The Potential of Hyper-temporal NDVI data to Assess Vegetation Condition and Grazing Intensity

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by

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Abstract

Land degradation has been reported to be a major environmental problem in Crete for a long time and is largely caused by excessive grazing. Several attempts have been done using satellite images for the purpose of monitoring the effect of excessive grazing on vegetation as a whole and their distribution. These studies lacked the temporal aspects of monitoring grazed lands since they used satellite imagery of one date. This study used 10 years MODIS hyper temporal NDVI images of 16 days temporal resolution to assess vegetation condition and grazing intensity. Grazed areas were classified by vegetation types into 8 groups. Grass Index measured from field was used as a direct estimate of Grazing Index. Seasonal analysis was done where the pixel NDVI value at the peak and at the end of grazing season was compared separately to Grazing Index to assess vegetation conditions. Not only that but also trend analysis was used to assess vegetation conditions, where the slope of 10 years NDVI was compared to the Grazing Index by vegetation types. Assessment of Grazing Intensity was done by comparing the difference of NDVI at the peak and end of grazing season with the Grazing Index. Seasonal analysis showed that at a confidence interval of 0.05 four groups had significant positive relation between the NDVI at a peak of growing season and grazing index and one had a negative relation. Moreover trend analysis revealed that at a confidence level of 0.15 two groups had significant positive and negative relation between slope of 10 years NDVI and grazing index. These analysis indicate that different vegetation types have different response to high grazing intensities. NDVI difference was found to have a positive relation with Grazing Index indicating it is possible to use this method to estimate grazing intensity. Not only that but also R^2 ranged between 25%-87% which means the analysis explained sufficient variability. MODIS hyper temporal NDVI has shown a potential to assess vegetation conditions and grazing intensity however studies should be done more on how to capture the amount of brown biomass this could improve the estimates and monitoring of grazed lands.

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1. Introduction

1.1. Background

The Mediterranean Basin in general and Greece in particular, is among Europe’s oldest settlement areas. Crete has a long history of human influence on mountainous ecosystem(Hostert et al., 2003). Sheep and goats mainly dominate their livestock and its Pastoralism has been characterized by moving livestock high up in the mountains during summer, in winter moving them back to the lowlands to live on crop residues, hay or preserved rangelands near farms and/or villages.
Remote Sensing and GIS has been used to detect change in vegetation. Results show that there is a strong link between landscape change and human influence (Kawamura et al., 2005; Peterson et al., 2002). However, detecting and monitoring changes that relate to ecosystem processes are still not fully quantified or understood. It requires among others not only consideration of the spatial but also of temporal aspects (Beltran Abounza, 2009).

One of the tools/indices used in quantifying green biomass is the normalized vegetation index (NDVI). It is a non-linear transformation of the visible (red) and near-infrared bands of satellite information. It is associated with vegetation canopy characteristics such as biomass, leaf area index and percentage of vegetation cover. Since NDVI is correlated to green biomass, it is also expected to be correlated to the amount of biomass for grazing.

In a study done by Kawamura (Kawamura et al., 2005), it was revealed that Grazing Intensity (GI) and estimated plant biomass had a poor negative correlation, which indicated that plant biomass reduced with increasing GI. When the plant biomass data was separated into different vegetation types, a stronger negative correlation was obtained which indicated different vegetation covers having different responses to grazing intensity. Another study by Peterson (Peterson et al., 2002) showed that there is a strong positive relationship between living biomass and NDVI values which suggests that NDVI values could potentially be used to indicate grazing intensity of grasslands/ranges.

Development of high temporal resolution satellites has made monitoring grazing over time possible. These satellites like NOAA-AVHRR, SPOT and MODIS have a very short revising time(Skidmore, 2002), which mean that it is now possible for example, to get an image of the same area after every 10days (hyper temporal).

An attempt was made to estimate degradation by overgrazing in Crete by using 13 observations over 20 years time. However, a time series consisting of 13 observations does not allow for piecewise linear or non-linear approaches. Nevertheless, as long as trends do not reverse, actual degradation rates may be over- or underestimated, but it is not likely that results based on 13 observations in 20 years will fail to represent the general development (Hostert et al., 2003). For this reason it is believed that using observations of higher temporal resolution like 10 days will produce better result. Remote

Sensing data particularly hyper-temporal images allow for research in larger study areas without doing too much fieldwork, it also makes it possible to calibrate the long time(dynamic) models by deriving vegetation cover change from time series of (satellite) images (Sluiter, 1998).

1.2. Grazing system in crete

The grazing system practiced in Greece is mainly animals grazing on natural pasture with herbaceous or woody (shrubby) species, this system is called Silvopastoral (Schultz et al., 1987). It includes both open and dense forests (Papanastasis, 1996). Greece has about 4.8 million goats, which is more than 43% of the goat population of the member countries of EU, moreover 9 million sheep heads which all depend on this system. In particular Crete has about 1.6 million sheep heads which is 18% of the total number of sheep heads in Greece and 580,000 goats which is 12% of total in Greece (National Statistical Service of Greece, 2005).

1.3. Study area

Crete is an Island in Greece located between 23°30'-26°20'E and 35°43'-34°47'N, figure 1 shows the location of Crete. The climate is Mediterranean with most rain falling during wintertime from November until April. The summer is very dry and the temperature can rise to 40 °C. The area is characterized by Mediterranean-type shrub ecosystems which are the evergreen sclerophylous formations, known as garrigue or marquis, and phrygana. Phrygana ecosystems are dominated by cushion-shaped shrubs with a height of 0.5 - 1.0 m. Phryganic ecosystems occupy more than 12 % of the total area of Greece. They are generally used as grazing land (Sluiter, 1998).

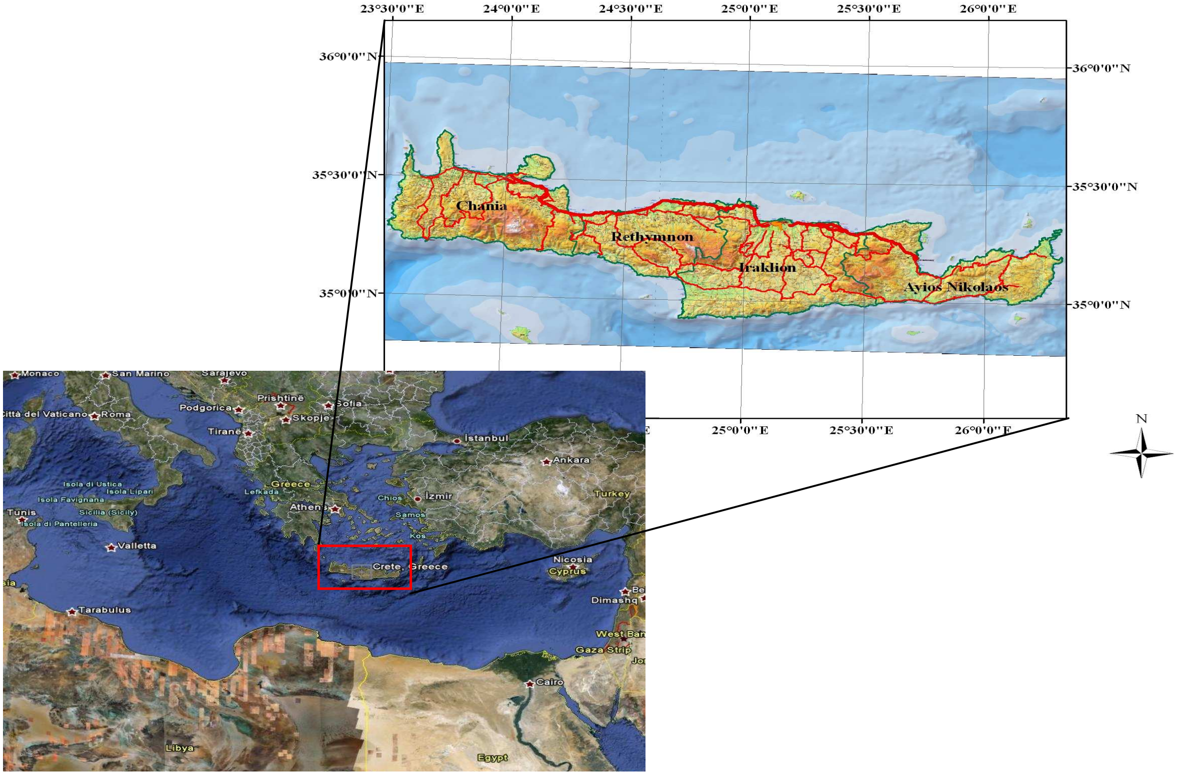


Figure 1: Map showing location of Crete Island.

1.4. Research problem

Grazing is one of the important land uses in Crete, Greece. Excessive grazing has resulted in severe land degradation in this area. However quantitative measures of intensity of grazing and its effect on vegetation condition are still not clear. Studies that have been done uses stocking rate as a measure of grazing intensity (Fischer et al., 2002; Numata et al., 2007), however due to commercial feed and movement of animals throughout the year it is not possible to relate the stocking rate with intensity of grazing .Vegetation condition in grazing lands can be monitored by linking it to biophysical properties like biomass, LAI, canopy height etc. (Fischer et al., 2002; Numata et al., 2007). Another Study shows that Grazing intensity not only has a direct negative impact on Biomass, but also has a significant correlation with NDVI (Peterson et al., 2002).

Using hyper-temporal NDVI images, it might be possible to assess the intensity of grazing by using the temporal behaviour of the vegetation index especially at the end of the grazing season. In this research it is planned to do this assessment by different vegetation types which are also defined by NDVI profiles. Since at the end of grazing season we expect different response of grazing for different vegetation types, it is therefore important to include the peak of growing season which is the time before grazing has taken places. By using these two periods it might be possible to see the different effects of grazing and estimate it. This method is expected to be more accurate as it will capture the temporal variation of the vegetation and can be an efficient tool for monitoring of grazing lands. Figure 2 shows the concept of the classification of grazed areas, moreover shows the NDVI behaviour over time with various benchmarks.

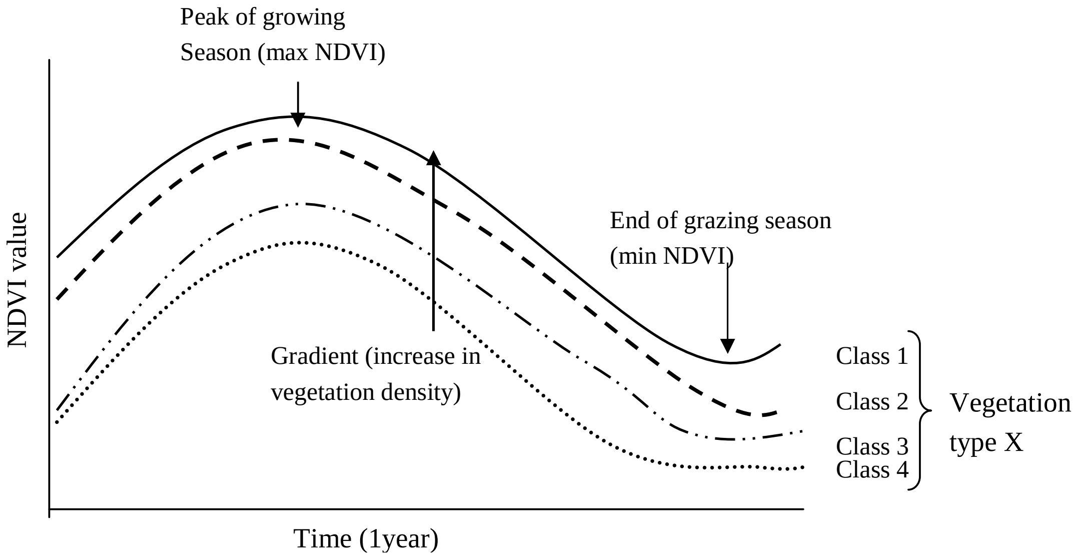


Figure 2: A Concept of the potential of NDVI data to assess grazing intensity

1.5. Research objective

To assess the possibility to use MODIS hyper-temporal NDVI images to assess vegetation conditions and estimate grazing intensity.

Definitions:

- Vegetation condition is defined as the greenness, which can be indicated by the vegetation index (NDVI) or canopy cover.
- Grazing intensity is a visual estimate of the degree of herbage removed during the Grazing Period through grazing and browsing or a representative related observation (grazing index).

1.6. Research questions

- Is MODIS NDVI able to classify grazed areas by vegetation types differently? And how do these types relate to one another?
- How does grazing intensity relate by vegetation types with NDVI data? Is NDVI data able to assess vegetation conditions?
- Can grazing intensity be estimated by vegetation type using MODIS NDVI?

1.7. Hypothesis

1.

- Ho: There is a significant negative and/or positive relation between NDVI data and grazing Index at a confidence level of 0.05-0.15.
- Ha: There is no significant negative and/or positive relation between NDVI data and grazing Index at a confidence level of 0.05-0.15.

2.

- Ho: There is a significant positive relation at 0.05 confidence level between grazing index and residual biomass (difference of NDVI between peak and end of grazing season at a pixel level).
- Ha: There is no significant positive relation at 0.05 confidence level between grazing index and residual biomass (difference of NDVI between peak and end of grazing season at a pixel level).

Figure 3 illustrates the concept mentioned in section 1.4 and 1.7. Pixels included in this figure must have comparable behaviour in time as related to vegetation type (Assumption), to make proper comparison possible. A more detailed explanation on the statistical hypothesis testing is given in the methodology chapter.

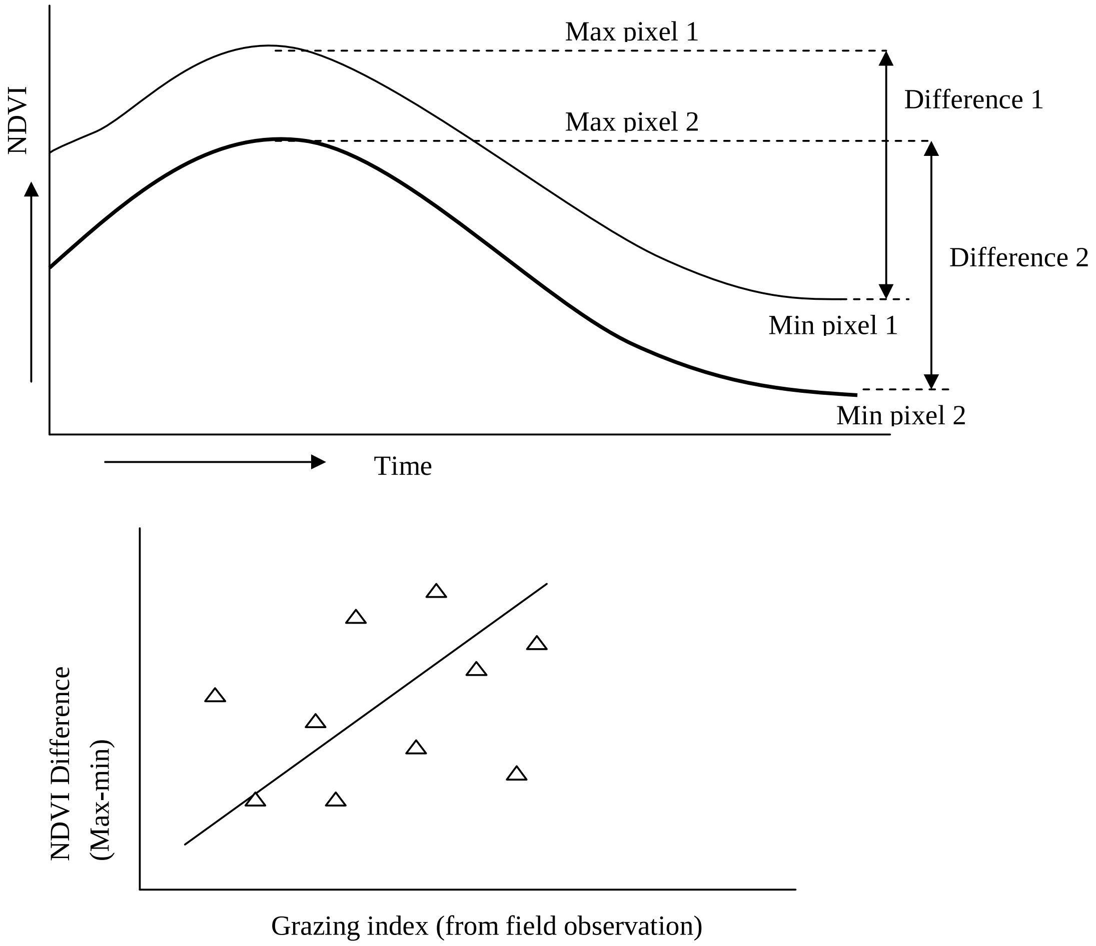


Figure 3: Conceptualization of hypothesis testing.

2. Methodology

2.1. General flow chart

Figure 4 shows the methodological flow chart, it has six parts. The detailed methodological flow chart for each part is provided in the respective sections. Generally the method follow the usual pattern in scientific work which is pre-processing of satellite images, field work, recording the field data and checking for its consistency, then follows analysis of the corrected data, including statistical tests and validation.

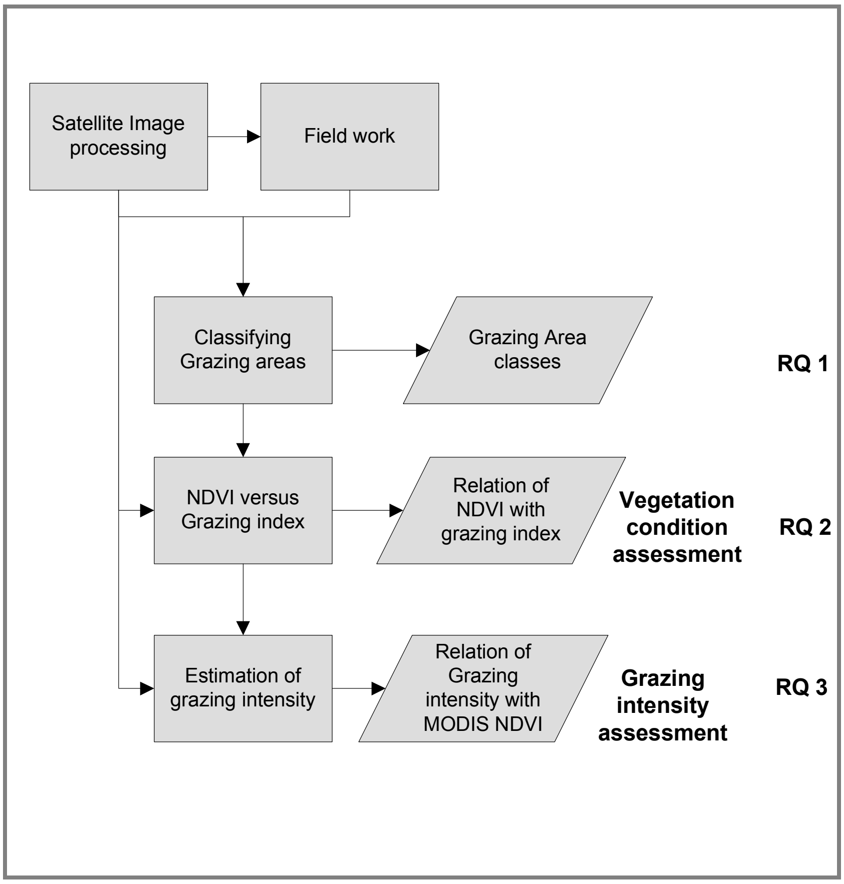


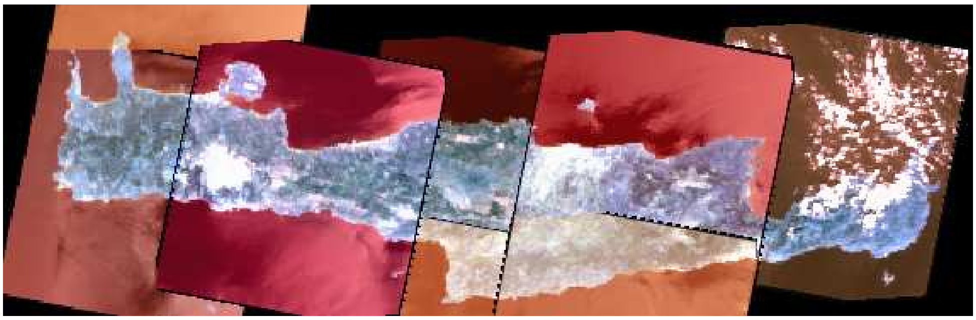
Figure 4: General Methodological Flow Chart

2.2. Satelite Imagery Description

Table 1: Data description

Type of imagery	Date	Spatial resolution	Temporal resolution
MODIS-NDVI	18th Feb. 2000-28th July 2009	250m	16days
ALOS Multi Spectral	9th July 2009,14th July 2009,26th July 2009, 9th may 2008,4th November 2008	10m	-
Aster DEM	N.A	30m	N.A

Orthorectification to correct for terrain displacement of the ALOS image was done using Aster DEM of the study area. It is based on collinearity equations, which is derived using 3D GCPs. In relatively flat areas, orthorectification is not necessary, but in mountainous areas like Crete, where a high degree of accuracy is required, orthorectification is a must (Pouncey et al., 1999). All images were projected in ERDAS to Transverse Mercator UTM Zone 35N using the WGS84 spheroid and datum. 8 different ALOS images of different parts of Crete were mosaic together as in figure 5 .The description of each image segment is also given in figure 5.



AV2_MMC_IP__ 0001266001 2009-07-14 T09:19:00.945Z scene-id AV2A18486288 0 scene-centre 35.754/23.933	AV2_MMC_IP__ 0001268001 2008-05-09 T09:12:45.625Z scene-id AV2A12199289 0 scene-centre 35.271/24.292	AV2_MMC_IP__ 0001267001 2009-07-26 T09:14:57.398Z scene-id AV2A18661289 0 scene-centre 35.266/24.860	AV2_MMC_IP__ 0001265001 2009-07-09 T09:12:42.949Z scene-id AV2A18413289 0 scene-centre 35.265/25.395	AV2_MMC_TP__ 0004651001 2008-11-04 T09:07:49.319Z scene-id AV2A14810289 0 scene-centre 35.282/25.960
AV2_MMC_IP__ 0001266002 2009-07-14 T09:19:09.160Z scene-id AV2A18486289 0 scene-centre 35.261/23.792		AV2_MMC_IP__ 0001267002 2009-07-26 T09:15:05.613Z scene-id AV2A18661290 0 scene-centre 34.772/24.720	AV2_MMC_IP__ 0001265002 2009-07-09 T09:12:51.163Z scene-id AV2A18413290 0 scene-centre 34.772/25.255	

Figure 5: ALOS Satellite imagery and its description

2.3. Satellite Image processing

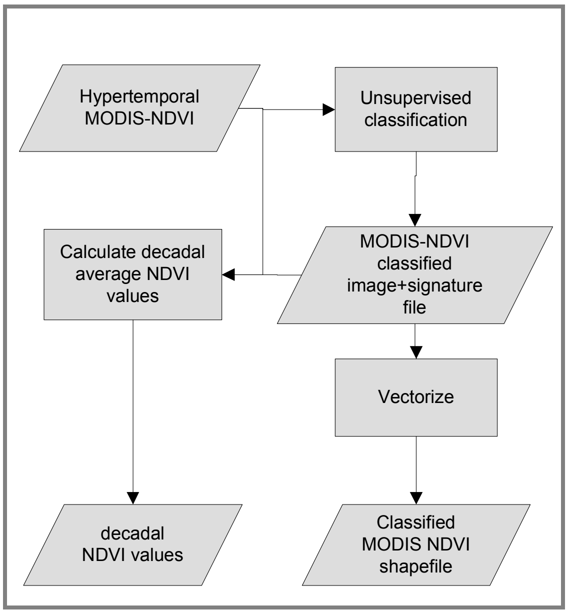


Figure 6: Satellite Image processing flow chart

2.3.1. Unsupervised classification of NDVI image

The ISODATA clustering algorithm of Erdas was used to classify the stacked MODIS images. MODIS NDVI was classified from 10 to 100 classes using 50 iteration with the convergence limit set to 1.The separability was extracted and plotted in Excel, this was done so as to determine the optimum number of classes to use(de Bie et al., 2008). 65 was selected as optimum number of classes. The number of classes is chosen where there is a peak in both the minimum and average separability profiles as shown Figure 7. The NDVI profiles of all classes were then plotted in Excel for visual inspection.

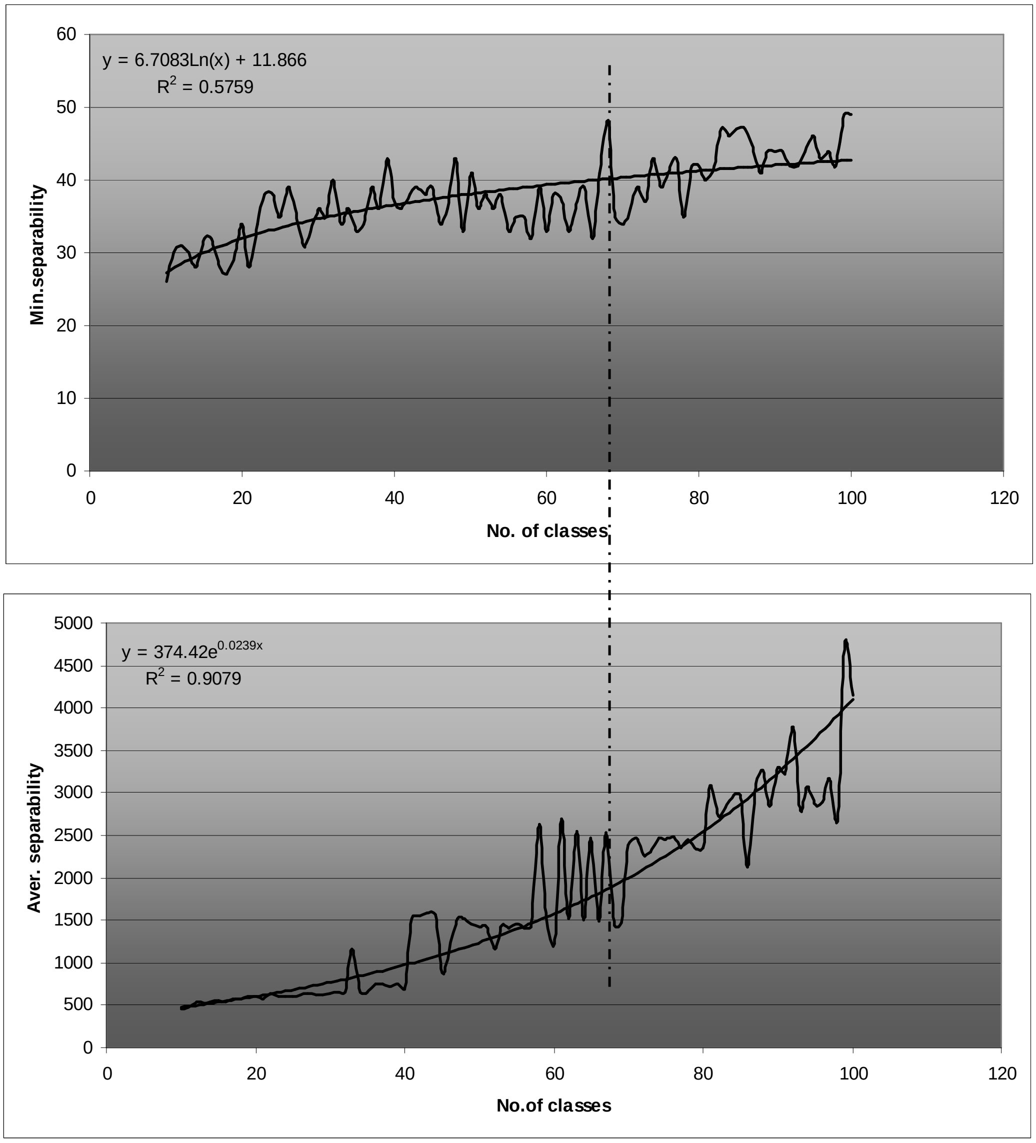


Figure 7: Minimum and Average Separability

2.3.2. Calculating decadal average NDVI using 10years data

The decadal NDVI values for all the classes were extracted from the signature file of the classified image using ERDAS software and exported to Excel. The decadal NDVI average for all the classes were calculated in Excel by averaging the values of each individual date of the year over 10 years. The result was average NDVI values for a year which were plotted in a graph.

2.4. Field work

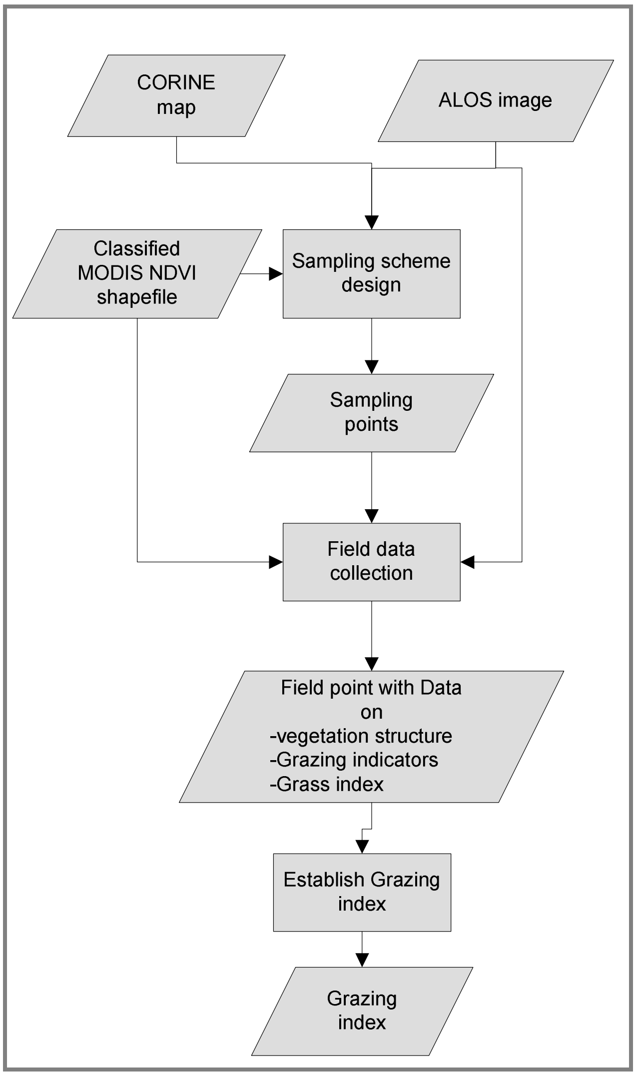


Figure 8: Field Work Flow Chart

2.4.1. Sampling scheme design

The Corine map and Classified MODIS NDVI were intersected and the result was exported as Excel file. The Corine classes were imploded into 10 leaving out the classes that were of no concern with grazing. Corine map legend was used to make new Corine classes that were simple. The Corine map legend is as shown in figure 9.Only agriculture, forest and semi-natural areas were considered in making the new classes, the artificial surfaces and water bodies were not of interest in this study. Table 2 shows the conversion of Corine classes. Not only that but also areas that were less than $9km^2$ were also eliminated.

Considering 15days of fieldwork and doing two samples in a day, we needed 28-30 sampling clusters. A sample cluster represents the areas to sample; the actual sample points are selected at the field by using the ALOS Image in order to get representative points, meaning we can have more points in one area. The scheme was made in such a way that we will have equal no of clusters for each Corine class in combination with Modis classes. 28 units of both MODIS and Corine classes combined were identified in Excel and were re-named. The map was dissolved using the new names and buffered by 50m inwards to assure the points will be inside the polygon. Two Random points were created for each unit with minimum of 1000m distance between points, thus making sampling clusters.

Corine land cover classes

1. Artificial surfaces
1.1 Urban fabric
1.1.1. Continuous urban fabric
1.1.2. Discontinuous urban fabric
1.2 Industrial, commercial and transport units
1.2.1. Industrial or commercial units
1.2.2. Road and rail networks and associated land
1.2.3. Port areas
1.2.4. Airports
1.3 Mine, dump and construction sites
1.3.1. Mineral extraction sites
1.3.2. Dump sites
1.3.3. Construction sites
1.4 Artificial, non-agricultural vegetated areas
1.4.1. Green urban areas
1.4.2. Sport and leisure facilities
2. Agricultural areas
2.1 Arable land
2.1.1. Non-irrigated arable land
2.1.2. Permanently irrigated land
2.1.3. Rice fields
2.2 Permanent crops
2.2.1. Vineyards
2.2.2. Fruit trees and berry plantations
2.2.3. Olive groves
2.3 Pastures
2.3.1. Pastures
2.4 Heterogeneous agricultural areas
2.4.1. Annual crops associated with permanent crops
2.4.2. Complex cultivation patterns
2.4.3. Land principally occupied by agriculture
2.4.4. Agro-forestry areas
3. Forests and semi-natural areas
3.1 Forests
3.1.1. Broad-leaved forest
3.1.2. Coniferous forest
3.1.3. Mixed forest
3.2 Shrub and/or herbaceous vegetation associations
3.2.1. Natural grassland
3.2.2. Moors and heathland
3.2.3. Sclerophyllous vegetation
3.2.4. Transitional woodland shrub
3.3 Open spaces with little or no vegetation
3.3.1. Beaches, dunes, and sand plains
3.3.2. Bare rock
3.3.3. Sparsely vegetated areas
3.3.4. Burnt areas
3.3.5. Glaciers and perpetual snow
4. Wetlands
4.1 Inland wetlands
4.1.1. Inland marshes
4.1.2. Peatbogs
4.2 Coastal wetlands
4.2.1. Salt marshes
4.2.2. Salines
4.2.3. Intertidal flats
5. Water bodies
5.1 Inland waters
5.1.1. Water courses
5.1.2. Water bodies
5.2 Marine waters
5.2.1. Coastal lagoons
5.2.2. Estuaries
5.2.3. Sea and ocean

Figure 9: Corine map legend

Table 2: Corine classes conversion

Corine code	**Corine Class**	**Modified Corine class**	**Sampled**
211	Non-irrigated areas	Annuals	X
212	Permanently irrigated areas		
221	Vineyards	Perennials	X
222	Fruit trees and berry plantation		
223	Olive groves	Olives	X
242	Complex cultivation patterns	Complex	X
243	Land principally occupied by agriculture		
311	Broad-leaved forest	Forest	√
312	Coniferous forest		
313	Mixed forest		
321	Natural grassland	Grass/herb	√
322	Moors and heath land	Heath	√
323	Sclerophyllous vegetation	Shrub	√
324	Transitional woodland shrub	Woodland/shrub	√
333	Sparsely vegetated areas	Sparse/bare	√

Due to the nature of the field work area being mountainous accessibility restricted the use of random sampling since it took a long time to locate the point and we needed more points. Not only that but also the areas is too fragmented. Therefore, during fieldwork the scheme was changed. The new method was to sample based on Modis classes. From the first samples the Modis classes that were already sampled were identified and eliminated in the new sampling scheme and leave only the classes that were not sampled.

2.4.2. Field data collection

The aim here was to get data on as much grazing indicators as possible to create a grazing index. The fieldwork was carried on 22ndseptember 2009 to 9thOctober 2009. In each sample point, observations were made by taking into consideration different characteristics object that can be seen around the pixel where the point is. Figure 10 shows an example of a sampling cluster. The pink star is where the cluster is, it is the random point that was created. The grids in the ALOS represent NDVI pixel, the pixel which the point is in was surveyed by first identifying different objects seen in it with the ALOS and compare it with what is seen in the field and the decision was made of where to sample so as to get all the variability seen within the pixel. The observations were made for 30x30m plots. The releveé sheet used is found in the appendix 1. Data that was collected was vegetation structure and dominant vegetation species and grazing indicators. The details on each data collected are explained in part 2.4.2.1- 2.4.2.2

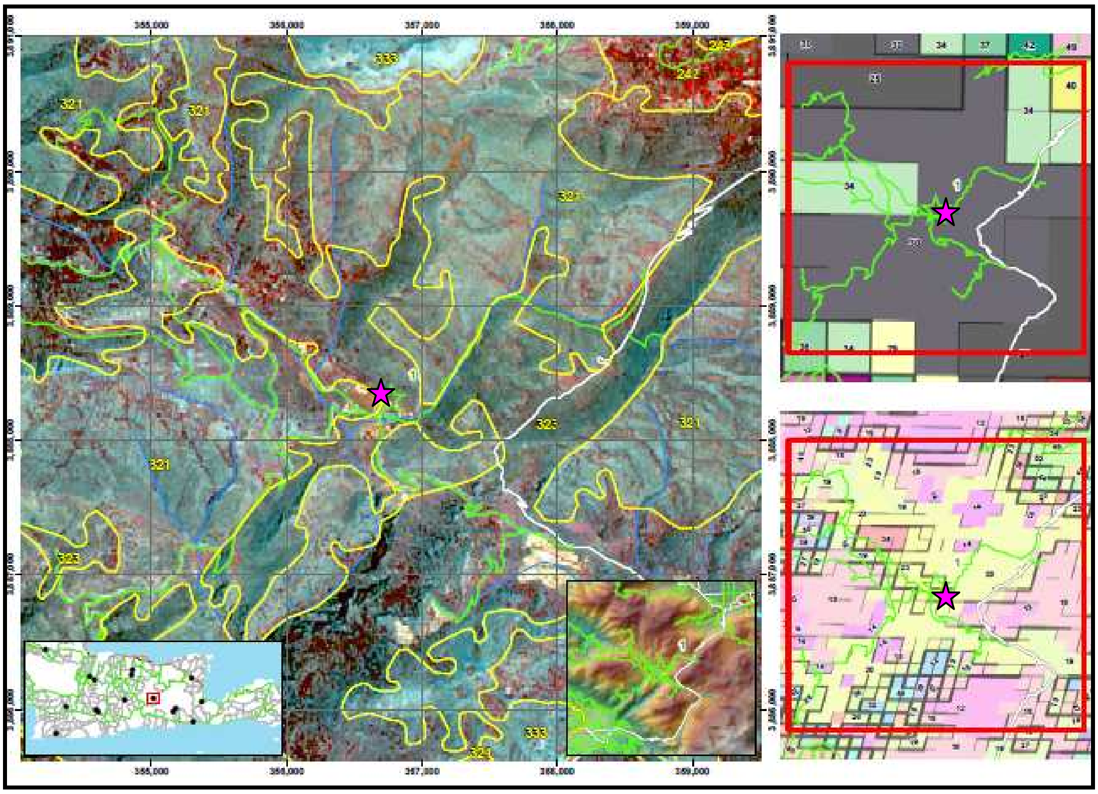


Figure 10: AlOS, SPOT and MODIS images showing the Sampling scheme

- **Vegetation structure**

The vegetation height and canopy cover were estimated visually, this was due to the nature of the area e.g. terrain and vegetation types that could not support the use of other methods like line intercept. Canopy cover was estimated by layer that means each layer was considered as the only layer present when estimating.

- **Grazing indicators**

The grazing indicators estimated were dry droppings, fresh droppings and grazing index. These indicators are a measure of the intensity of grazing.

1. Dry and fresh droppings were estimated using Braun Blanquet codes. This method is mainly used to classify plant communities or their abundance (Jones, 2007), however in this case it was used to estimate the abundance of droppings. Table 3 shows the conversion to Braun-Blanquet score and the codes as adapted from (Daniel Connolly et al., 1999).

Table 3: Braun-Blanquet score conversions (CoRIS, 2008)

Percentage	Braun –Blanquet score	code
0	0	Absent
<5%	1	Rare
5-10%	2	Occasional
10-25%	3	Frequent
25-50%	4	Common
50-90%	5	Very Common
>90%	6	Dominant

2. Grass index was estimated at a scale of 0-100%, zero means the grass has not been grazed and 100 means all the grass has been grazed. In Figure 11, the arrows show different stages of grass that has been grazed. It relates to the condition of grass present and not the amount. This means the abundance/density doesn't matter only what was originally there and has been taken off.

Figure 11: Field picture showing grazed grass

2.4.3. Establishing the Grazing Index

The grazing index was based on grass index. Grass was used because it is visible and easy to estimate compared to other species like shrubs which are very hard to tell if they have been grazed or not. Not only that but also the density of grass does not impact this index since it's the condition of the grass present that determines it. The other reason to use grass as an indicator of intensity of grazing is that we assume if the grass has been grazed, then other plants like shrubs are also grazed. Therefore, this index represents all grazable plants.

Grass index together with other indicators were tested to see which can be used, Cross tabulation and box plots was done in SPSS software. A Box plots is a type of chart that display batches of data., five values from a set of data are conventionally used; the extremes, the upper and lower hinges (quartiles), and the median (McGill et al., 1978). It is used to establish relation between two variables. Cross-tabulation is the procedure with which a Table of two (or more) categorical variables is produced, in order to compare the incidence of one characteristic against another.

Droppings are categorical so they were compared against each other using the cross tabulation and they were further compared with grass index using the box plots.

2.5. Classification of Grazed areas

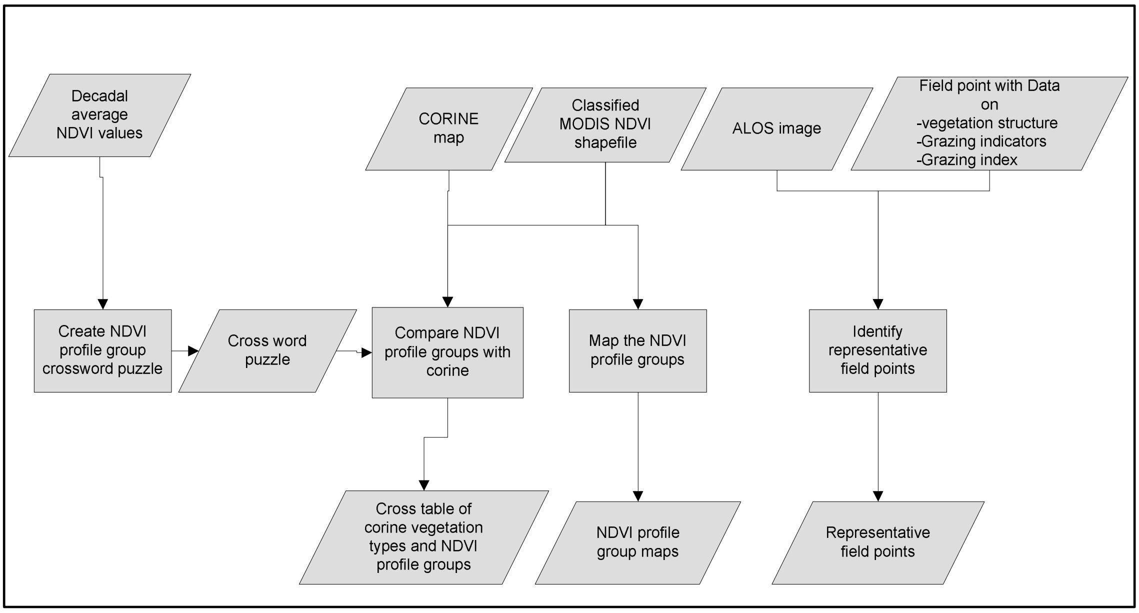


Figure 12: Flow chart for Classification of Grazed areas

2.5.1. Creating NDVI profile group cross word puzzle

From the calculated decadal averages of all the classes the profiles were plotted in excel. The classes that were not in natural areas were eliminated as pre-determined during sampling design. The profiles were grouped in such a way that they should have the same temporal behaviour as well as they should not cross each other. The grouping was also done by considering that the classes are not mutually exclusive, meaning a class can appear in more than one group. The reason behind this was to try and group profiles of the same behaviour but at the same time establish a vegetation gradient within the group.

By using the classes that appear in more than one group, the relation between these groups was established. This relation was found by creating a crossword puzzle; this puzzle was made by arranging the classes in ascending order (lower NDVI to higher NDVI) for each group and then connecting the ones having similar classes.

2.5.2. Comparing NDVI profile groups with Corine

To understand how the profile groups relate with different vegetation types, Corine map was used to identify the different vegetation types occurring in these MODIS classes. This was done by intersecting the MODIS classified vector with Corine map in ArcGIS software, the resulting data was exported to Excel and the relation was established. The field data was used to further explain land cover details by groups.

2.5.3. Mapping the NDVI profile groups

Not only the Corine and field data was used to explore the pattern in these groups but also spatial aspect of these MODIS classes were explored, each group was made into a single map given lighter colour to the lower profiles and brighter colour to the higher classes. At the end all the groups were mapped together with the same colour code to see how they are distributed spatially. This was also to explore the spatial relation between groups.

2.5.4. Identifying representative field points using ALOS

Before the field data could be used for further analysis they were checked if they are representative for the pixel. To do this ALOS image was used overlaid by MODIS classified image and the field points to be checked. If the point was on the dominant vegetation cover within the MODIS pixel then it was regarded as representative otherwise, it is taken out. The vegetation cover in this case is represented by object and colour differentiation done visually on the ALOS image. All the points that were found to be representative were used for further analysis. This process resembles the one done in the field as seen in figure 10.

2.6. Use of NDVI Data to Assess vegetation Condition

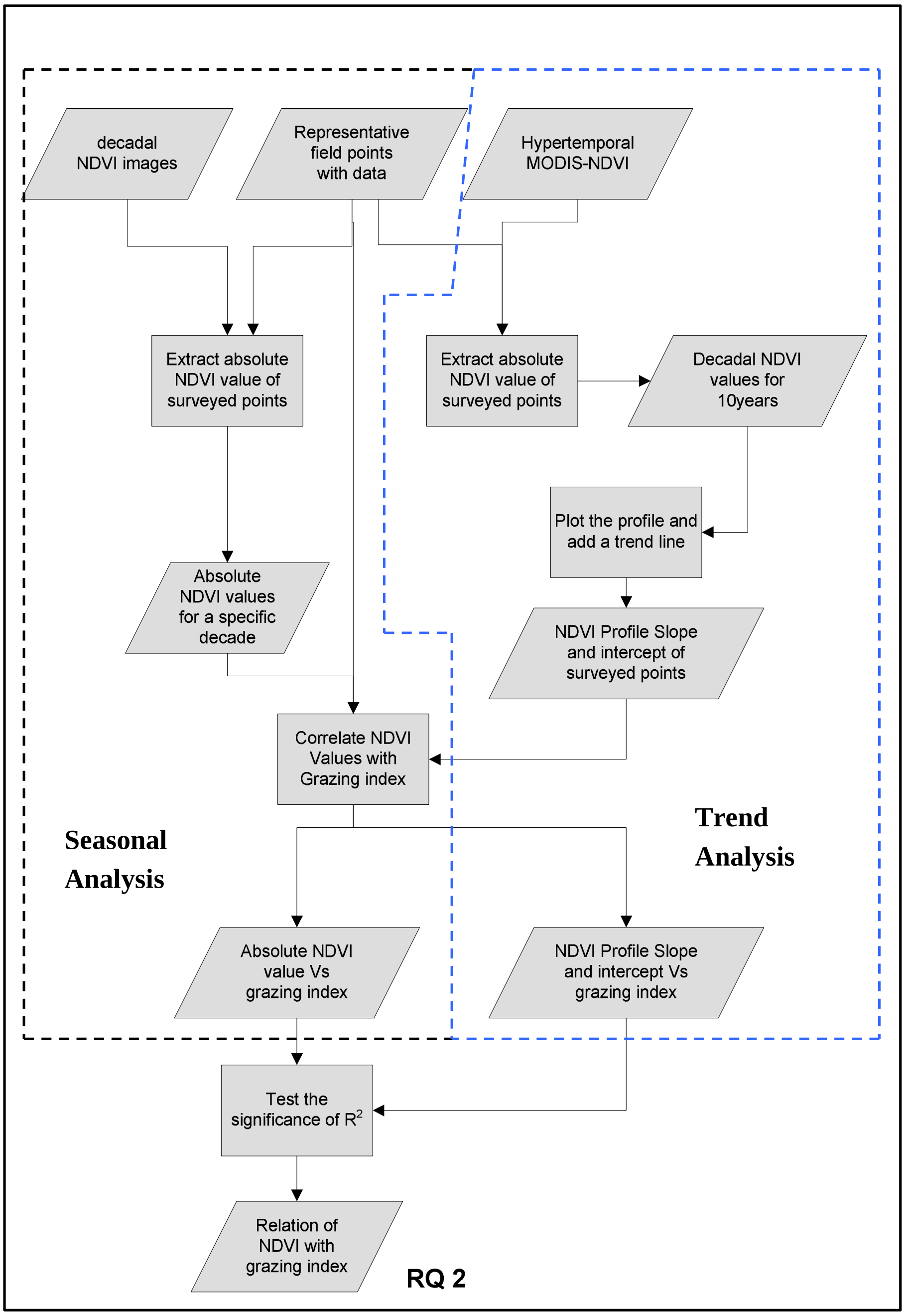


Figure 13: NDVI data Vs Field data Flow chart

2.6.1. Seasonal Analysis

Each group of NDVI profile is compared with the grazing index from the field. The gps points were used to extract absolute NDVI value of the pixel where the point is located. The value extracted was the average of the date where the NDVI peaks and the end of season. These dates are different for each group. Using cell statistics in arc GIS images of average NDVI for a specific date was obtained. The NDVI values were then extracted to points and exported to Excel where the scatter diagram was drawn for the NDVI values versus the grazing index. A scatter plot is a type of mathematical diagram using Cartesian coordinates to display values for two variables for a set of data. The data is displayed as a collection of points, each having the value of one variable determining the position on the horizontal axis and the value of the other variable determining the position on the vertical axis, a line of best fit (alternatively called 'trend line') was drawn in order to study the correlation between the variables. An equation for the correlation between the variables is determined by established best-fit procedures.

2.6.2. Trend Analysis

For every gps point the spectral signature was extracted in Erdas and exported to excel. The profile was plotted and a trend line was added with its equation that gave a slope and intercept. The slope and intercept of every point was then related to the grazing index from field using a scatter diagram and the nature of relation was established as has been explained in part 2.6.1. This was done for the different NDVI groups separately.

2.7. Use of NDVI Data to Assess Grazing intensity

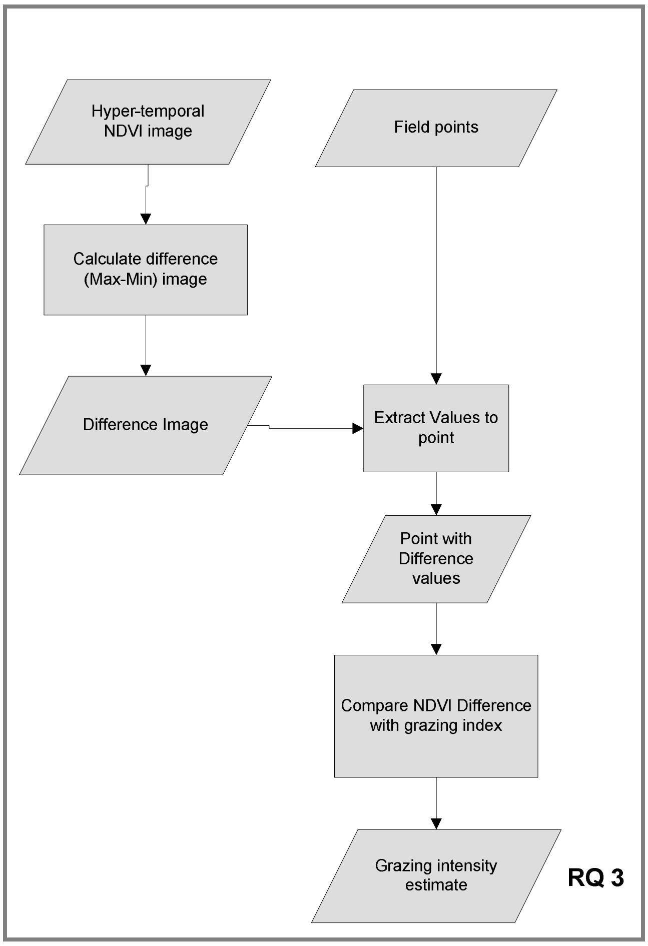


Figure 14: Flow chart for Assessment of grazing intensity

2.7.1. Calculating NDVI difference Image

To calculate the difference of annual maximum and minimum NDVI 3 models were created in Erdas. The first model was for calculating the maximum as seen in figure 15, for each year the maximum NDVI value of each pixel is extracted and saved in temporary memory. To get the Maximum NDVI image the values of the nine years was averaged. The second model is the same as the first only its calculation of minimum NDVI. Finally the difference NDVI image was made by creating a model using the two output from the first two models and finding their difference.

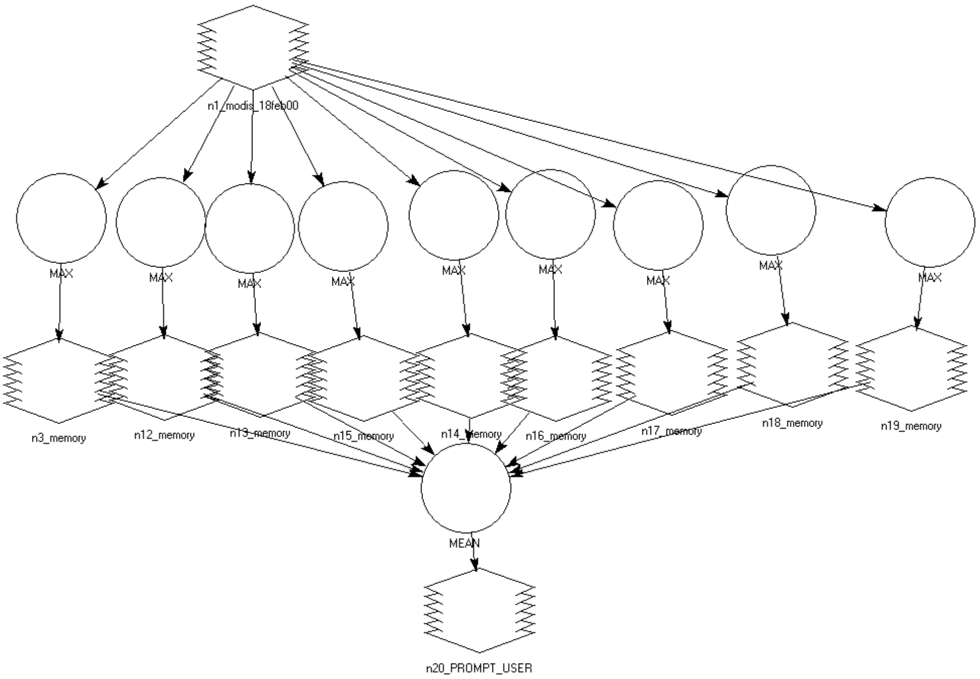


Figure 15: Erdas model for calculation of maximum NDVI image

2.7.2. Grazing intensity estimation

The estimation of grazing intensity was done by plotting the difference of maximum and minimum NDVI with the grazing index. These plots were done differently for all vegetation/profile groups. The equations obtained are the estimate of grazing intensity. The plots only give the equation but do not indicate anything about the significance of the relation; therefore using regression analysis tool the significance of relation was indicated. This was also done for part 2.6.1-2.6.2. Regression analysis works in the same way as a scatter plot explained in part 2.6.1; only in regression you can compare more than one variable and the result is more than just the equation it also shows how significant the relation is.

3. Result

3.1. Grazing index

Normally it is expected that dry and fresh droppings to have a certain trend since one depend on the other. The cross tabulation revealed that these two grazing indicators did not have any trend in occurrence hence they are not useful to use. Table 4 shows the occurrence of dry droppings against fresh droppings. When compared to grass index using box plots as seen in figure 16a and b these two indicators did not show any trend relation with grass index. It is expected that if there is more droppings there the grass index should be high but that is not the case in this result. Figure 16a shows that with the droppings being occasional the grass index goes up to 85% in the middle quartile while when it is common the grass index is up to 45%.The droppings was not used since they had no relation with grazing index and even when compared themselves, the reason to compare with grass index is that it is the direct estimate of grazing intensity while the other are indirect. Most of the time the animal eat at one place and drop their shit on the other or on roads on their way back that is why droppings could not explain sufficiently the intensity . Due to these reasons, the grass index was used directly as a grazing index.

Table 4: Fresh and Dry Droppings Cross tabulation

		DROPPINGS DRY							
		absent	rare	occasional	frequent	common	V.Common	dominant	Total
DROPPINGS FRESH	absent	24	4	4	1	5	1	0	39
	rare	0	0	1	0	3	7	1	12
	occasional	0	0	0	0	0	0	5	5
	frequent	0	0	1	0	0	3	0	4
	common	0	0	0	0	1	5	2	8
	V.Common	0	0	0	0	0	20	0	20
	dominant	0	0	0	0	1	1	1	3
	Total	24	4	6	1	10	37	9	91

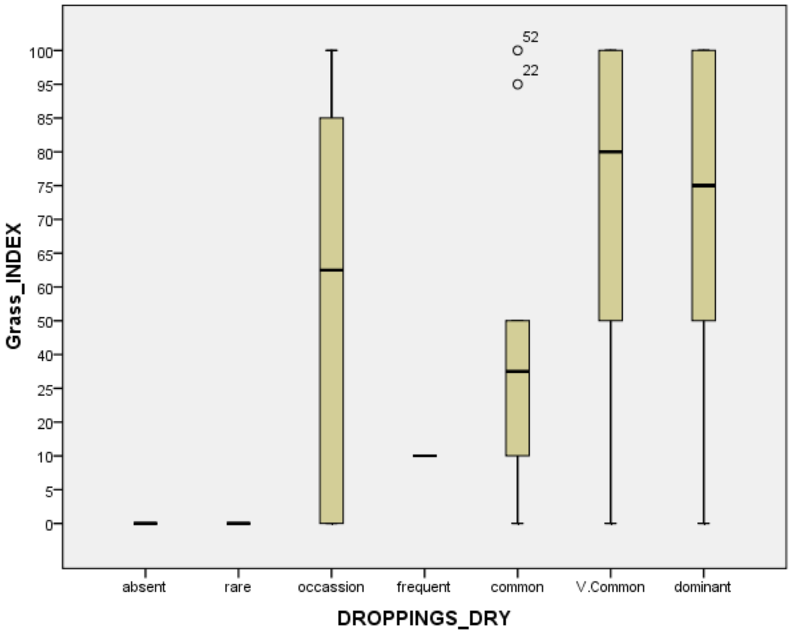


Figure 16a: Grass index Versus Dry dropping box plot

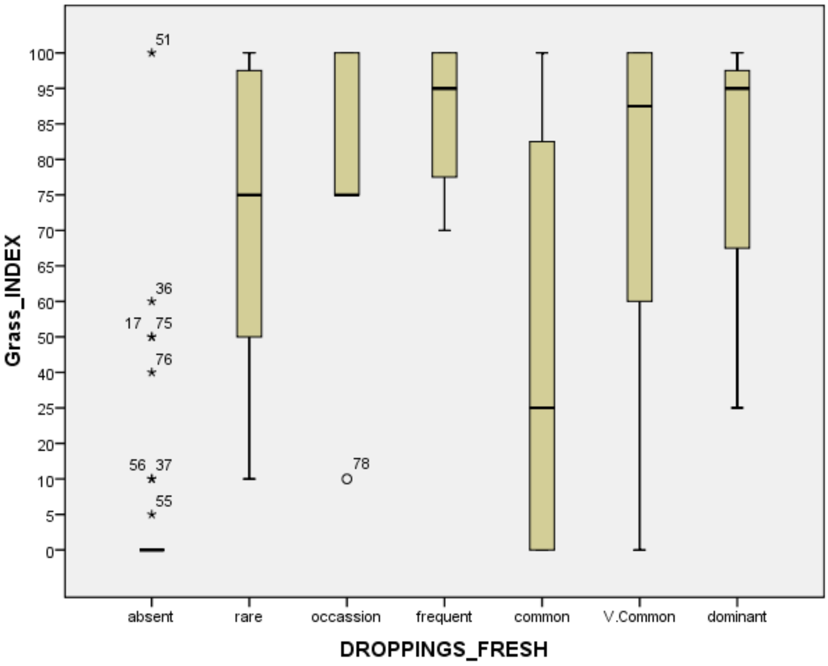


Figure 16b: Grass index Versus Fresh droppings box plot

3.2. Classification of Grazed areas

3.2.1. NDVI profiles Groups/Cross word puzzle

The classification of profile groups revealed that not only the Modis classes within the group have relations but also the groups are related to one another. 8 groups were differentiated namely A-H. The relation between the groups is as seen in figure 17.

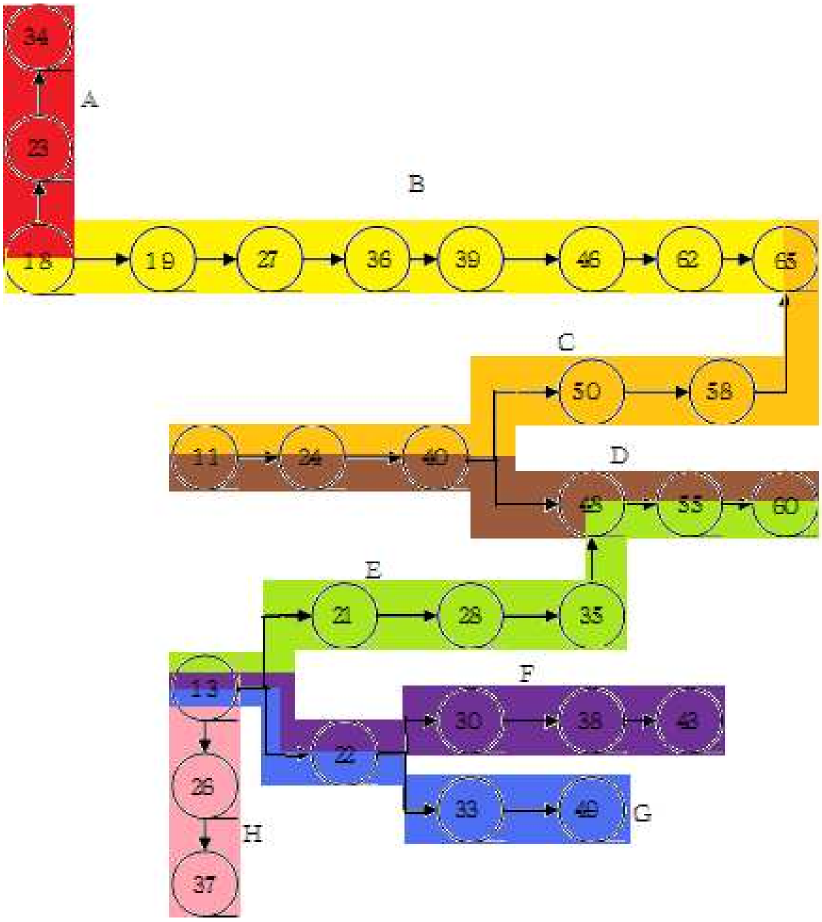


Figure 17: A crossword puzzle showing relation between profile groups

Group B and C are an example of this grouping, although they have one MODIS class in common, their group differs in terms of temporal behaviour. Figures 18a and 18c shows the temporal behaviour of these two groups, group B has profiles that are almost flat with no clear seasonality while C has a moderate dip at its minimum NDVI season.

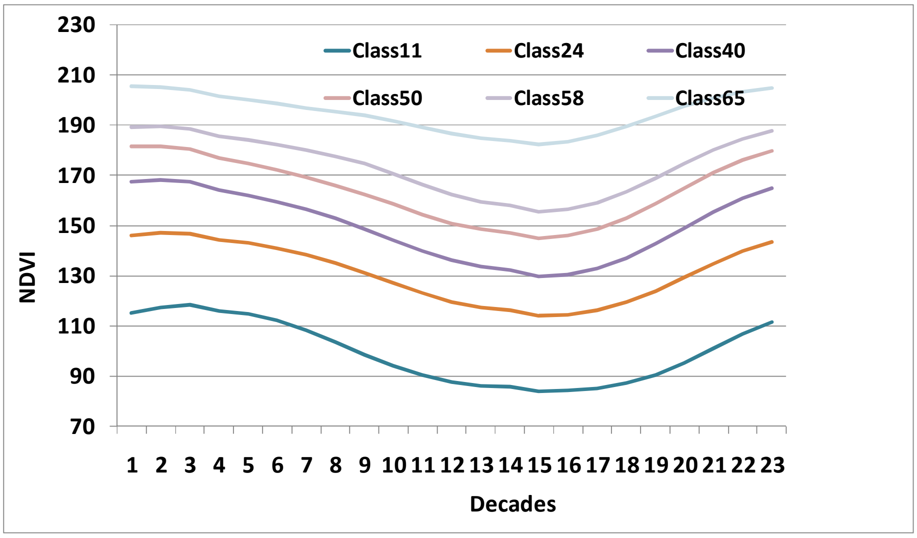


Figure 18a: Profile group C

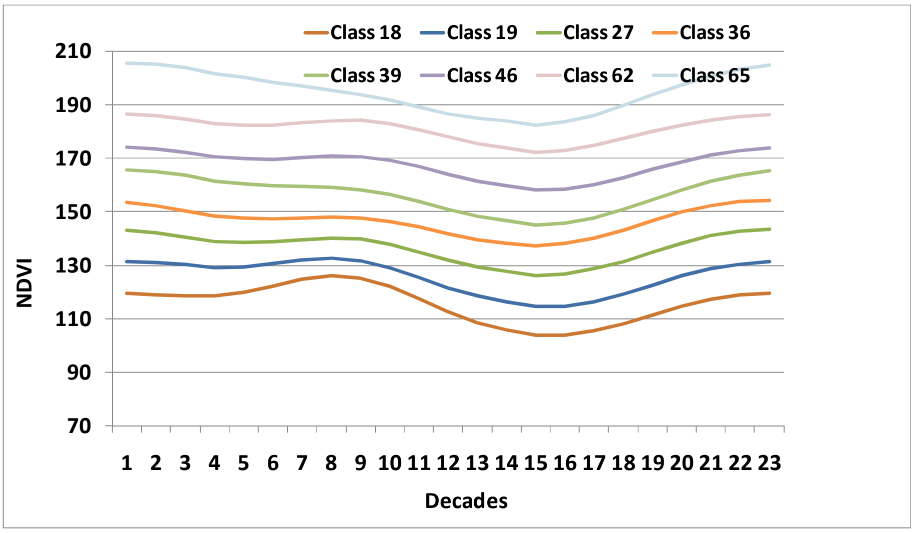


Figure 18c: Profile group B

This goes also for group C and D which have three MODIS classes in common, yet their profiles are such that C has a moderate dip and group D seems to have a more dip at its minimum NDVI season as shown in figure 18a and c. This shows that from group A-H there is a change in temporal behaviour of these groups from almost no seasonality to a clear seasonality with a smooth transition which gives the connection between groups.

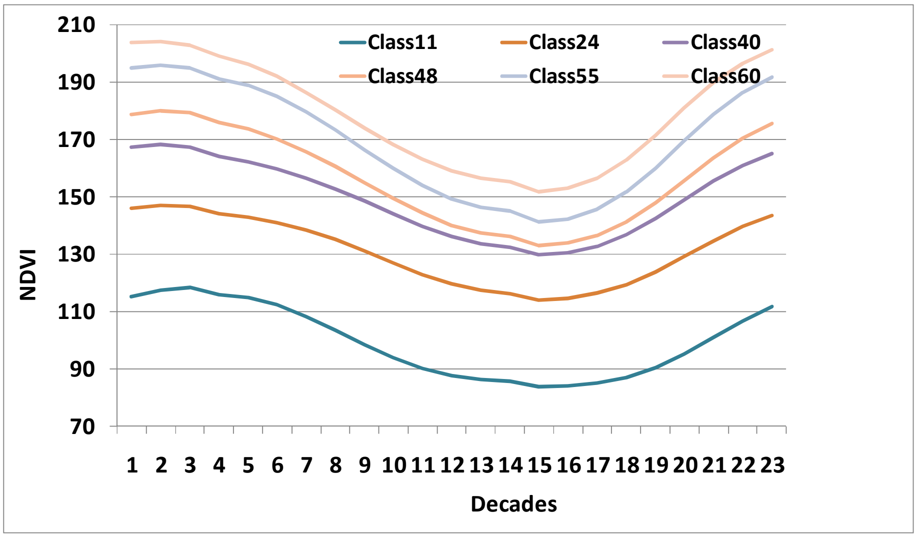


Figure 18b: Profile group D

3.2.2. Relation of NDVI profile groups and Corine vegetation types

Figure 19a-c shows an example of the result of comparison of profile groups with Corine. There seems to be an increase in Olive plantation area from the lower NDVI classes to higher, as well as a decrease in sparse/bare area. Group C and D have more shrub area in medium NDVI classes. Group B has more forest area in high NDVI classes. This analysis helped in realizing that these profiles grouping as seen in figure 19a-c were actually indicating vegetation gradients with an increase in vegetation density from the lower profiles to higher ones.

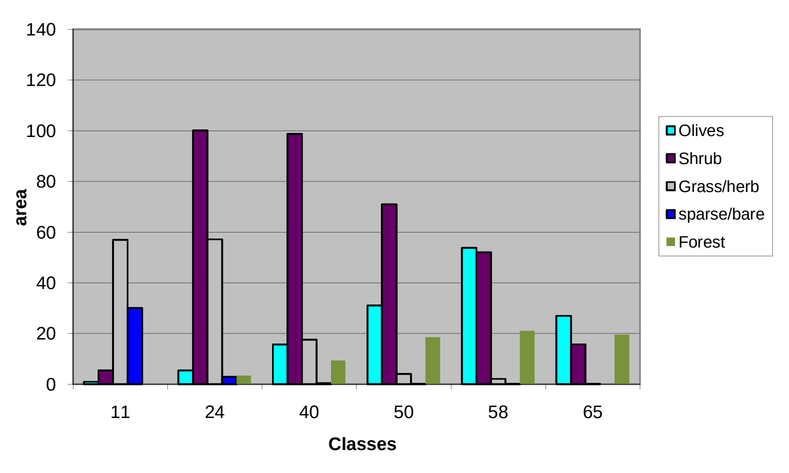


Figure 19a: Vegetation type distribution per MODIS class for group C

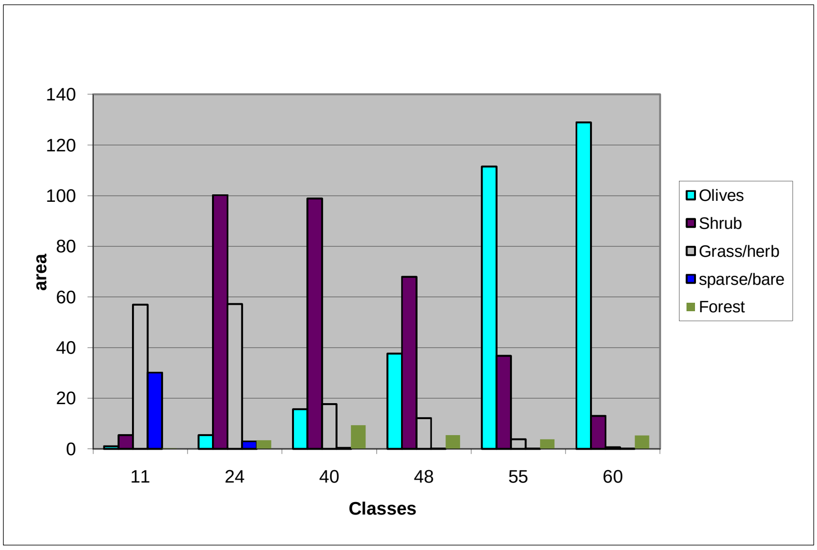


Figure 19b: Vegetation type distribution per MODIS class for group D

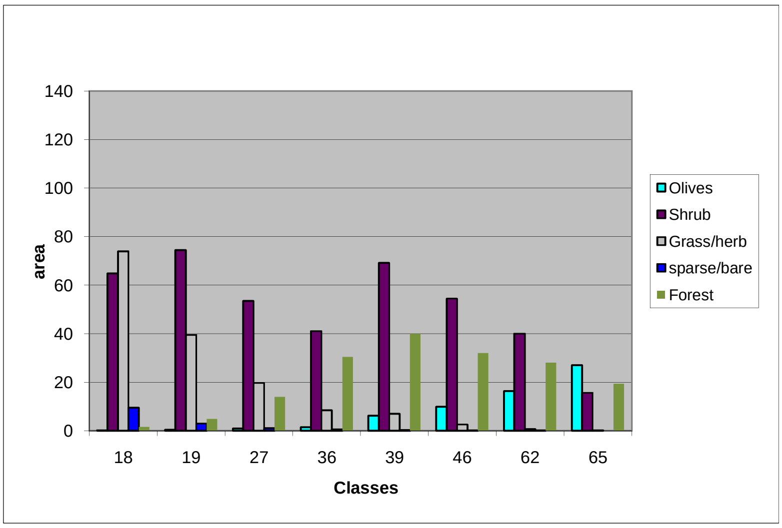


Figure 19c: Vegetation type distribution per MODIS class for group B

3.2.3. NDVI profile groups Maps

Visualization of the group in form of maps revealed that the classes with lower NDVI in most of the groups are mainly in the coastal areas as seen in figure 20a and 20b. Not only that but also they are found in mountainous areas as can be seen in figure 20c and 20d. The classes with higher NDVI are situated in medium altitude. Mountainous areas and the coastal areas are used for grazing and the medium heights are used for agriculture. The maps also revealed that the yellow areas as seen in maps are the most fragmented areas.

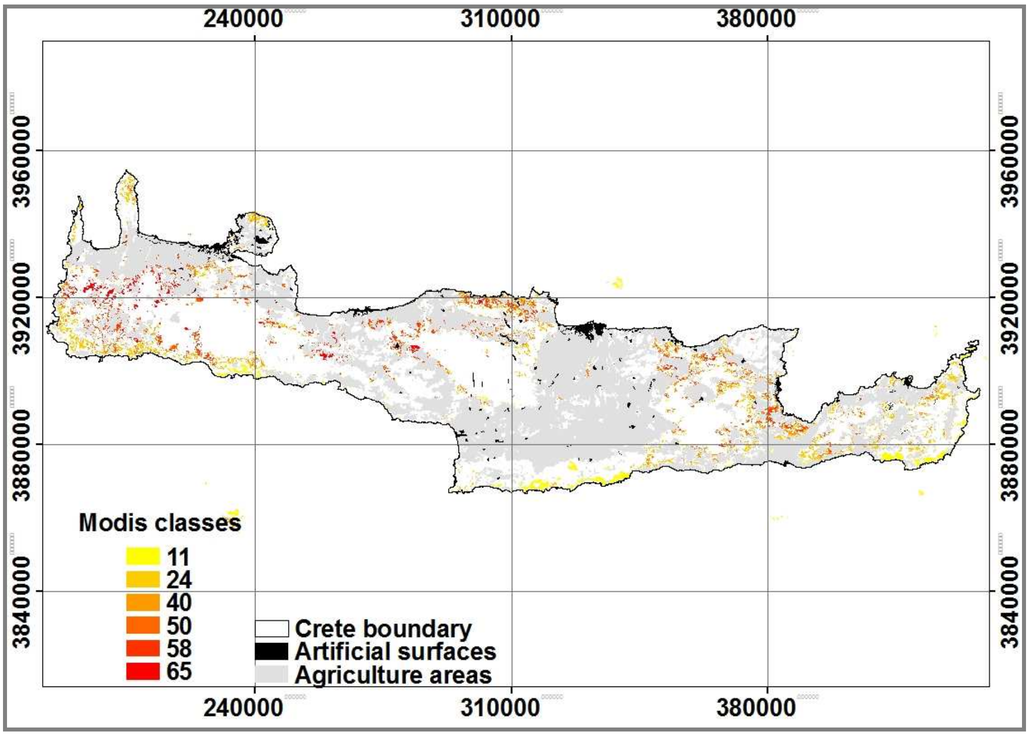


Figure 20a: NDVI map for group C

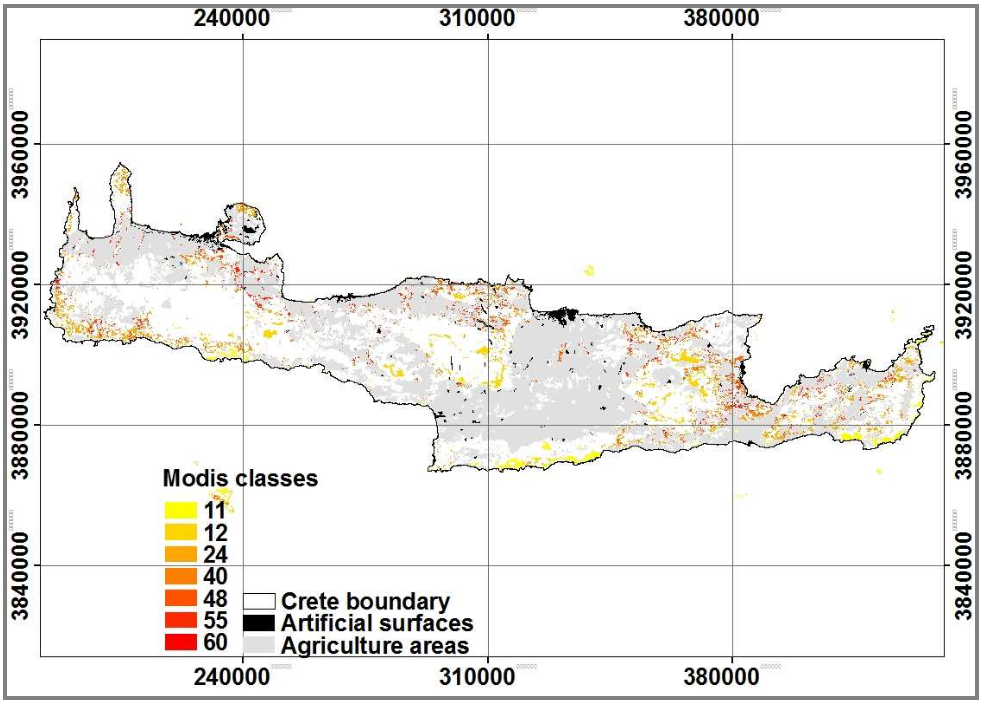


Figure 20b: NDVI map for group D

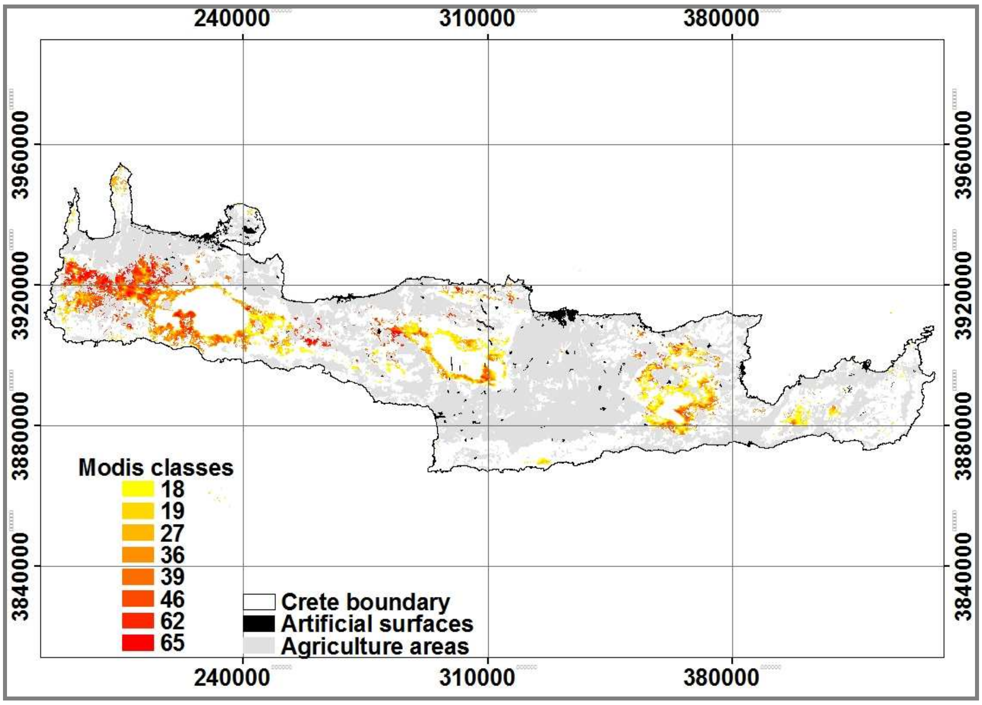


Figure 20c: NDVI map for group B

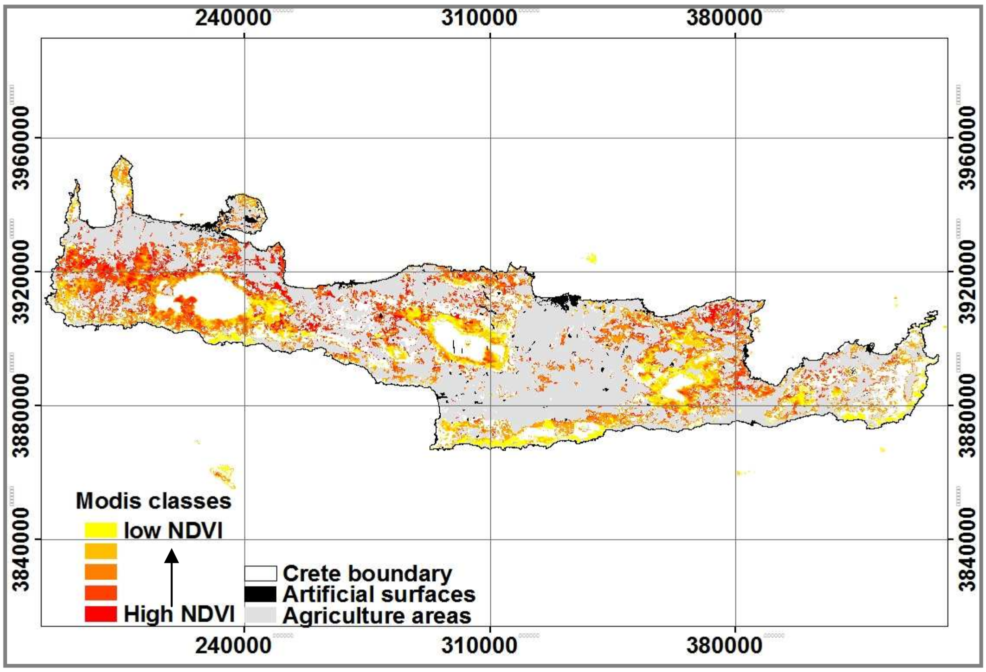


Figure 20d: Map showing the areas of the NDVI groups A-H

3.3. Use of NDVI Data to Assess Vegetation Condition

3.3.1. Seasonal Analysis

The results given in table 5 shows that NDVI values decreases with an increase in grazing index. This means that the higher the intensity of grazing the lower the NDVI which implies lower vegetation condition. Only group A show a different behaviour, which appears to be the same for both peak of growing season and end of grazing season. Group A has a positive relation between NDVI and grazing intensity that means with high intensity the NDVI is high. This type of vegetation shows that even with high grazing the condition of vegetation is good. The significance of the relation is more during the peak of growing season compared to the end of grazing season, the same goes for R^2. The R^2 ranged from 18%-91% for peak of growing season and 11%-98% for end of grazing season. The relations that were significant at a significant level of 0.05 are the ones in grey shade in table 5.

Table 5: Relation between pixel specific NDVI value(y) and the grazing index(x) for both peak and end of grazing season

Peak of growing season				**30th September(field date)**			
Group	**R^2**	**P-value (slope)**	**Relation**	**R^2**	**P-value (slope)**	**Relation**	**No. samples**
A	0.91	8.E-04	y = 0.45x + 127	0.56	0.05	y = 0.23x + 109	9
B	0.18	0.03	y = -0.24x + 173	0.11	0.1	y = -0.18x + 160	28
C	0.67	4.E-03	y = -0.66x + 193	0.64	6.E-03	y = -0.70x + 167	10
D	0.7	0.02	y = -0.70 x + 199	0.56	0.08	y = -0.57x + 158	11
E	0.33	0.05	y = -0.19x + 181	0.47	0.01	y = -0.39x + 141	12
F	0.5	0.01	y = -0.27x + 188	0.75	5.E-04	y = -0.26x + 119	11
G	0.31	0.09	y = -0.24x + 186	0.44	0.04	y = -0.30x + 127	10
H	0.46	0.14	y = -0.27x + 173	0.98	2.E-04	y = -0.25x + 116	6

3.3.2. Trend Analysis

The slope of the profile shows how the vegetation condition changes over time. If the slope is positive it means the vegetation condition has been getting better over the years if not then the condition has been deteriorating over the years. Figure 21 shows the trend of NDVI over 10 years for two different pixels in group A with their slopes. Different NDVI profile groups shows different slope behaviour when compared to grazing index. Table 6 shows these different relations between slope and grazing index for all profile groups that had significant relationship at p=15%. Group A showed a negative relation, which shows that with high grazing the slope is lower indication vegetation condition deteriorate over the years, group C shows the opposite behaviour of A. The slopes of the relationships were small which indicate there is almost no change in vegetation condition over the past 9 years. The R^2 ranges from 0%-35%, which also indicates that this analysis explained only a small amount of variability.

Table 6: Relation between Slope(y) of 9years NDVI values and grazing index(x)

	Slope			
Group	**R^2**	**Relation**	**P-value(slope)**	**No. samples**
A	0.32	y = -0.0003x + 0.05	0.11	9
C	0.35	y = 0.0002x + 0.01	0.07	10

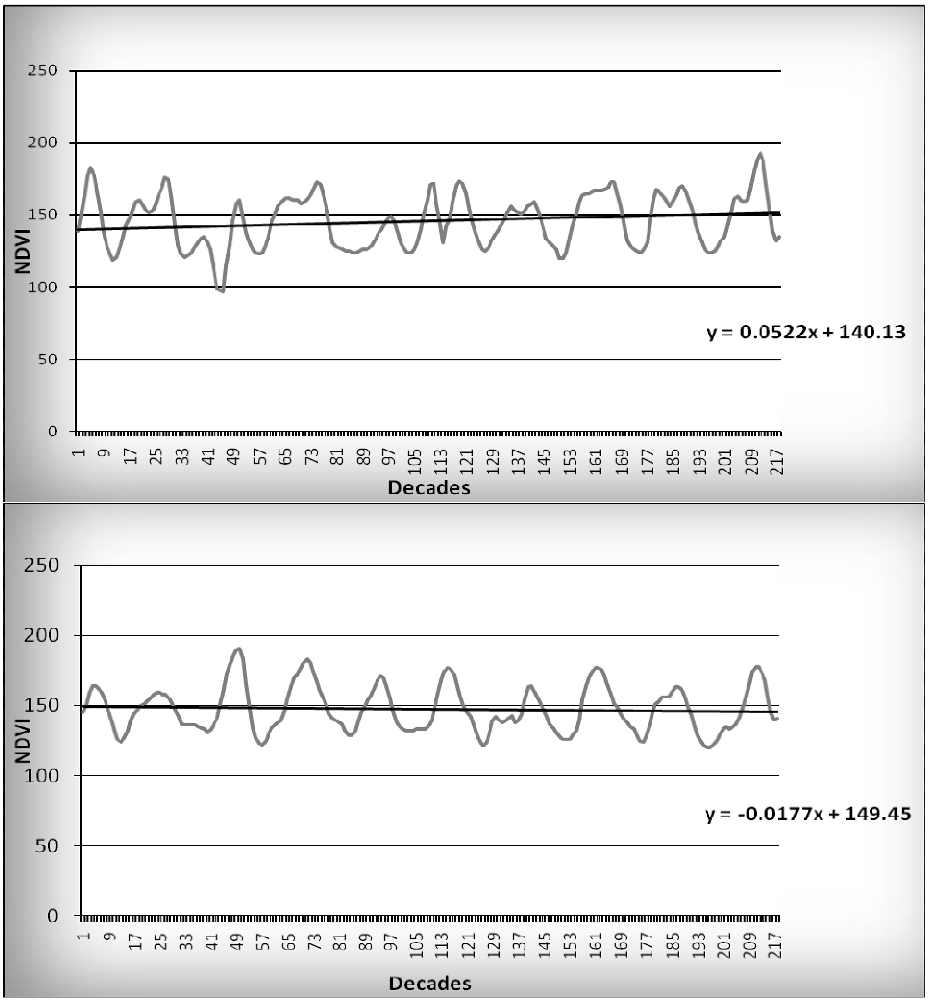


Figure 21: Trend of 10 years NDVI values for pixels in Group A

3.4. Use of NDVI Data to Assess Grazing intensity

3.4.1. NDVI difference image

According to the hypothesis The NDVI difference will be used as an estimate of the intensity of grazing. It was expected that the higher difference associates with high intensity of grazing. Figure 22 shows the NDVI difference image, this image indicates that the highest difference is associated with agriculture areas when compared with Corine land cover that was generalized to only agriculture and natural areas as shown in figure 22b. This also shows the potential of NDVI to estimate grazing intensity because the agriculture areas are expected to have higher differences due to harvesting, this means that even the intensity of grazed areas can be differentiated.

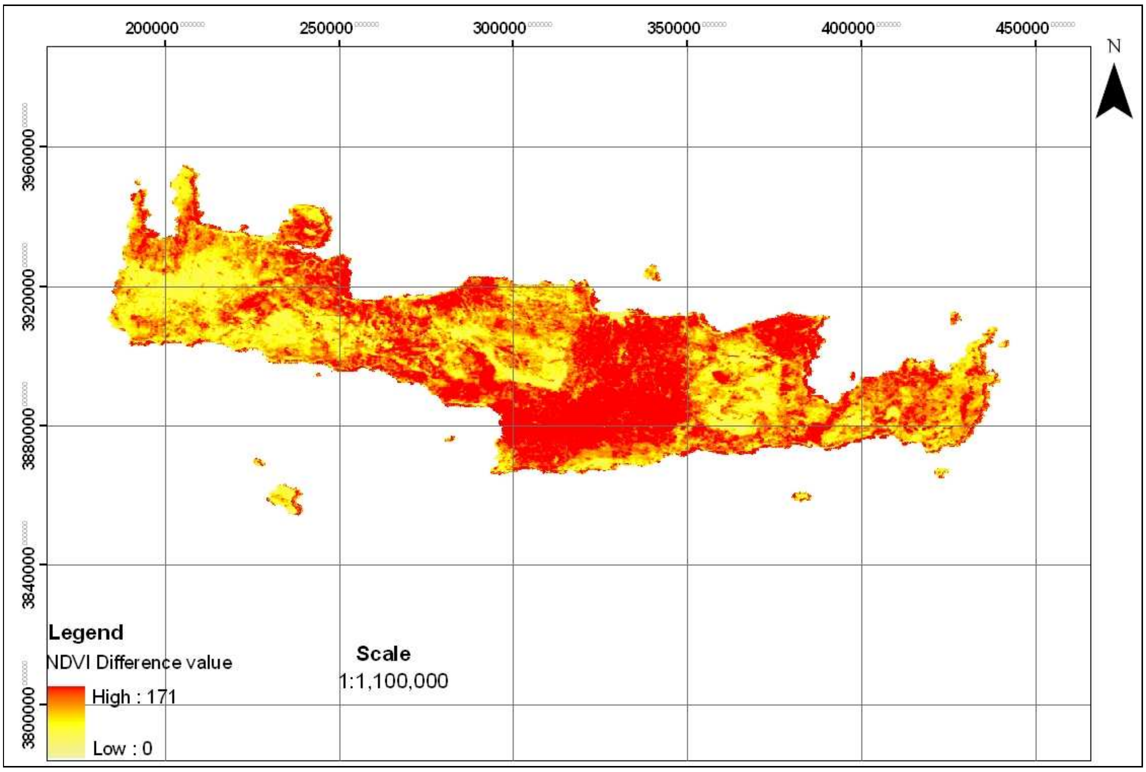


Figure 22a: The NDVI difference map

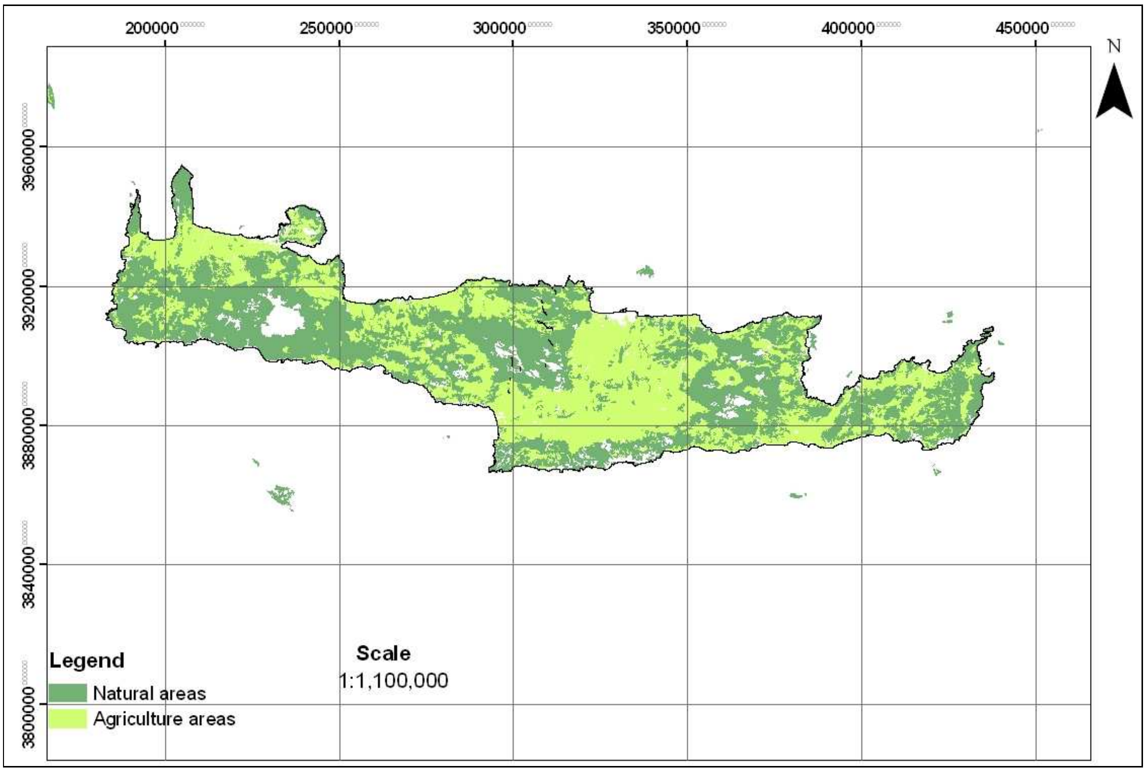


Figure 22b: Map showing Agriculture and Natural areas from Corine

3.4.2. Grazing intensity estimate

Results shows that there is a positive relation between the difference of max and min NDVI at pixel level and the grazing index. The meaning of this positive relation is that higher NDVI differences indicate higher grazing intensity, which is what was hypothesised before and illustrated in figure 3. Only four groups had a significant relation at 0.05 significant levels after statistical test and they are indicated in table 7. The R^2 ranges from 3%-87% with only one group having R^2 above 50%. Figure 23 shows an example of these relations graphically.

Table 7: Relation between difference of max and min NDVI(y) with Grazing Index(x)

Group	R^2	**P-value(slope)**	**Relation**	**No. samples**
A	0.87	0.00	y = 0.29x + 25	9
B	0.25	0.00	y = 0.07x + 25	28
C	0.39	0.05	y = 0.15x + 33	10
E	0.42	0.01	y = 0.13x + 55	12

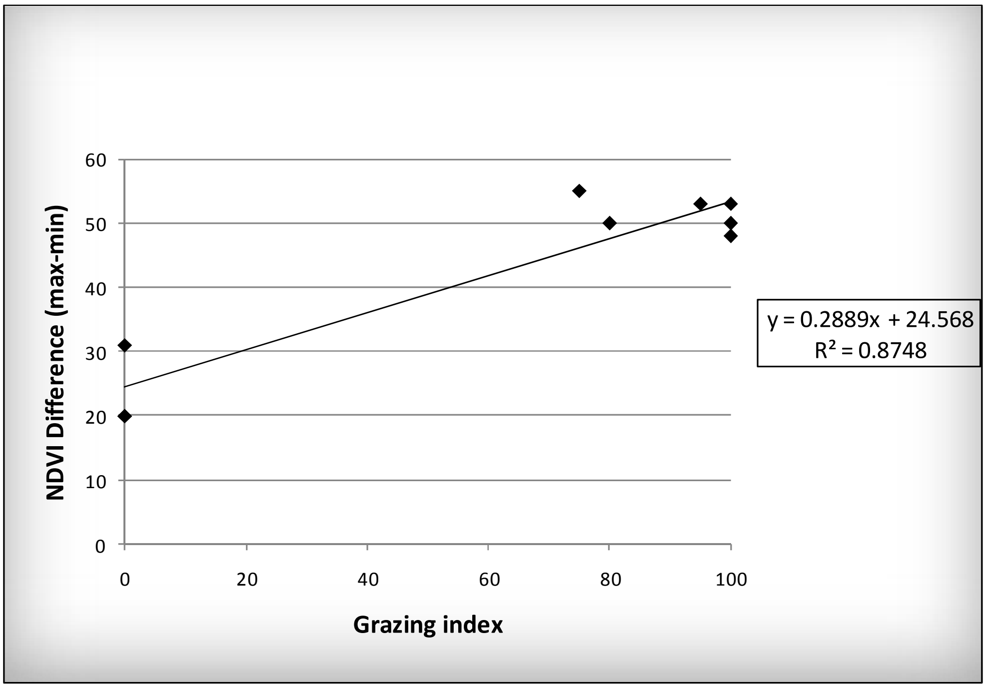


Figure 23: NDVI Difference versus Grazing Index for group A

4. Discussion

In a study done in Greece it was found that, overgrazed sites had significantly lower plant cover (by 20 percent) than the protected ones in all the three years that were analysed regardless of the vegetation type. Indeed, woody phryganic species tend to increase under heavy grazing due to the reduction of competition exerted by the palatable to animal's herbaceous species (Arianoutsou-Faraggitaki, 1985; Koutsidou et al., 1998; Papanastasis et al., 1992). This increase of woody cover counteracted the decrease of herbaceous cover thus mitigating the impact of overgrazing on total plant cover, which does not significantly reduce (Papanastasis et al., 2003). This was also found in this study by using the trend analysis where there was no significant change in vegetation greenness (NDVI) in all eight vegetation types, this can be explained by the fact that the phryganic species which dominates can withstand grazing pressure and are not preferred by the animals.

Vegetation indices tend to have positive relationships with pasture measurements. In general, the correlations are highest for water content indices and lowest for biomass indices. NDVI, which rely on the spectral contrast between red and near‐infrared bands, is sensitive to leaf‐chlorophyll content and LAI in vegetation, Low correlation coefficients between field measurements of grass biophysical properties and chlorophyll based indices can be accounted for by the fact that pastures under dry conditions and intense grazing have small amounts of green leaves, and non-photosynthetic materials such as stems and dry leaves dominate pasture biomass.(Numata et al., 2007)

This research not only shows the potential of NDVI to classify grazed areas but also in assessing the vegetation condition as well as grazing intensity. By using the concept of vegetation gradient, it was possible to classify the grazed areas based on vegetation types into eight groups which are interconnected in one way or the other. These groups vary in their temporal behaviour as well as spatial; however, the variation is not discrete but continuous changing from one group to the other.

By using the seasonal and trend analysis the vegetation condition was assessed where by almost all groups showed a positive relation between NDVI and grazing index. The fact that the trend analysis found significant relation at lower confidence level between the slope of 9 years NDVI and grazing index indicates that there is little change in vegetation condition over the 9 years. Literature has been reporting the changes due to grazing in Crete especially in 80's and 90's however from this analysis it looks like degradation has been constant for the past 10years.

Due to environmental degradation that has been going on for years, the natural feed is no longer enough to feed the animals and so the shepherds feed their animals with commercial food, and this is also supported by the EU subsidies. This makes the estimation of grazing intensity difficult but not impossible.

5. Conclusion and recommendation

5.1. Conclusion

By using MODIS NDVI, the grazed areas were able to be classified into 8 groups which represented different vegetation types. These groups share some common characteristics but also differ in a way. Corine map was used to compare these groups, it was found out that within the group there is a vegetation gradient, from low vegetation density to higher, and between groups there is seasonality change from group with almost no seasonality to the ones with a clear seasonality.

To assess vegetation condition NDVI data was compared to grazing index using two approaches, the seasonal analysis and trend analysis. The seasonal analysis compared pixel NDVI value at the peak of growing season with grazing index and the result showed that there is a negative relation between the NDVI and grazing index meaning high grazing index results into low biomass. This was however not true for one group that had a positive relation indicating high grazing is associated with high biomass. At 0.05 confidence limit, only five vegetation groups showed a significant relation. With the trend analysis, the slope of 9 years NDVI was compared to grazing index and statistical analysis shows that at 0.15 confidence limit there was significant relation for two vegetation groups A and C.

It was hypothesised in the beginning of this research that the high NDVI difference between peak and end of grazing season indicates high grazing. After the analysis that was proven right for 4 vegetation types that were found to have a significantly positive relation at 0.05 confidence limit. The R^2 for these groups ranged from 25%-87% which also indicates that the relationship could explain sufficient variability.

Limitations

From the fieldwork, it was found that the study area was highly fragmented such that even with MODIS resolution there is still variability at pixel level. All the plant species are found everywhere except for few such that was not easy to use them to explain the vegetation groups made from NDVI profiles. The shrub species in Crete do not favour the use of instrument that measure LAI or such parameters and also the measurements of biomass that could have improved the analysis.

6. Recommendation

Since this study has shown the potential of hyper-temporal NDVI to assess vegetation condition and grazing intensity more effort should be done to improve this method in order to have more accurate estimates. Knowing the condition of vegetation in areas like Crete effort should be to find an improved way to estimate grazing in field as well as finding a way to include the brown biomass when using satellite images since it will be valuable in differentiating vegetation conditions caused by grazing or seasonality.

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Appendix 1: Land cover and Grazing Relevé sheet

Cluster no.: ……………… Date: …………………
Name of observer (s): ………………………………………………….

A.

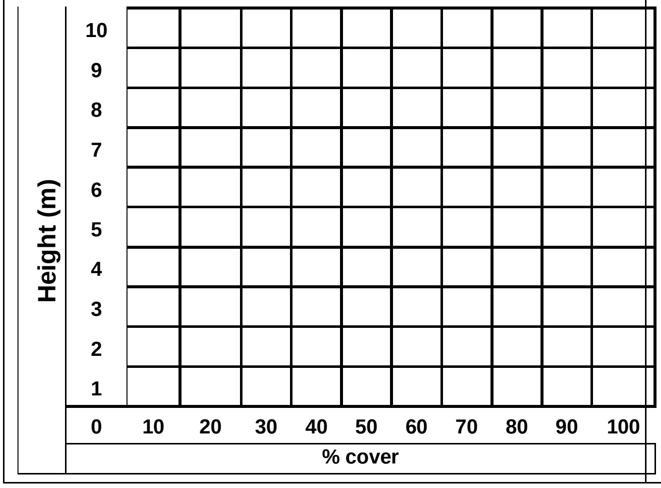
Day/Sample No.: ……………	**Sample size:**
X-Coordinates:	**Corine classes:**
Y-Coordinates:	**MODIS classes:**

B.

Ground cover:	**%**		
Stones			
Litter			
Basal cover			
Bare soil			
Water			
Total	**100%**		
Roughness ***	**S**	**M**	**R**
Infiltration rate			
Soil colour			
Texture			

Erosion features of bare soil	**BB scale***	**%**
Pre-rills**		
Rills**		
Sheet wash**		

C.

Vegetation structure (drawing)	**Vegetation composition vertical**
	

D.

Properties vegetation layer	**1**	**2**	**3**	**4**	**5**
Dominant spp.					
% cover					
Biomass density*					
Photo nos.:					

F.

Grazing indicators:

Droppings: **Fresh ……………………..**
Dry……………………….

Animal tracks: **………………………...**

Grass index: **………………………...**

Appendix 2: Field data sheet

DAY_SAMPLE	X_COORD	Y_COORD	CORINE_CLASS	MODIS_CLASS	DROPPINGS_FRESH	DROPPINGS_DRY	G_INDEX
D13/S3	366765	3876373	243	48	absent	absent	0
D13/S5	366833	3876380	243	48	absent	absent	0
D14/S2	356892	3879250	321	12	rare	V.Common	100
D14/S3	351081	3879480	321	26	Absent	Absent	0
D14/S3	351097	3879590	321	26	absent	occassion	0
D14/S1	361673	3881417	324	27	Occassion	dominant	100
D14/S1	362911	3881540	321	10	V.Common	V.Common	100
D13/S2	329601	3886820	242	33	V.Common	V.Common	100
D13/S3	328740	3886920	223	43	V.Common	V.Common	50
D13/S2	328830	3886970	223	43	absent	absent	0
D16/S1	365213	3894829	321	23	Occassion	dominant	75
D16/S1	365396	3894880	321	23	V.Common	V.Common	100
D16/S2	361155	3894933	212	44	Occassion	dominant	75
D16/S2	365504	3895190	321	23	V.Common	V.Common	100
D15/S5	366757	3897161	324	39	rare	V.Common	60
D15/S4	366595	3897303	243	39	V.Common	V.Common	100
D15/S6	366765	3897327	243	39	absent	common	50
D11/S1	264417	3898360	321	30	common	V.Common	70
D11/S1	264792	3898428	321	30	Rare	occassion	70
D10/S9	251103	3898639	323	21	Occassion	dominant	100
D10/S6	241068	3898880	321	11	rare	V.Common	100
D10/S7	241137	3899043	321	11	Rare	Common	95
D11/S2	263855	3899478	333	14	frequent	occassion	85
D13/S1	340504	3899570	243	38	absent	absent	0
D13/S1	340411	3899833	321	38	absent	absent	0
D10_S5	241868	3901835	324	40	V.common	V.common	100

D10/S5	241516	3901843	323	40	frequent	V.Common	70
D10/S6	241498	3901887	323	32	rare	dominant	95
D11/S3	252629	3903596	323	19	V.Common	V.Common	100
D11/S3	252491	3903600	323	19	dominant	dominant	100
D11/S4	252307	3903830	321	27	frequent	V.Common	100
D11/S4	252113	3903990	321	27	V.Common	V.Common	0
D15/S2	359407	3905230	323	35	V.Common	V.Common	20
D15/S2	359343	3905322	242	35	rare	V.Common	25
D14/S5	351176	3906660	243	24	absent	absent	0
D14/S6	351154	3906960	243	24	absent	V.Common	60
D14/S4	351044	3907174	323	28	Absent	frequent	10
D14/S5	351114	3907231	323	28	absent	occassion	0
D15/S3	380122	3907680	321	33	V.Common	V.Common	100
D15/S1	355432	3907966	324	36	absent	absent	0
D15/S1	355399	3908090	142	16	absent	absent	0
D15/S4	379842	3908235	323	33	absent	absent	0
D12/S5	341180	3909310	121	22	absent	rare	0
D12/S4	341090	3909480	321	13	absent	rare	0
D10_S4	244713	3909547	324	19	Common	V.common	10
D12/S4	341140	3909864	242	21	absent	absent	0
D10_S3	244938	3909867	321	18	Absent	Rare	0
D10/S3	245064	3909898	321	18	absent	absent	0
D10/S4	245082	3909934	321	18	Absent	Absent	0
D12/S3	339200	3910490	321	22	rare	common	50
D12/S3	339303	3910510	321	22	absent	occassion	100
D12/S1	338023	3910963	321	22	common	common	100
D12/S1	338140	3911010	321	13	V.Common	V.Common	100
D12/S2	337983	3911052	321	13	frequent	V.Common	100
D8/S4	191757	3911070	243	37	absent	common	5
D8/S3	191622	3911130	243	37	absent	common	10
D8/S3	192217	3911753	323	34	rare	V.Common	100
D8/S4	192369	3911858	323	27	common	V.Common	100
D5/S2	219575	3912750	323	29	V.Common	V.Common	75

D5/S3	216844	3913410	323	34	V.Common	V.Common	80
D5/S5	216965	3913453	211	34	dominant	V.Common	95
D5/S3	219169	3913547	211	34	absent	absent	0
D5/S4	219140	3913549	211	34	common	V.Common	0
D10/S2	245839	3913686	321	49	dominant	common	25
D10_S2	245912	3913726	321	49	Rare	V.common	50
D4/S4	244986	3915960	243	55	V.Common	V.Common	50
D4/S3	244807	3916101	243	50	absent	absent	0
D4/S3	244915	3916186	323	55	Rare	Common	10
D6/S1	220882	3917129	324	36	common	dominant	50
D6/S2	220832	3917400	324	36	V.Common	V.Common	75
D6/S1	220681	3917430	321	36	V.Common	V.Common	65
D10_S1	246455	3917559	223	60	Absent	Rare	0
D10/S1	246309	3917614	223	60	Absent	Absent	0
D5/S1	219259	3918210	324	36	V.Common	V.Common	70
D5/S1	219484	3918283	324	36	absent	occassion	50
D7/S1	207151	3919130	311	46	absent	common	40
D7/S1	207028	3919159	323	46	common	dominant	0
D7/S2	207012	3919217	323	62	Occassion	dominant	10
D9/S1	195490	3920430	242	50	rare	V.Common	80
D9_S2	195628	3920439	242	50	Absent	Absent	0
D9/S3	195573	3920810	242	58	common	V.Common	0
D7/S4	201032	3921719	311	65	absent	absent	0
D7/S3	203307	3921922	242	58	absent	absent	0
D9/S5	197337	3923580	323	62	V.Common	V.Common	0
D9/S4	196988	3923710	323	62	V.Common	V.Common	100
D9/S2	197023	3923880	311	62	absent	common	0
D9/S3	196977	3923911	311	62	Absent	Absent	0
D6/S3	213582	3926006	311	65	absent	absent	0
D6/S2	213817	3926662	323	62	absent	absent	0
D8/S1	205699	3935410	223	59	absent	absent	0
D8/S2	205518	3935540	223	63	absent	absent	0

Appendix 3: Cross table of Corine vegetation types and field data by NDVI vegetation types

	CORINE SIMPLIFIED										**Veg.structure**			
NDVI	**Agriculture**				**Natural areas**						**shrubs**			**Trees**
Mod.class	**Annuals**	**Perennials**	**Complex**	**Olives**	**Forest**	**Shrub**	**Wood/shrub**	**Grass/herb**	**Sparse/bare**	**Total**	**Low <0.5m**	**Med (0.5-2m)**	**High (2-3m)**	**Trees >4m**
11	3		7	1	0	5	0	57	30	103	65	0	0	0
24	0	0	22	5	3	100	12	57	3	204	4	25	8	0
40	0	4	28	16	9	99	19	18	0	192	8	18	15	57
50	0	5	31	31	19	71	13	4	0	175	100	40	80	50
58	0	5	48	54	21	52	10	2	0	193	40	103	0	90
65		16	17	27	19	16	3	0		99	43	53	0	23
Total	4	31	154	134	72	343	57	138	33	966				
11	3		7	1	0	5	0	57	30	103	65	0	0	0
24	0	0	22	5	3	100	12	57	3	204	4	25	8	0
40	0	4	28	16	9	99	19	18	0	192	8	18	15	57
48		5	46	38	5	68	7	12	0	181	80	52	2	5
55	0	7	69	112	4	37	4	4	0	236	70	38	50	5
60	0	8	45	129	5	13	3	1	0	204	55	55	0	10
Total	4	24	217	300	27	322	45	148	34	1120				
13	6	0	13	2	0	13	0	39	6	78	58	15	0	0
21	3	0	37	12	0	25	0	13	3	94	60	5	0	0
28	1	1	51	24	0	40	2	25	1	145	68	45	41	18
35	0	3	53	39	2	48	4	17	0	166	63	38	70	0
48		5	46	38	5	68	7	12	0	181	80	52	2	5
55	0	7	69	112	4	37	4	4	0	236	70	38	50	5
60	0	8	45	129	5	13	3	1	0	204	55	55	0	10
Total	13	23	321	355	17	249	21	168	41	1208				

13	6	0	13	2	0	13	0	39	6	78	58	15	0	0
22	1	0	11	4		23	0	82	7	129	43	35	0	30
30	1	0	24	4		17	0	84	1	132	55	30	2	0
38	0	2	40	21	0	24	0	62	1	150	75	18	2	1
43	0	2	36	39		13	0	17	0	106	98	5	0	0
Total	11	4	131	71	0	96	0	341	45	699				
13	6	0	13	2	0	13	0	39	6	78	58	15	0	0
22	1	0	11	4		23	0	82	7	129	43	35	0	30
33	1	0	33	8		6	0	15	0	63	98	25	0	0
49	2	1	41	28	0	36	1	15	0	124	25	35	6	0
Total	12	2	105	44	0	83	1	208	43	498				
13	6	0	13	2	0	13	0	39	6	78	58	15	0	0
26	0	1	11	3	0	56	1	95	2	169	85	92	5	16
37	5	0	23	2	0	21	1	39	0	93	115	43	5	0
Total	11	1	47	8	0	90	2	173	8	341				
18		0	4	0	2	65	13	74	9	167	62	40	0	30
23	1	1	6	0	1	61	4	54	1	129	70	4	0	3
34	3	1	12	1	2	47	7	30	0	104	78	18	0	14
Total	4	2	22	2	4	172	23	158	11	400				
18		0	4	0	2	65	13	74	9	167	62	40	0	30
19	0	0	3	0	5	75	21	39	3	146	61	5	0	0
27	0	0	2	1	14	53	35	20	1	127	88	38	5	20
36	0	1	2	1	30	41	34	8	0	119	42	41	5	32
39	1	2	11	6	40	69	24	7	0	161	50	51	0	4
46	1	1	18	10	32	54	11	3	0	129	50	30	45	0
62		1	25	16	28	40	8	1	0	118	55	43	30	89
65		16	17	27	19	16	3	0		99	43	53	0	23
Total	2	21	82	63	170	413	148	152	14	1066				