammophila arenaria*) are examples of vegetation change occurred in the area (Kros *et al.*, 1994). Therefore monitoring vegetation change is pertinent to sand lizard habitat monitoring.

3.5 Monitoring vegetation change

Over the last decades open dune grasslands in the Netherlands have experienced extensive tall grass encroachment (Kooijman *&* Veer, 1997). Atmospheric nitrogen deposition may be one of the possible reasons for this extensive grass encroachment (Kooijman & Veer, 1997). There has been an accelerated spread of shrubs in the Dutch dunes as well (Kros, 1994). According to Staatsbosbeheer of Vlieland (forest department responsible for dune management) there has been an increase in grass species in dunes in recent years.

NDVI time series were used in this study to monitor vegetation change in Terschelling and Vlieland. NDVI represents degree of greenness in an area (Fung & Siu, 2000). Change in NDVI over the years can be an indication of change in vegetation. NDVI has a well established link with vegetation productivity (Pettoreli *et al.,* 2005). Increasing trend of NDVI during peak phenological period in dunes can be an indication of increase in vegetation, which can be related to grass or shrub encroachment in dunes. A general trend of dune vegetation can be obtained from NDVI time series. From NDVI time series it is not possible to identify the areal extent of vegetation change.

The study included SPOT VEG 10 days composite NDVI of 288 decades starting from April 1998 to March 2006. SPOT NDVI images of Terschelling and Vlieland were classified in five classes. Decadal average NDVI of each NDVI class has been presented to facilitate monitoring vegetation change. It is to be mentioned that first decade represents first ten days of April 1998; second decade represents 11th to 20th April 1998 and so on. Decade 1-27, 28-63, 64-99, 100- 135, 136-171, 172-207, 208-243, 244-279, 280-288 represent April 1998 to December 1998, January 1999 to December 1999, January 2000 to December 2000, January 2001 to December 2001, January 2002 to December 2002, January 2003 to December 2003, January 2004 to December 2004, January 2005 to December 2005 and January 2006 to March 2006 respectively. Classified NDVI images of Terschelling and Vlieland and proportion of different land covers in each NDVI class of Terschelling and Vlieland are shown below.

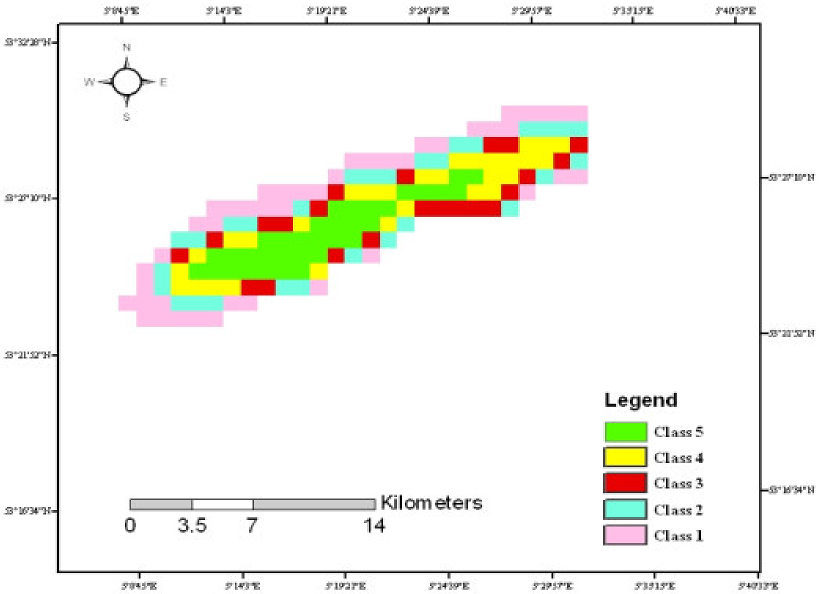

Figure 7: NDVI classes of Terschelling (April 98 to March 06)

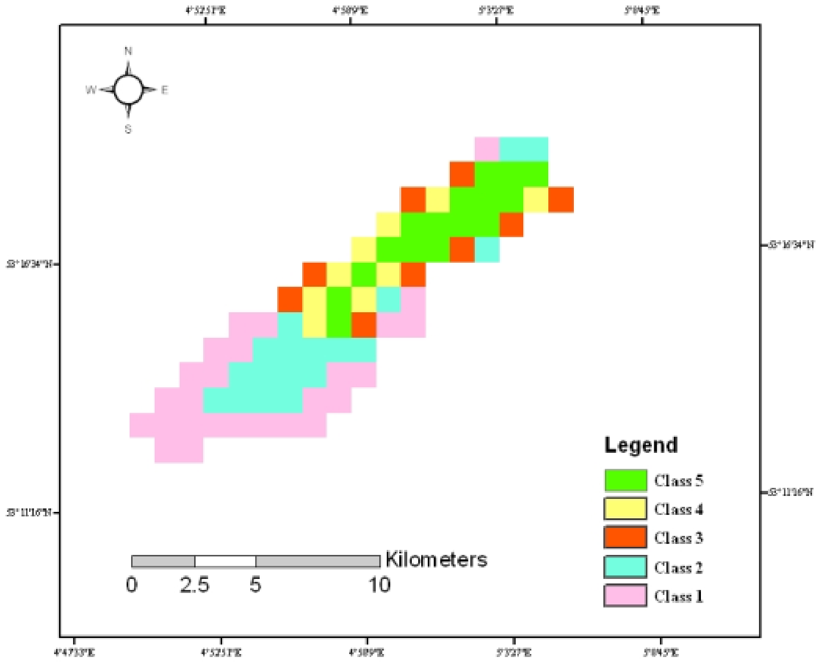

Figure 8: NDVI classes of Vlieland (April 98 to March 06)

Table 1: Proportion of different land cover types in five NDVI classes of Terschelling

		Land cover							
		Dune grass (%)	Dune grass & bare sand (%)	Heath (%)	Heath, shrub & dune grass mixed (%)	Agricultural & grazing land (%)	Bare sand (%)	Forest (%)	Water (%)
NDVI class	1	**42.46**	28.65	4.88	8.42	0	14.43	0.91	0
	2	24.43	**32.48**	10.60	15.93	3.55	11.95	0.96	0
	3	19.46	18.22	14.93	**25.76**	12.78	1.71	6.85	0.18
	4	15.31	12.60	14.56	**26.40**	19.42	0.47	7.74	3.50
	5	17.45	15.15	15.20	**36.08**	10.72	0.41	3.93	1.04

Table 1 shows general overview of percentage of different land covers in each NDVI class of Terschelling. Dune grass is the dominant land cover in areas represented by class 1 and class 2 of Terschelling. Class 1 and class 2 of Terschelling are also characterized by presence of bare sand. Class 3, class 4 and class 5 of Terschelling mostly represent mixed land cover classes.

Table 2: Proportion of different land cover types in five NDVI classes of Vlieland

		Land cover							
		Dune grass (%)	Dune grass & bare sand (%)	Heath (%)	Heath, shrub & dune grass (%)	Agricultural & grazing land (%)	Bare sand (%)	Forest (%)	Water (%)
NDVI class	1	**46.31**	2.12	0	0	0	**51.49**	0	0
	2	9.87	1.63	0.14	0.25	0	**38.09**	**50**	0
	3	18.42	8.06	15.89	**23.49**	16.23	13.86	3.79	0.26
	4	16.02	14.29	13.50	**28.93**	10.89	3.69	12.15	0.43
	5	14.40	8.55	13.32	**29.10**	20.86	0.60	12.83	0.16

Table 2 provides a general overview of different land covers represented by each NDVI class of Vlieland. Class 1 of Vlieland is characterized by dune grass and bare sand. Forest and bare sand are two major land cover types present in areas represented by class 2 of Vlieland. Class 3, class 4 and class 5 of Vlieland mostly represent mixed land cover types.

3.5.1 NDVI time series of class 1 of Terschelling and Vlieland

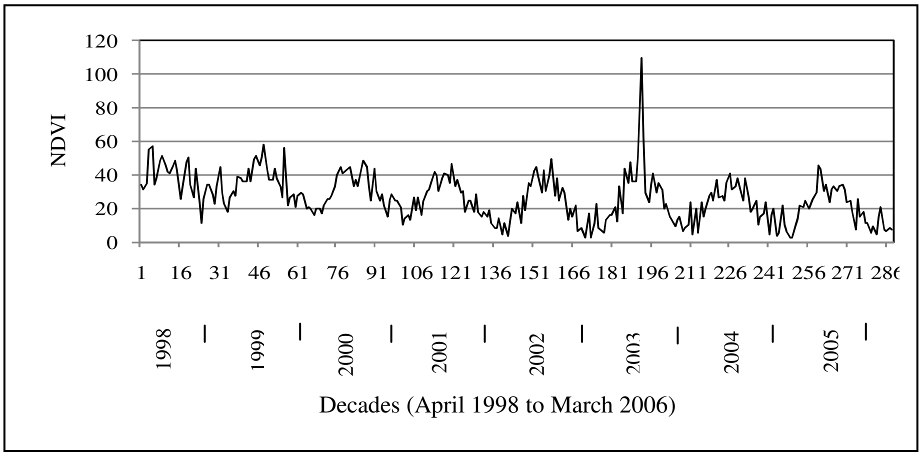

Figure 9: Mean NDVI of Class 1 of Terschelling in 288 decades

Figure 9 represents decadal (10 days) mean NDVI of class 1 of Terschelling in eight years. Class 1 of Terschelling mostly represents dune grass and bare sand (see table 1). Dune grass is the dominant vegetation in this area. The class is characterized by peak phenological period during June, July and August(7-15, 43-51,79-87,115-123, 151-159, 187-195, 223-231, 259-267) and less photosynthetic activities during November to March (22-36, 58-72, 94-108, 130-144, 166-180, 202-216, 238-252, 274-288). Figure 9 shows decline in NDVI during peak phenological period of 2000 to 2005. In 1998, range of NDVI during peak phenological period was around 40 to 55. In 2005 the range of NDVI during peak phenological period was around 30 to 40. It shows decline in NDVI during 1998 to 2005. The decline started in the year 2000. **The decline in NDVI can be attributed to decline in vegetation in the area represented by class 1 of Terschelling.**

Two sample t test was carried out to find out whether there was significant difference in NDVI of class 1 of Terschelling during peak phenological period of 1999 (43-51) and 2005 (259-267). Result showed that there was no significant difference in NDVI during peak phenological period of 1999 and 2005(t stat=1.29, df=16 and P= 0.217). Therefore the decline in NDVI was statistically insignificant.

Compared to other classes of Terschelling, class 1 appeared to have lower NDVI. It implies that the area is less vegetated than other areas of Terschelling. There was an abnormal rise in mean NDVI of class 1 in June 2003(181-216), which can be a false high. SPOT NDVI is derived by maximum value compositing procedure, which can be biased by a single false high (Pettoreli et al 2005). False high is mainly caused by presence of cloud.

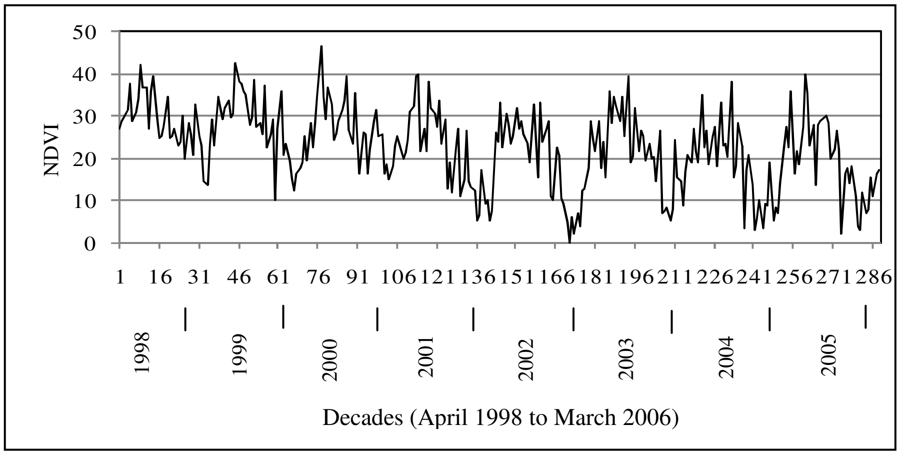

Figure 10: Mean NDVI of class 1 of Vlieland in 288 decades

Figure 10 shows decadal (10 days) mean NDVI of class 1 of Vlieland in eight years. Class 1 of Vlieland mostly represents bare sand and dune grass (see table 2). The peak phenological period of this class is in the months of June, July and August (Decade 7-15, 43-51,79-87,115-123, 151-159, 187-195, 223-231, 259-267). Winter and early spring months (Decade 22-36, 58-72, 94-108, 130-144, 166-180, 202-216, 238-252, 274-288) are characterized by low NDVI. Figure 10 shows a noticeable decline in NDVI during peak phenological period of 2002(decade 151-159). In 1998, range of NDVI during peak phenological period was around 30 to 40. In 2002 the range of NDVI during peak phenological period went down to 25 to 30. **Mean NDVI during peak phenological period of 2002 to 2005 were comparatively lower than those of 1998 to 2001. It also indicates a decline in vegetation in that area during 2002 to 2005.**

Two sample t test was performed to find out whether there was significant difference in decadal mean NDVI of class 1 of Vlieland during peak phenological period of 2001 and 2002. Result showed that there was no significant difference in NDVI during peak phenological period of 2001 and 2002(t stat= 1.08, df=16, P= 0.295).

Therefore the decline in NDVI during peak phenological period of 2002 was statistically insignificant.

Compared to other classes of Vlieland, class 1 had lower NDVI. It can be attributed to land cover characteristics of the class. The area is less vegetated and large portion of the class is covered by bare sand. It is to be noted that class 1 of Terschelling had higher NDVI than class 1 of Vlieland. It can be attributed to presence of more bare sand in class 1 of Vlieland.

3.5.2 NDVI time series of class 2 of Terschelling and Vlieland

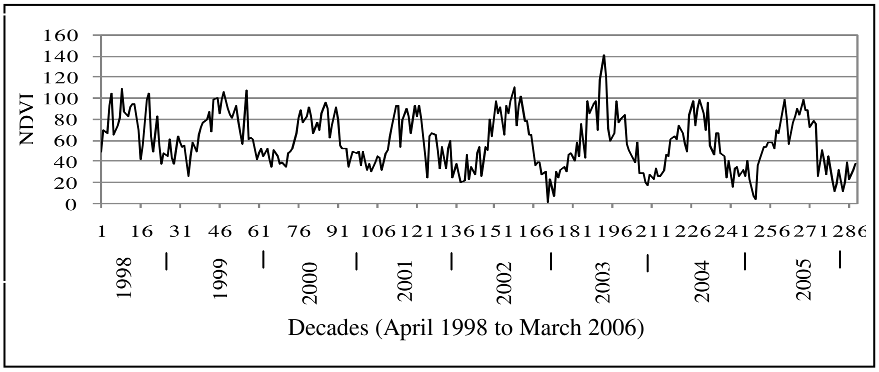

Figure 11: Mean NDVI of class 2 of Terschelling in 288 decades

Figure 11 shows NDVI profiles of class 2 of Terschelling over eight years. It represents mostly dune grass, bare soil, heath and shrubs (see table 1). Dune grass is the dominant vegetation here. Figure 11 shows peak phenological period in the months of June, July and August (Decade 7-15, 43-51,79-87,115-123, 151-159, 187-195, 223-231, 259-267). Winter months were characterized by low NDVI values. The class appeared to have comparatively lower average NDVI during peak phenological period of 2000 (decade 79-87) and 2001(decade 115-123). Except these two years, mean NDVI during peak phenological period in other six years remained more or less unchanged. There is an abnormal rise in NDVI in the month of July, 2003. It can be a false high due to presence of cloud. Maximum NDVI of this class during peak phenological period was around 100.

Two sample t test was performed to find out whether there was significant difference in NDVI of class 2 of Terschelling during peak phenological period of 2001(decade 115-123) and 2002(decade 151-159). Result showed that there was no significant difference in mean NDVI during peak phenological period of 2001 and 2002(t stat=

-1.40, df=16, P= 0.179). Therefore the decline in NDVI during peak phenological period of 2000 and 2001 was statistically insignificant.

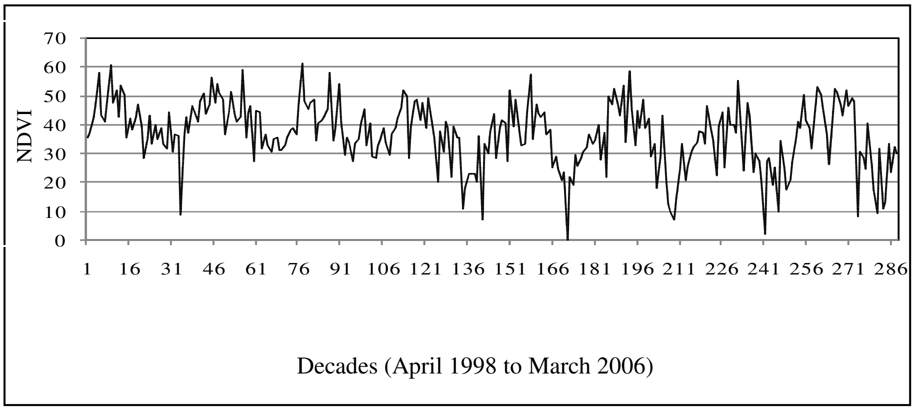

Figure 12: Mean NDVI of class 2 of Vlieland in 288 decades

Figure 12 shows decadal mean NDVI of class 2 of Vlieland over eight years starting from April 1998 to March 2006. Class two of Vlieland represents mostly forest and bare sand (see table 2). Peak phenological period of this class is in the months of June, July and August (Decade 7-15, 43-51, 79-87,115-123, 151-159, 187-195, 223-231, 259-267). There was no marked change in NDVI during peak phenological period over the years. However, this class appeared to have slightly lower NDVI during peak phenological period of 2001(decade 115-123).

Two sample t test was performed to find out whether there was significant difference in NDVI of class 2 of Vlieland during peak phenological period of 2001 and 2002. Result showed that there was no significant difference in NDVI during peak phenological period of 2001 and 2002(t stat= 0.02, df=16, P= 0.983). Therefore the decline in NDVI during peak phenological period of 2001 was statistically insignificant.

It is to be noted that maximum NDVI of class 2 of Vlieland during peak phenological period was around 60 which is lower than that of class 2 of Terschelling. Presence of more bare sand in class 2 of Vlieland could be responsible for this.

3.5.3 NDVI time series of class 3 of Terschelling and Vlieland

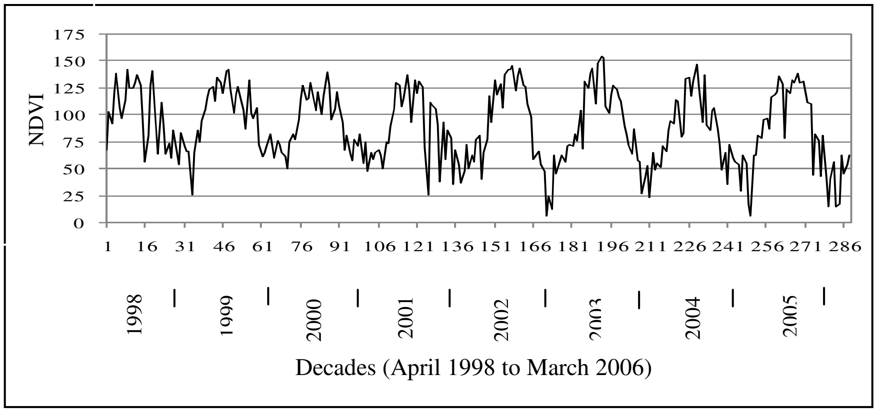

Figure 13: Mean NDVI of class 3 of Terschelling in 288 decades

Figure 13 shows decadal average NDVI of class 3 of Terschelling in eight years. The class represents a combination of dune grass, heath, bare soil, shrub and agricultural land (see table 1). Mixed land cover classes are dominant in this area. The figure shows peak phenological period during the months of June, July and August (Decade 7-15, 43-51, 79-87,115-123, 151-159, 187-195, 223-231, and 259-267). NDVI during peak phenological period of 2000 (decade 79-87) and 2001(decade 115-123) were slightly lower than those of other years. Maximum NDVI of this class during peak phenological period was around 140.

Two sample t test was performed to find out whether there was significant difference in NDVI of class 3 of Terschelling during peak phenological period of 1999 and 2000. Result showed that there was no significant difference in NDVI during peak phenological period of 1999 and 2000(t stat= 1.057, df=16, P= 0.306). Therefore the decline in NDVI during peak phenological period of 2000 was statistically insignificant.

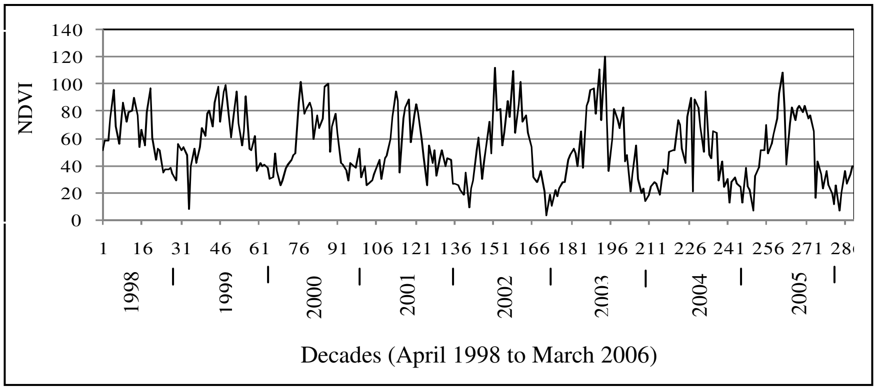

Figure 14: Mean NDVI of class 3 of Vlieland in 288 decades

Figure 14 shows decadal mean NDVI of class 3 of Vlieland in 8 years from April 1998 to March 2006. It represents mostly dune grass, heath, shrub, bare soil and agricultural land (see table 2). Mixed land cover classes are dominant here. The figure shows peak phenological period in the months of June, July and August (Decade 7-15, 43-51, 79-87,115-123, 151-159, 187-195, 223-231 and 259-267). Winter months were characterized by low NDVI values like other classes. This class appeared to have higher NDVI during peak phenological period of 2002 (decade 151-159) and 2003(decade 187-195).

Two sample t test was performed to find out whether there was significant difference in NDVI of class 3 of Vlieland during peak phenological period of 2001 and 2003. Result showed that there was no significant difference in NDVI during peak phenological period of 2001 and 2003(t stat= -1.47, df=16, P= 0.163). Therefore the rise in NDVI during peak phenological period of 2003 was statistically insignificant.

It can be observed that although class 3 of Terschelling and Vlieland have similar land cover classes, NDVI in Vlieland were comparatively low. Presence of more sand in class 3 of Vlieland could be responsible for the low NDVI in Vlieland.

3.5.4 NDVI time series of class 4 of Terschelling and Vlieland

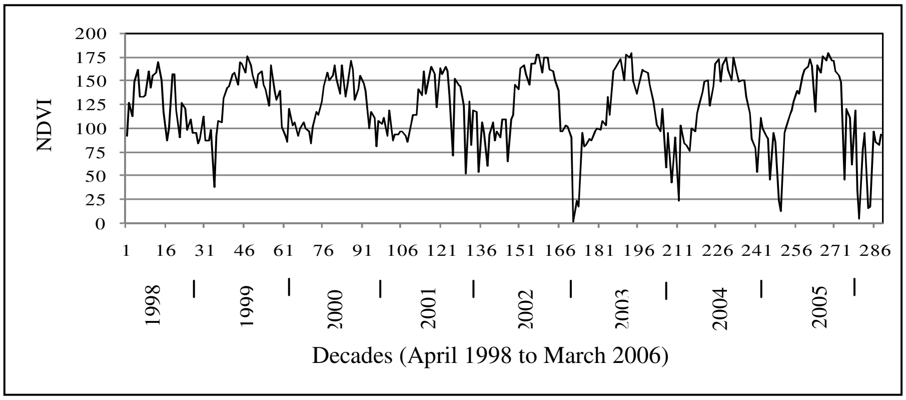

Figure 15: Mean NDVI of class 4 of Terschelling in 288 decades

Figure 15 shows decadal average NDVI of class 4 of Terschelling over eight years from April 1998 to March 2006. It represents mainly heath, shrubs, agricultural and grazing land (see table 1). It also contains dune grass and a small portion of forest. Mixed land cover classes are dominant here (see table 1). NDVI appeared to be to some extent higher during peak phenological period of 2002 to 2005(decade 151-159, 187-195, 223-231 and 259-267). In 1998 maximum NDVI during peak phenological period was around 160, which reached to around 180 in 2002 to 2005.

Two sample t test was performed to find out whether there was significant difference in NDVI of class 4 of Terschelling during peak phenological period of 2001(decade 115-123) and 2002(decade 151-159). Result showed that there was no significant difference in NDVI during peak phenological period of 2001 and 2002(t stat= -1.84, df=16, P= 0.086). Therefore the rise in NDVI during peak phenological period of 2002 was statistically insignificant.

Although it was not significant, the increase in NDVI over the four years (2002-2005) could be due to increase in vegetation in the area. Shrub encroachment could be the reason of rise in mean NDVI during that period.

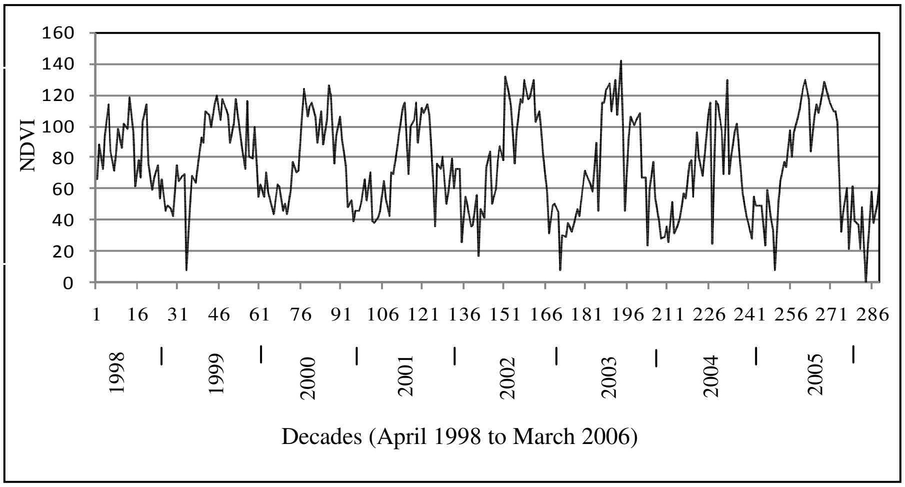

Figure 16: Mean NDVI of class 4 of Vlieland in 288 decades

Figure 16 represents decadal average NDVI of class 4 of Vlieland over eight years. This class represents dune grass, heath, agricultural land and forest (see table 2). Mixed land cover classes are dominant here as well. This figure shows peak phenological period in the months of June, July and August (Decade 7-15, 43-51, 79-87,115-123, 151-159, 187-195, 223-231, and 259-267). There is no single dominant vegetation type in this area as well. NDVI profile shows minor increase in mean NDVI during peak phenological period after 2001(decade 100-135). The maximum NDVI of this class was around 120, which is lower compared to class 4 of Terschelling.

Two sample t test was performed to find out whether there was significant difference in NDVI of class 4 of Vlieland during peak phenological period of 2001(decade 115-123) and 2002(decade151-159). Result showed that there was no significant difference in mean NDVI during peak phenological period of 2001 and 2002(t stat= -1.48, df=16, P= 0.157). Therefore the rise in NDVI during peak phenological period of 2002 was statistically insignificant.

3.5.5 NDVI time series of class 5 of Terschelling and Vlieland

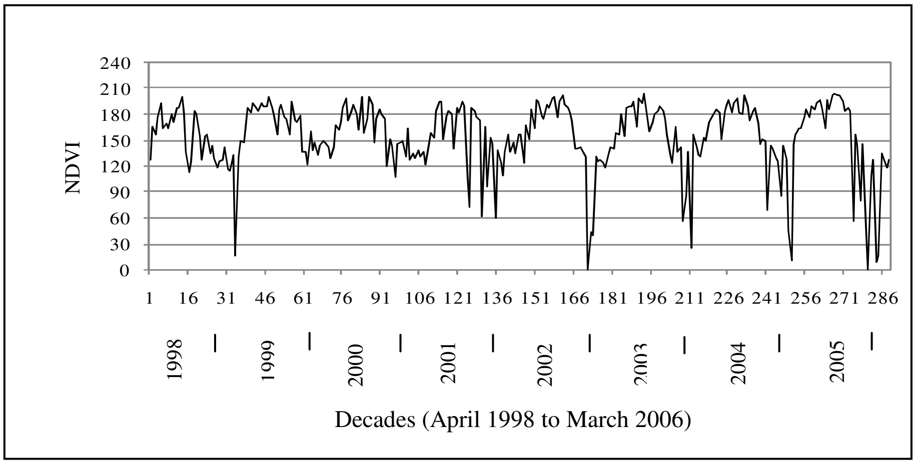

Figure 17: Mean NDVI of class 5 of Terschelling in 288 decades

Figure 17 represents decadal average NDVI of class 5 of Terschelling. The class represents mostly heath, shrubs and dune grass (see table 1). Mixed land cover classes are dominant in this area. Decadal mean NDVI of this class during peak phenological period (Decade 7-15, 43-51, 79-87,115-123, 151-159, 187-195, 223-231, and 259-267) remained more or less unchanged over the years.

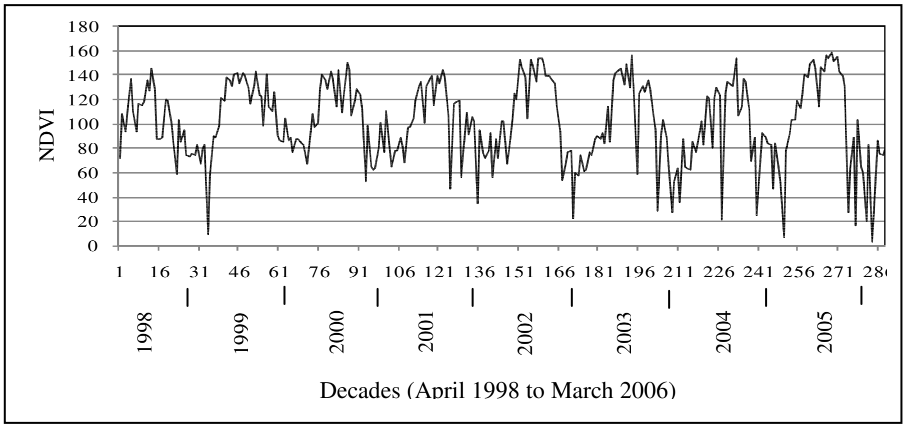

Figure 18: Mean NDVI of class 5 of Vlieland in 288 decades

Figure 18 shows decadal mean NDVI of class five of Vlieland during April 1998 to March 2006. Class 5 of Vlieland mostly represents heath, shrubs, dune grass, agricultural and grazing land (see table 2). Mixed land cover classes are dominant in this area. The class appeared to have an increase in NDVI during peak phenological period of 2002 and 2005.

Two sample t test was performed to find out whether there was significant difference in NDVI of class 5 of Vlieland during peak phenological period of 2001(decade 115-123) and 2002(decade 151- 159). Result showed that there was no significant difference in mean NDVI during peak phenological period of 2001 and 2002(t stat= -1.67, df=16, P= 0.112). Therefore the rise in NDVI during peak phenological period of 2002 was statistically insignificant.

It can be observed that maximum NDVI of this class was within 140-160, while class 5 of Terschelling had higher maximum NDVI (180 - 200).

3.6 Observed sand lizard population in Terschelling and Vlieland

Sand lizard population observation data of Terschelling and Vlieland are available since 1998. These two islands are inhabited by a very small size of sand lizard population. Following figures show observed sand lizard population in Terschelling and Vlieland during 1998 to 2005.

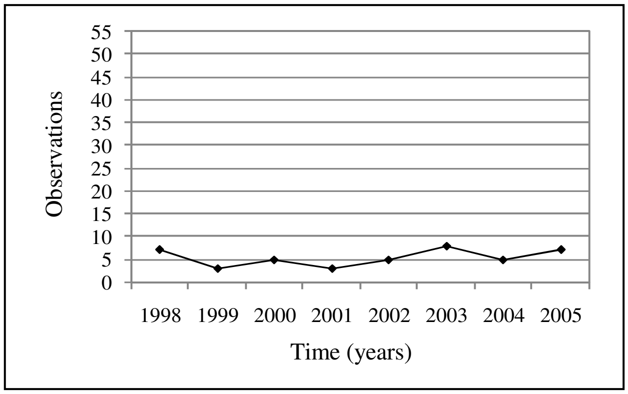

Figure 19: Observed sand lizard population in Terschelling

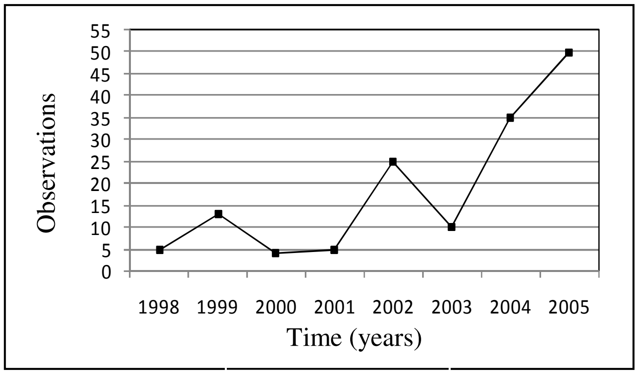

Figure 20: Observed sand lizard popualation in Vlieland

According to figure 20, in 1998 only 5 sand lizards were observed in Vlieland. During 1998 to 2003 observed sand lizard population in Vlieland was in the range of 5 to 25. There was a notable increase in number of observed sand lizard population in Vlieland in the year 2004. In 2005 the observed population further increased and the number of sand lizard observed rose to 50. The rise in observed sand lizard population in Vlieland has been significant compared to the number of the species in

1998. Observed sand lizard population in Terschelling remained very small throughout the period (see figure 19). The highest number of sand lizard found in Terschelling was eight in 2003. Although Terschelling is larger in size than Vlieland, sand lizard population in Terschelling is much smaller than that of Vlieland. Sand lizards in both islands are endangered and particularly in Terschelling the species is at severe risk of extinction.

3.6.1 Sand lizard observation and NDVI classes

It was found that sand lizard observation points in Terschelling were located in areas represented by NDVI class 1, 2 and 3(see appendix 5). Class 1 and 2 in Terschelling are dominated by dune grass and bare sand and class 3 is dominated by mixed land cover classes. Sand lizard observation points in Vlieland were mostly located in areas represented by NDVI class 4 and 5 of Vlieland (see appendix 5). Unlike Terschelling, class 4 and class 5 of Vlieland are dominated by mixed classes, although dune grass and bare sand are present in these classes.

4 Discussion

4.1 How vegetation change can affect sand lizard habitat

Vegetation and sandy open patches are two important elements of sand lizard habitat. Particularly presence of open patches around vegetation is essential for the survival of the species. Sandy open patches are used by the species for basking and hatching eggs during active season. That is why sand lizard habitats are not found in shrubs. Dunes are suitable habitat for sand lizards as both vegetation and open sandy patches are available there. In Terschelling and Vlieland sand lizard habitats are mostly found in areas of dune grass (Zuiderwijk, 2006). Sand lizard habitats in dry mature heath have almost disappeared due to eradication of dry mature heath (Bird and Edgar, 2005; Stumpel, 2004). Therefore in Terschelling and Vlieland, sand lizard habitats can be negatively affected by severe decline in sandy open patches. Decline in sandy open patches can be caused by grass or shrub encroachment in dunes. It can be concluded that large scale grass or shrub encroachment in dunes possesses potential threat to sand lizard habitat.

4.2 Vegetation change in Terschelling and Vlieland

It can be observed from NDVI time series of five classes of Terschelling and Vlieland that there was no distinct increasing or decreasing trend in NDVI over the years except in class 1 of Terschelling. NDVI profiles of Terschelling and Vlieland showed insignificant increases or declines in NDVI mostly for short period of time. In most cases, increase in NDVI during peak phenological period of a year was followed by a decline in NDVI next year. Therefore most likely those insignificant increases in NDVI did not indicate large scale grass or shrub encroachment. It can also be observed that average NDVI in Vlieland during peak phenological period over the years were lower compared to those of Terschelling. It indicates that there is more vegetation cover in Terschelling than Vlieland.

There were some unusual declines in NDVI of all classes of both Terschelling and Vlieland during winter and early spring months of 1998-99, 2001-02, 2002-03, 2003-04, 2004-05. As it was common in all classes of two islands, it is unlikely that those declines were related to vegetation change. Winter and early spring months in the study area are characterized by presence of cloud. Those declines could happen due to removal of pixels with cloud or shadow.

It can be concluded that NDVI time series of Terschelling and Vlieland did not indicate extensive grass or shrub encroachment in the area which could cause severe decline in open patches in dunes. There were declines in vegetation in Terschelling in areas dominated by dune grass and bare sand (class 1) starting from 2000 to 2005. Vegetation also declined in areas dominated by dune grass and bare sand in Vlieland during 2002 to 2005.

4.3 Sand lizard population and vegetation change

Observed sand lizard habitats are located in areas represented by class 1, 2 and 3 of Terschelling (see appendix 5) and class 4 and 5 of Vlieland (see appendix 5). Therefore changes in these classes are more relevant to sand lizard population.

Sand lizard population is extremely small in Terschelling. Figure 19 shows the species is at severe risk in Terschelling. Sand lizard population in the island did not recover during 1998 to 2005. It indicates that the factors responsible for the present state of sand lizard population in Terschelling prevailed during 1998 to 2005. Decline in sandy patches due to grass or shrub encroachment might be one of the prime reasons of sand lizard habitat degradation. However, NDVI time series analysis did not show any significant increase in vegetation during 1998 to 2005 in class 1, 2 or 3 of Terschelling. There was decline in vegetation during 2000 to 2005 in areas represented by class 1 of Terschelling, although the decline was of small magnitude. Even the decline in vegetation in Terschelling does not establish any relation between vegetation change and sand lizard population, because sand lizard population remained extremely low (within the range of 5 to 8) throughout 1998 to 2005.

Sand lizard is an endangered species in Vlieland, although unlike Terschelling observed sand lizard population in Vlieland increased in 2002, 2004 and 2005 (see figure 20). There was a threefold increase in observed sand lizard population in 2004 in the island. During 1998 to 2001 and 2003 observed sand lizard population was significantly low (see figure 20). In order to find out whether there was any relation between sand lizard population and vegetation change in Vlieland, it is important to look at the vegetation status of class 4 and class 5 of Vlieland. NDVI profiles of these classes did not show rise in NDVI during 1998 to 2001 and 2003. Apparently there was no wide spread grass or shrub encroachment in Vlieland in those years. It appeared from the analysis that low sand lizard population in Vlieland during 1998 to 2001 and 2003 was not related to vegetation change. It can also be observed that there was no significant change in vegetation in class 4 and 5 of Vlieland during 2004 onwards. Therefore the noticeable increase in sand lizard observation in Vlieland during 2004 and 2005 could not be explained by vegetation change in class 4 and 5 of Vlieland.

It appeared from the study that sand lizard population in the study area was not influenced by vegetation change.

4.4 Other possible reason of low sand lizard population in Terschelling

Apart from habitat degradation sand lizard population can decline due to presence of predators. Sand lizards are consumed by a wide variety of predators including mustelids, foxes, badgers, various birds of prey and many species of snake (Martens, 1996). House cat, pheasants and chickens are also prey on sand lizards (Hensaw, 1998). It has been documented that ordinary house cats can have damaging effect on sand lizard population (Hensaw, 1998). Presence of predators could be responsible for low sand lizard population in Terschelling.

4.5 Limitations of the study

It is to be noted that in habitat study scale is an important issue to be considered. The Sand lizards are characterized by home range of few hundred meters (Bird and Edgar, 2005). Sand lizard habitats are more likely to be influenced by changes occurred within home range of the species. From this point of view, study of sand lizard habitat change with images at 1 km² resolution could be misleading.

It is unlikely that localized changes in vegetation can be depicted using coarse resolution imageries at 1 km² resolution. There is a possibility that small scale significant changes occurred in some places but they were not detected by the coarse resolution NDVI data. In addition to this, mean NDVI was used to monitor vegetation change, which can result in depiction of crude vegetation condition (Fung and Siu, 2000). However due to unavailability of frequent high resolution imageries, the study was an attempt to utilize easily available coarse resolution SPOT VEG NDVI imageries for sand lizard habitat monitoring.

Sand lizard population data have some limitations as well. Sand lizard population data were collected based on sighting active lizard on fieldwork day. The quality of the data can vary according to dedication and precision of monitoring.

5 Conclusions and recommendations

5.1 Conclusions

Based on literature study and expert opinion it appeared that vegetation, soil type and aspect are three important environmental parameters relevant to sand lizard habitat. Jackknife analysis showed that land cover is the most important environmental parameter in predicting sand lizard distribution in the area.

NDVI time series of Terschelling and Vlieland did not indicate extensive grass or shrub encroachment in the area which could cause severe decline in open patches in dunes. There were declines in vegetation in Terschelling in some areas dominated by dune grass and bare sand starting from 2000 to 2005. Vegetation also declined in some areas dominated by dune grass and bare sand in Vlieland during 2002 to 2005. Those declines in vegetation in Terschelling and Vlieland were of small magnitude. No significant changes in vegetation were found in areas where sand lizards were observed. There was no indication of wide spread habitat change in Terschelling and Vlieland.

Sand lizard is an endangered species in Terschelling and Vlieland. Sand lizard population is alarmingly low in Terschelling. Unlike Terschelling the species has increased recently in Vlieland. It appears, however, that habitat change has no or very little influence on the observed sand lizard population in the area. Other factor, like predation might play a role and is recommended to be studied in future research.

5.2 Recommendations

- Use of high resolution remote sensing imageries for habitat monitoring. Small scale changes in habitat can be detected with high resolution images.

- Research on presence of predators and their influence on sand lizard population. It will reveal whether predators are having any impact on sand lizard population.

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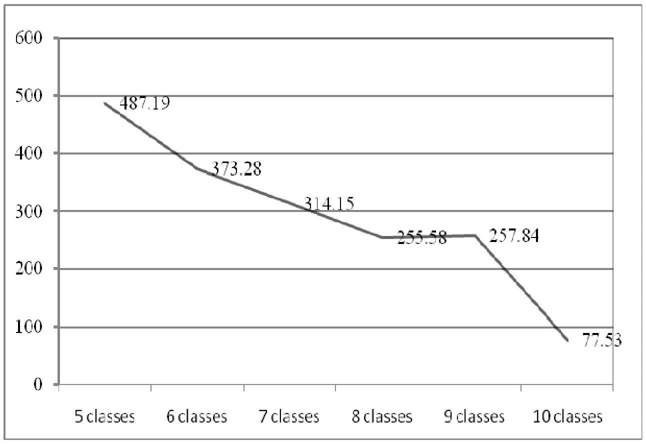
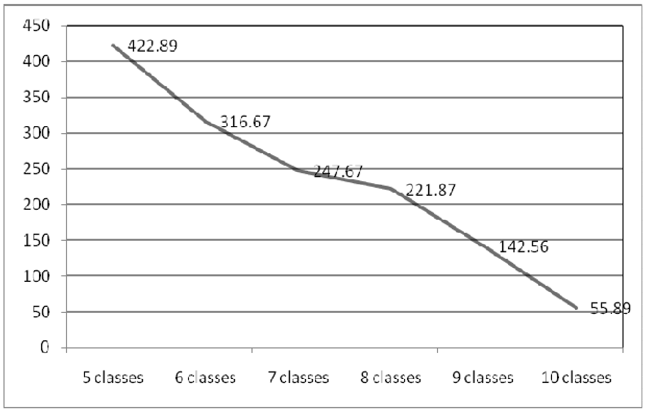
Appendices

Appendix1: Signature separability of different classes of Terschelling and Vlieland



1 (a): Signature separability of Terschelling using Euclidean distance method



1(b) Signature separability of Vlieland using Euclidean distance method

Appendix 2: Area of different land cover classes in Terschelling and Vlieland

2 (a) Area of different land cover classes in Terschelling.

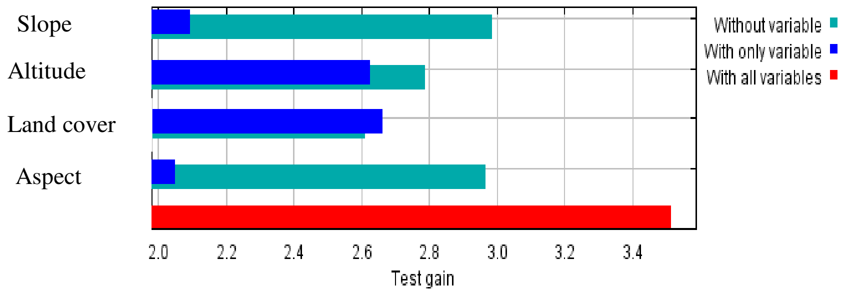
Land cover	**Area (hectare)**
Dune grass	**1711.64**
Dune grass and bare sand	252.12
Heath	**2133.09**
Heath , dune grass & shrub	1632.10
Agricultural and grazing land	1275.08
Bare sand	711.31
Forest	377.78
Water	74.74

2 (b) Area of different land cover classes in Vlieland.

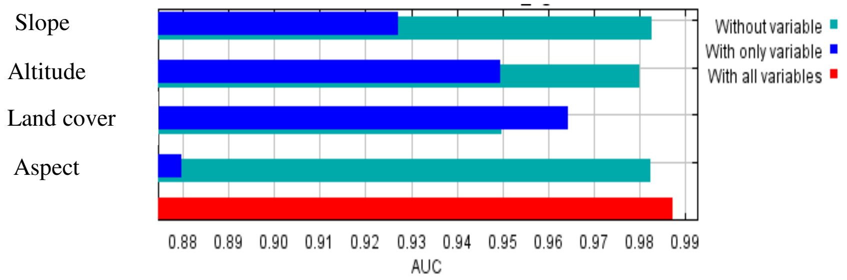
Land cover	**Area (hectare)**
Dune grass	**1187.911**
Dune grass and bare sand	127.8037
Heath	371.9162
Heath , dune grass & shrub	369.7581
Agricultural and grazing land	70.65274
Bare sand	**1028.158**
Forest	150.7878
Water	51.67544

Appendix 3: Jackknife of test gain and AUC

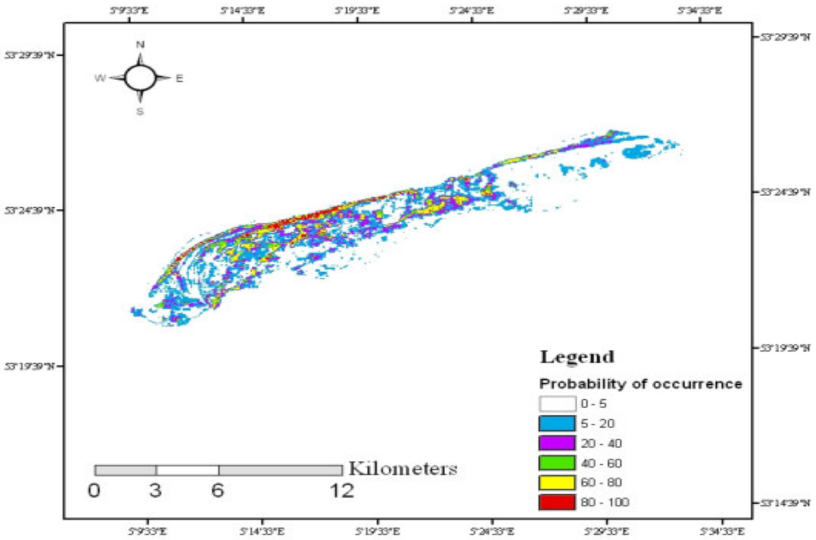
3 (a) Jackknife of test gain



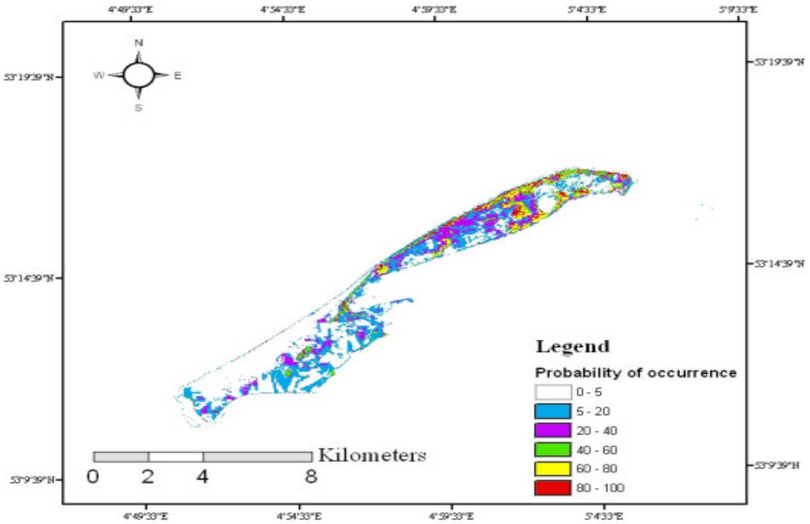
3 (b) Jackknife of AUC



Appendix 4: Potential sand lizard distribution in Terschelling and Vlieland

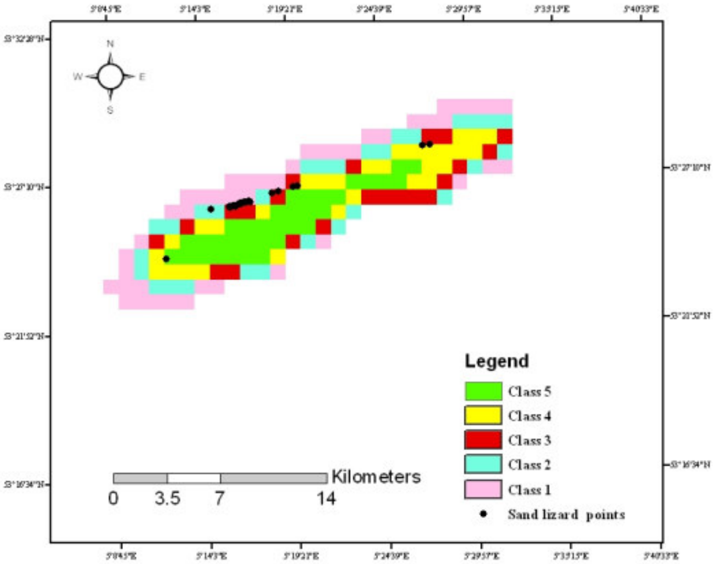


4 (a) Potential sand lizard distribution in Terschelling

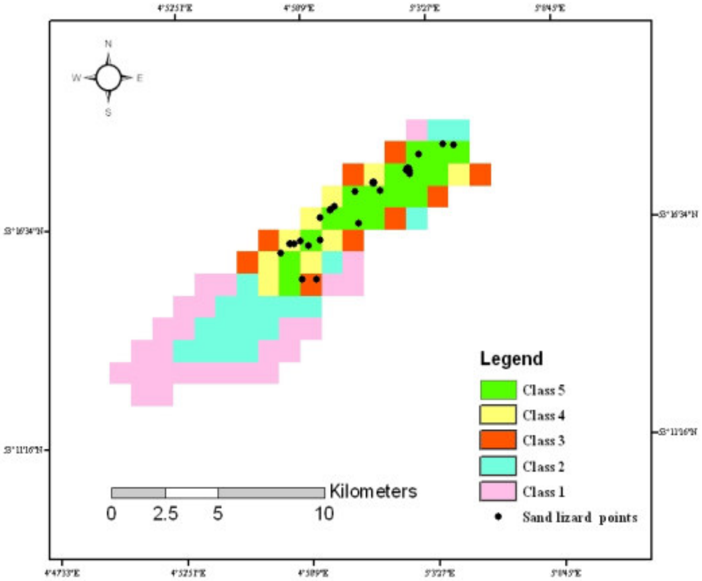


4 (b) Potential sand lizard distribution in Vlieland

Appendix 5: Sand lizard observation points overlaid on NDVI classes of Terschelling and Vlieland



5 (a) Sand lizard observation points in Terschelling



5 (b) Sand lizard observation points in Vlieland