ASSESSING THE FORAGING DISTRIBUTION OF EURASIAN GRIFFON VULTURE (*Gyps fulvus*) IN CRETE

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Abstract

The Eurasian Griffon Vulture (*Gyps fulvus*) is a colonial cliff nesting raptor whose population has been declining in the past years. Crete holds the biggest viable Griffon Vulture population in the Aegean and Eastern Mediterranean region and has a vital position as a stepping stone supporting the last stronghold population in the Balkans. It is important to know about the foraging distribution of Griffon vulture to understand and decide conservation strategies for this species

In this study, the foraging distribution of the Griffon Vulture was examined with respect to the distribution of the potential prey, which is mainly livestock. The areas suitable for grazing of livestock were determined based on landcover / use suitability and altitude and livestock densities were estimated using this suitability and the livestock numbers registered to the municipalities. Carcass densities were also estimated using line transect in ten regions of Crete. The relation between the foraging distribution of vultures and livestock and carcass density were examined. The differences in foraging behaviour in summer and winter and between adults and juveniles were also examined.

It was seen that the presence of vultures coincides strongly with the presence of livestock. However, no relation was observed between the estimated livestock or carcass density and the vulture density. This lack of correlation has been attributed to the livestock density estimation methodology used in the present study, the high density of livestock and the wide foraging range of the vultures.

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1. Introduction

1.1. Background and significance

Increasing human activities are changing the global landscape more rapidly and tremendously than ever before and are leading to big changes in nature. These changes alter the quality and the quantity of services offered by natural ecosystems (Travis, 2003). Fragmentation and degradation of natural habitats, climate change and sudden habitat loss are some important problems driven by these changes. Environmental problems over the last decades caused big changes in the distribution and abundance of species (Parmesan and Yohe, 2003). All of these changes increase the pressure on wildlife and speed up the decline processes of many species and many raptor species are among them (Thiollay, 2006).

1.2. GIS and species distribution modeling

Knowledge of the relation between the geographic distribution of a species and the factors affecting it is very important for protecting threatened species. As the number of threatened species increase with increasing anthropogenic pressure, to save a threatened species first we need to know where the species prefers to live and what the requirements are for its survival (Hutchinson, 1957). Geographical Information Systems (GIS) and remote sensing enables us to analyze and process large amounts of geographical data together with data on distribution of species. Making use of these methods can provide valuable information on the requirements of a species for survival and the relations between a species with other species and environmental factors.

1.3. Normalized Difference Vegetation Index (NDVI)

Remote sensing makes it possible to create indices which give information about facts happening on the land such as vegetation indices, by allowing us to examine the radiated energy by Earth's surface in broader wavelengths of electromegnetic spectrum. A Normalized Difference Vegetation Index (NDVI) is one of commonly used vegetation indices as a representative of plant biomass in species distribution estimations (Pettorelli et.al., 2005, Plummer, 2000, Shunlin, 2004). NDVI is calculated using near-infrared (NIR) and red (R) bands of electromagnetic spectrum, by dividing the difference between two bands by their sum. This ratio increases from zero to one with increasing green biomass cover.

$$NDVI = \frac{NIR-R}{NIR+R} \qquad \text{Equation 1}$$

NDVI can be related with the amount of biomass found within pasture over large areas (Parmesan and Yohe, 2003). Because there is a correlation between NDVI and green biomass, it is also expected to have a correlation between NDVI and available biomass for grazing livestock. So, the NDVI map can be used for estimation of suitable areas for grazing in a certain space and time.

1.4. Research problem and justification

The Eurasian Griffon Vulture (*Gyps fulvus)* is a colonial cliff nesting raptor inhabiting open areas of Eurasia and North Africa. It is a specialized scavenger depending mainly on carrion for food [Xirouchakis, 2005, Xirouchakis, 2005]. The total number of European breeding pairs is estimated to be around 20,000. The Griffon Vulture breeds on cliffs and exceptionally also on trees in colonies varying from one to hundred pairs. Breeding populations are sedentary whereas younger birds are migrants or vagrants. Most of the juvenile vultures leave their nests after fledging, probably in order to locate better feeding resources and thereby avoiding competition with adults (EGVWG,2004).

Main threats for the Eurasian Griffon Vulture population are poisoning, lack of food, changes in land use practices with decreasing numbers of domestic and wild ungulates, electrocution, disturbance and persecution (shooting and egg robbing). The European Union regulation prohibiting leaving carrions in nature also has a negative effect on vultures like all other scavenger species of Europe (European Regulation 999/2001 and 1774/2002).

The Griffon Vulture is one of the species threatened all over its natural habitats (Van Beest et al., 2008) Although reports from six European countries showed a decline in number of Griffon Vultures (Xirouchakis and Mylonas, 2005), the status of the bird is reported as secure in the European Threat Status List [12].This is mainly due to the big Spanish population which holds more than 80% of the European population and showed a significant increase during last decades (Xirouchakis and Mylonas, 2005, Parra and Telleria, 2004). According to the East European / Mediterranean Griffon Vulture Working Group (EGVWG), the populations in Eastern Europe and the Mediterranean range must be considered as “endangered” despite an increase in Western Europe (EGVWG,2004).

There are fewer viable Griffon populations nowadays in locations where the species showed a continuous distribution before. Greece is one of these locations, but hunting, poisoning and a decrease in pastoralism caused the extinction of the species from most of the country (Xirouchakis and Mylonas, 2005, EGVWG,2004, Van Beest et al., 2008). According to Xirouchakis, in Crete Griffon’s feeding ecology may be more closely related to pastoralism than anywhere else in Europe (Xirouchakis, 2005). The island holds the biggest breeding population in Greece (379 individuals or an estimated population of 141 breeding pairs, 73–80% of the Greece population), the largest insular griffon vulture population in the world and 20% of the Balkan population (Xirouchakis and Mylonas, 2005). Crete has a vital position as a steppingstone and supports the last stronghold population in the country and Balkans. Therefore the status of the Cretan population is important in determining the status of the species since it is the biggest viable population in the Aegean and East Mediterranean region. The Cretan population decreased 33% in number since the early 1980’s (Xirouchakis, 2007) and nowadays the population density on the island is lower than the continental regions. This is in contrast to earlier studies where bird densities were higher in island communities (Xirouchakis and Mylonas, 2005).

The Griffon Vulture mainly depends on carcasses for food and in Crete its diet consists of livestock (goats, sheep, cows and donkey), especially small domestic ungulates (Xirouchakis, 2005). While determining the habitat of the vulture, seasonal movements of the livestock (to uplands in summers and back to the lowlands in winters) are important variables (Xirouchakis, 2005, Donazar et al., 1993). According to Xirouchakis et al., about 86% of livestock are bred in semi-mountainous and upland communities while 77% consist of transhumant flocks (National Statistical Service 2001) namely they are kept in pens inside the large enclosures and supported with fodder during late autumn – early spring. For the rest of the year they are set loose to range freely in the uplands (Xirouchakis and Andreou, in press). These uplands are found mostly in the areas higher than 600 meters which is the line above which there is no significant cultivation. These areas are covered with snow during winter and snow cover starts to melt in spring when the grasses start to grow and then they are used as summer pastures for livestock. This is the time when owners transfer their livestock from lowlands to the uplands, during late April – early May.

Some environmental factors such as solar radiation, wind speed and cliff aspect, slope and altitude of nest site, land cover of the foraging area, distance to roads, power lines and urban area and NDVI can also be considered as factors affecting Griffon's habitat (Zhou, 2006).

Apart from the studies on the Griffon Vulture mentioned above, there appears to be a lack of literature on factors determining the foraging distribution and foraging habitat requirements of griffons in Crete. Although it is known that there is a relation between food abundance and occurrence of the Griffon Vulture it does not explain the survival and spatial distribution by itself. The factors related with foraging behaviour of Griffon Vulture are the essential factors effecting abundance and distribution of the species [Van Beest, 2008, Parra and Telleria, 2004, Donazar and Fernandez, 1990, Fernandez et al., 1998)]. Also in the report of EGVWG in 2004, foraging related factors (poisoning, decline of pastoralism, food shortage and availability of nesting sites) are described as critically or highly threatening factors for the species (EGVWG, 2004).

It is very important to understand the foraging behaviour to explain population dynamics and spatial distribution of the Griffon Vulture population in Crete. Information on foraging behaviour, dispersal patterns and home range can assist wildlife managers in the successful and proper designation of protected areas and the re-evaluation of conservation strategies.

1.5. Research objectives

1.5.1. General objective

The main objective of this study is to investigate to what extent the spatial distribution of prey (livestock) contribute to the spatial foraging distribution patterns of Eurasian Griffon Vulture at seasonal base.

1.5.2. Specific objectives

1. To analyze the spatial relationship between foraging griffons and potential prey at seasonal base.

2. To identify whether there is a difference in spatial and seasonal foraging behavior between adult and juvenile vultures; if there is to explain why.

1.6. Research questions

1. Is there a spatial relationship between foraging distribution of the Griffon Vulture and seasonal distribution of potential prey?

2. Is there a difference in spatial and seasonal foraging behaviours between adult and juvenile vultures?

1.7. Research hypotheses

Hypothesis 1

Testing the concept that foraging distribution of Griffon Vulture is related with the seasonal distribution of prey in Crete, Greece.

H_0: There is no significant relationship between foraging distribution of Griffon Vulture and distribution of potential prey at seasonal base.

H_1: There is a significant relationship between foraging distribution of Griffon Vulture and distribution of potential prey at seasonal base.

Hypothesis 2

Testing the concept that adult and juvenile vultures behave differently and this influences the foraging distribution of two age classes differently.

H_0: There is no significant difference in spatial and seasonal distribution of adult and juvenile vultures while foraging.

H_1: There is significant difference in spatial and seasonal distribution of adult and juvenile vultures while foraging.

1.8. Research approach

To find out if there is a relationship between foraging distribution of griffon vulture and distribution of potential prey, observations of griffon vulture and data on small ungulates in Crete were used. The spatial and temporal distribution of griffon vulture observations were compared with estimated spatial and temporal distribution of potential food, which will be referred to as livestock from here on. Livestock data were processed with the aim of estimating the seasonal distribution of food. Only sheep and goat were considered as representing potential food for griffon vulture while other kind of livestock species such as pig were not taken into consideration. The spatial and temporal distribution of livestock were based on available literature on livestock keeping and Landuse/cover suitability for grazing in Crete. The grazing suitability map was produced based on a previously produced NDVI map of the island with 1 km resolution (Zabalaga, 2008) and another Landuse/cover

(CORINE) map was used to assess the accuracy. The aim is to see to what extent the NDVI-based suitability map for livestock grazing agrees with another suitability map for grazing, which was produced using a different approach.

To find out if there is a difference in foraging distributions of adult and juvenile griffon vultures, the observations were classified according to observed individual's maternal status (juvenile-adult) and to the time f observation (summer-winter). Later these classified observations were analyzed to find out if there is a significant difference in seasonal distribution of adults and juveniles according to distance to the nearest colony, number of observations and suitability for livestock grazing of the area in which observation was made.

A schematic drawing of the research approach is given in Figure 1.

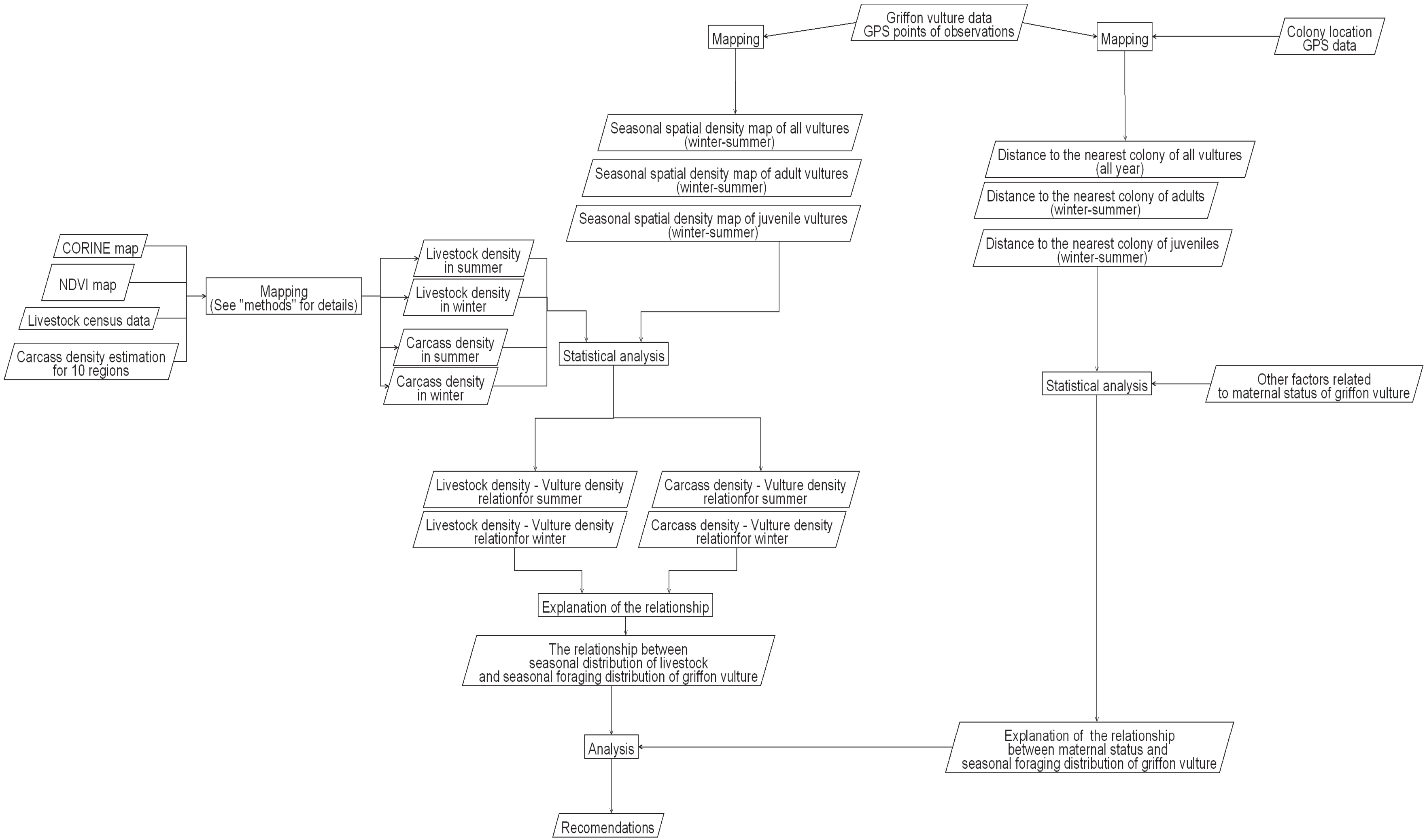


Figure 1. **Research approach**

2. Methods and Materials

2.1. Study area

Crete is located in the Eastern Mediterranean, south of Greece (35° N 24° E) and lies in the Southern Aegean Sea and at the crossroads of three continents Europe, Asia and Africa. The island is the fifth largest island of the Mediterranean and the largest island of Greece. It covers approximately 8,336 km^2 and holds approximately 650,000 inhabitants. The length of the island is 260 km and the shore-length is 1,046 km. The biggest width is 60 km while the smallest is 12 km. A high mountain range covers most of the island in the West-East direction with few coastal plains.

The climate in Crete is temperate. The temperature mostly remains mild in the low-lying areas while snowfall rarely takes place, except at some high altitudes. The island is surrounded by the Mediterranean Sea waters and carries a weather that resembles both the Mediterranean and the North African. The atmosphere can be quite humid, depending on the proximity to the sea.

The differences in climate create many micro-climates and with the combination of long term isolation from mainland (around five million years) lead to high biodiversity and endemism (Sfenthourakis and Legakis, 2001, Chartzoulakis and Psarras,2005). Both fauna and flora of the island contain high number of species. Crete holds nearly 1700 plant species, with approximately 10 % being indigenous to the island. The Cretan flora is especially rich in herbal and pharmaceutical plants. Vegetation and variations in climate are dependent on geographical regions. The impressive abundance of flora and fauna arises from Greece's unique geographical location between Europe and Africa and the specific climate of this region, affected by the mountain range crossing the island from east to west and dividing Crete in a northern, typical Mediterranean climate area, and a southern, almost subtropical one.

The main reason to choose Crete as study area for this research is due to the significance of the Cretan griffon vulture population. On top of that the available data from Crete and the collaboration between local institutions (University of Crete/Museum of Natural History) and ITC was also important for logistics in the fieldwork and data acquisition.

2.2. Materials

2.2.1. Data

2.2.1.1. Species data

A dataset of presence only data was obtained form the Natural History Museum of Crete (NHMC). This dataset consists of 1375 observation points recorded using radio tracking and a GPS. For each observation point date, name, age, gender and X and Y coordinates (Geographic Coordinate System: GCS_GGRS_1987) of 15 griffon vultures were recorded between 2003 and 2008 (Table 1). For this study the data from NHMC is assumed correct and any analysis related with presence of vultures is done on the basis of this assumption.

Table 1 Species data.

Name	Age	Sex	Starting date	End date	Months tracked	Number of radiolocations
Alkinoos	Immature	Male	23/10/2005	22/07/2007	21	135
Argiris	Immature	X	22/05/2007	19/12/2007	7	49
Asterios	Adult	Male	30/03/2006	08/03/2007	12	113
Fratianos	Adult	Male	20/06/2006	09/10/2007	16	128
Garifalos	Adult	Female	04/12/2003	31/05/2005	18	91
Jakovina	Immature	Female	23/10/2005	03/09/2007	22	317
Julia	Immature	Female	13/04/2006	19/08/2006	4	40
Kofinas	Immature	X	24/10/2007	17/06/2008	8	50
Markos	Adult	Female	20/06/2006	23/02/2007	8	65
Melina	Immature	X	22/11/2007	20/06/2008	8	45
Nervous	Immature	Female	06/06/2003	12/09/2004	15	70
Nevriki	Immature	X	6/6/2003	12/9/2004	15	67
Romea	Immature	Female	01/05/2006	12/12/2007	19	91
Rouvas	Adult	Male	20/06/2006	4/12/2007	18	77
Viannos	Immature	X	24/10/2007	17/062008	8	37

2.2.1.2. Livestock census cata

Livestock census data were obtained from the Natural History Museum of Crete (NHMC). The data were based on statistical data declared by the Ministry of Agriculture of Greece in 2001 and refers to average livestock numbers for each municipal unit in Crete for the decade 1991-2001. The dataset was obtained as an ArcGIS shapefile, consisting of 623 polygons which represent the borders of municipalities and holds the average number of pig, sheep and goat for each municipality.

2.2.1.3. CORINE map

Corine Land Cover 2000 (CLC2000) was obtained from ITC. It was produced by the European Environment Agency (EEA) and its member countries in the European Environment Information and Observation Network (Eionet). It was based on the results of IMAGE2000, a satellite imaging programme, and provided consistent information on land cover and land cover changes during the past decade across Europe. CLC2000 is based on the photo interpretation of satellite images by the national teams of the participating countries. The resulting national land cover inventories are further integrated into a seamless land cover map of Europe.

2.2.2. Data dollection

2.2.2.1. Carcass density data

Carcass densities were estimated from line transect of 10 regions in Crete (Figure 2) by Stavros Xirouchakis (Xirouchakis, 2003). Average number of carcasses per square kilometre for each region and for each month was obtained during fieldwork from Xirouchakis.

Table 2: Estimated monthly and regional carcass densities by S. Xirouchakis (Xirouchakis, 2003)

Month	N	Carcass/km^2
January	30	5.6±17.94
February	46	4.5±13.02
March	22	2.7±6.02
April	18	6.2±20.56
May	25	9.3±34.36
June	15	4.4±11.62
July	22	9.0±22.72
August	11	7.9±26.23
September	27	7.7±19.04
October	30	12.9±26.31
November	34	4.0±16.38
December	30	8.1±30.30

Region	N	Carcass/km^2
1.Dikti	91	3.8±16.28
2.Idi	68	3.5±20.00
3.Asterousia	36	3.7±13.77
4.Trypti-Orno	29	0.4±2.23
5.Lefka Ori	23	21.6±40.88
6.Kisamou-Selinou	18	17.2±29.13
7.Kedros-Asiderotas	16	8.3±23.58
8.Heraklion midlands	12	26.3±25.77
9.Retymnon midlands	9	8.9±10.54
10.Krioneritis-Kalikratis	8	4.3±8.15

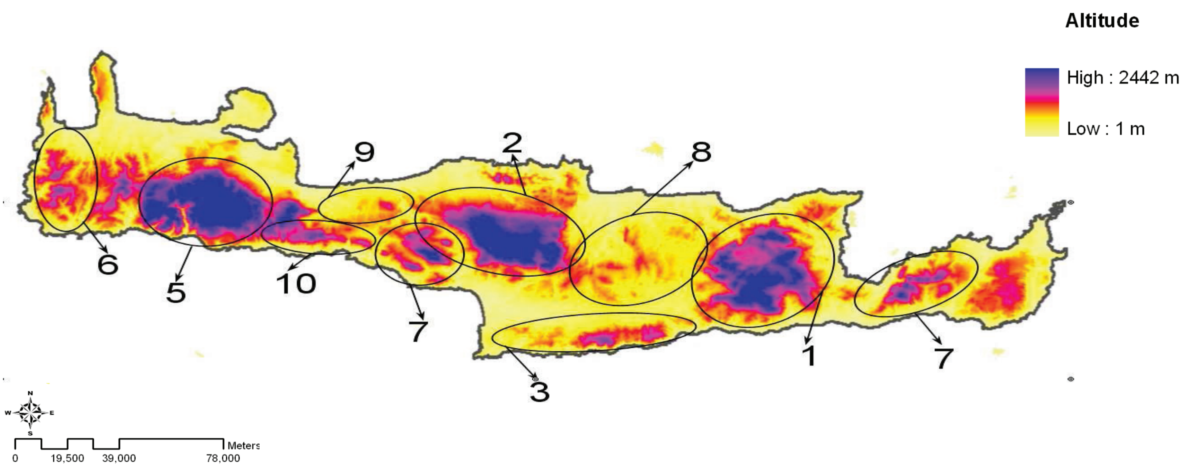


Figure 2: The 10 regions that carcass estimations were based on.

2.2.2.2. Nest location and feeding station data

The data set was obtained from NHCM, consisting four ArcGIS shapefiles (Geographic Coordinate System: GCS_GGRS_1987). It included GPS points of 41 active colonies (1995 – 2007), 9 winter roosts, 17 summer roosts and 8 feeding stations. During fieldwork, five of the active colonies, two of the feeding stations and one of the summer roosts were visited and the coordinates were recorded with an Ipaq in combination with a GPS for spatial validation.

2.2.2.3. NDVI Map

The NDVI map of Crete produced by Natalie Alem Zabalaga for the MSc thesis submitted in March 2008 to ITC was obtained from ITC. This map was created with the 10-day composite multi-temporal images, in total 300 NDVI images with 1 km^2 resolution from the VEGETATION sensor on SPOT-4 platform. Images from eight years from April 1998 to July 2006 were combined to produce one NDVI map by using unsupervised classification method (convergence threshold: 1.0, number of max-iterations: 50) with 27 NDVI classes, which was found robust and detailed enough (Zabalaga, 2008).

During fieldwork, the NDVI map was monitored with an Ipaq and every NDVI class along the road was observed. In total 44 points were visited, photos and notes were taken about the vegetation cover from each point. All the classes higher than class 8 were visited at least once. Beside the validation of NDVI map, the aim of checking NDVI classes was to assess whether each class was suitable or unsuitable for livestock grazing in Crete. In total 80 photos were taken for 19 NDVI classes (9 – 27). The minimum number of photos (visit) per class was 1 photo for class 17, while the highest was 9 for classes 19 and 24. NDVI classes lower than 9 could not be visited because the classes (except 5 and 7) were over the sea and these classes were considered as water bodies in this study. The classes 5 and 7 were aggregated in three areas, which were in high areas of the island and inaccessible with a small vehicle like we had in the field.

2.3. Methods

2.3.1. Distinguishing between summer and winter periods

To be able to make analysis at seasonal base, determination of summer and winter periods needed to be done. This was done according to available information about three factors. The first factor was the population dynamics of the griffon vulture. The second factor was the changes that occur annually in the spatial distribution of food for vulture. Geographical structure of Crete was the last factor taken into account.

The period from 15 April to 14 November was considered as summer while the period from 15 November to 14 April was considered as winter. This distinction was made according to seasonal changes which occur in climatology, in nest occupancy and in availability of food all around the year. Rainfall duration and time span of snow cover in the areas higher than winter roosts were considered as climatological indications of change between seasons for griffons by Xirouchakis and Mylonas (Xirouchakis and Mylonas, 2004).

In addition to climatological factors, change in the nest occupancy by Griffon Vultures can also be considered as an indicator of shift between summer and winter (Figure 3). Activity decreases in the colonies which are found in lowlands (6m – 1143m) between March and May while the activity in the summer roosts in the uplands (615m – 1987m) increases. This occurs when failed breeders and immatures abandon the colonies to use summer roosts and this is also the time when chicks are started to be left alone in the colonies during day by successful breeders for foraging. The activity in the colonies starts to increase when all individuals abandon the roosts during late October (Xirouchakis, 2006).

Selection of these dates for discriminating two seasons for griffon vulture was supported by the annual movements of food source, which is mainly livestock for griffon vulture in Crete. Late April-Early May is the period when transfer of livestock from lowlands to summer postures in the uplands occurs.

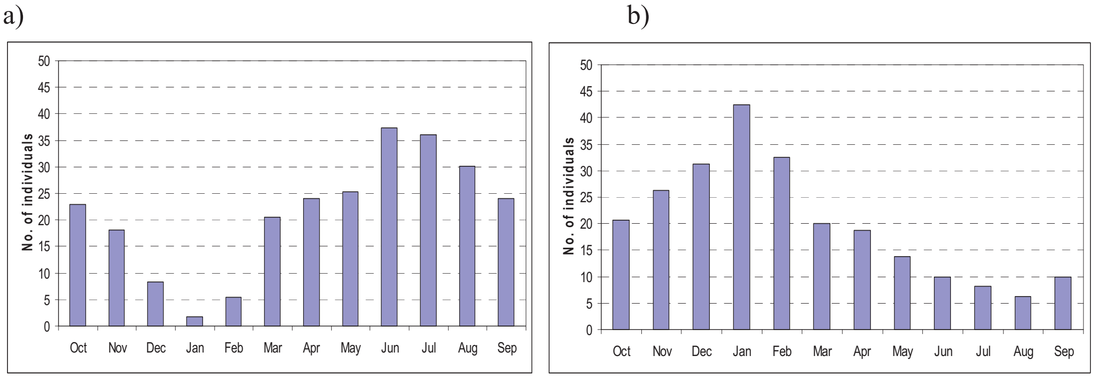


Figure 3: Seasonal pattern of griffon vulture activity (a) in two communal roosts and (b) in two colonies in Crete during 1998-2000. Data from Xirouchakis (Xirouchakis, 2006).

2.3.2. Production of seasonal foraging griffon vulture distribution maps

To examine the distribution of griffon vulture in Crete at seasonal (winter and summer) and maternal (adult and immature) base, separate maps were created for each condition based on the species data. Presence only data from NHMC of 15 individuals was combined to create one file having the coordinates and dates of 1375 observation points. Three new columns (season, age_class and name_code) were added to this file in ArcMap 9.2 to separate observations according to season of the observation and maternal status of the observed individuals. Later the fourth column, distance to the nearest griffon vulture colony was added to distinguish between foraging and non-foraging individuals. Within 1375 observation points 1191 points, which were in a distance larger than 1 km to the nearest colony, were considered as representing the foraging individuals while the remaining were considered as within the colony.

2.3.3. Production of seasonal livestock distribution maps

2.3.3.1. Suitable areas for livestock grazing based on the NDVI map

NDVI map was used to estimate the suitable areas for grazing. Within 27 NDVI classes 13 classes were chosen as suitable based on the fieldwork observations and photos from sampling points. According to fieldwork records, NDVI classes higher than 19 were considered as olive fields, vineyards or other kind of woody vegetation while the classes lower than 9 (except 5 and 7) were considered as water bodies because these classes were over the sea. Although the reflectance values of classes 5 and 7 were as low as the reflectance of water bodies they were not considered as water because these areas were located inlands of the island far from the coast and it is known there are not any big water bodies in those locations (Figure 5). These two classes were found in the highest parts of Crete and they are aggregated in three areas, which were used traditionally as communal pastures and they were also known as highly grazed and desertificated areas. Based on this classification, the classes 5, 7 and from 9 to 19 (13 classes) were considered as suitable NDVI classes for animal grazing in Crete.

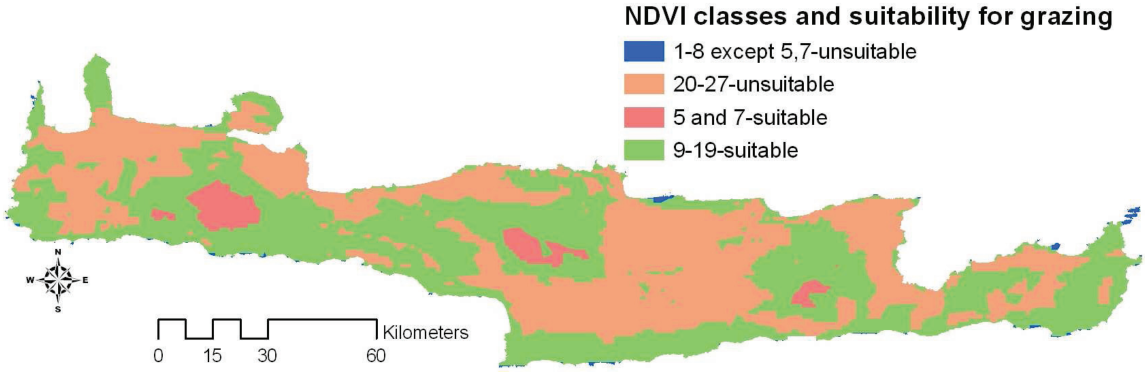


Figure 4: NDVI classes and suitability for grazing

CORINE Land Cover map was used to assess the accuracy of the estimation of suitable grazing areas map produced from NDVI map because it was not based on just reflection of vegetation cover in two bands but based on expert knowledge in image processing and classification of land covers and the polygons representing each separate landcover were drawn more detailed. This fact was important while dealing with land shapes which are mostly amorphous in reality rather than having a geometrical shape. Classified polygons in the NDVI map were in more geometrical shapes because of the pixels in the original image, whose resolution was 1 km^2. Because the NDVI map was not post-classified according to an expert knowledge of landcover/use types in Crete, it can be suspected that it was not able to detect different vegetation types if they occur within areas smaller than its resolution (1 km^2). This can lead to the classification of small unsuitable areas surrounded by relatively big suitable areas as suitable and vice versa. To sum up, the NDVI map is more sensitive to the change in the green biomass while the CORINE map is more sensitive to the changes within small distances in landcover/use types

CORINE map landcover classes representing the areas between woody forest and water bodies were considered as suitable while the other classes were considered as unsuitable. During this classification of CORINE map, 8 classes were classified as suitable for livestock grazing within 28 landcover classes (see Appendix).

To assess the consistency between two grazing suitability maps the areas classified as suitable for livestock grazing were compared to each other. The Chi-square test, which is used to investigate whether distributions of categorical variables differ from one another, was implemented to see if there is a significant difference between classifications of two maps.

H_0: There is no significant difference between reclassified NDVI and CORINE maps in suitability for livestock grazing.
H_a: There is significant difference between reclassified NDVI and CORINE maps in suitability for livestock grazing.

Secondly to see whether there is a significant difference between the effect of different classified areas by these two maps on distribution of griffon vulture, these two maps were overlaid with observation points of foraging birds (N=1191) separately and number of occurrences on suitable grazing areas were compared by using the Chi-square test.

H_0: There is no significant difference in classifications of the areas where foraging griffon vultures were observed between the NDVI based and CORINE based suitability maps for livestock grazing.

H_a: There is significant difference in classifications of the areas where foraging griffon vultures were observed between the NDVI based and CORINE based suitability maps for livestock grazing.

The aim of this assessment was that if the consistency between two maps is low then at least one of two maps should be suspected for their low accuracy in estimation of suitable areas for livestock grazing in Crete. Because the accuracies of the livestock density and carcass density estimations and analysis of griffon vulture observations with respect to suitable/unsuitable areas for livestock grazing primarily depended on the NDVI-based suitability map, it was important to assess the accuracy of this map with another Landuse/cover map from a completely separate data source.

After assessing the consistency of the reclassified NDVI suitability map with the reclassified CORINE suitability map for livestock grazing, the reclassified NDVI suitability map was tested for its relation to foraging griffon vulture observations. This was done based on the assumption that if there is a significant relation between seasonal distribution of livestock and seasonal distribution of griffon vulture the same relation should also be represented between suitable areas for livestock grazing and distribution of griffon vulture. Chi-square test was implemented to analyze the relation.

Ho: The observation of the griffon vulture is independent of the area's suitability for livestock grazing.

Ha: The observation of the griffon vulture is associated with the area's suitability for livestock grazing.

Ho: The observation of the griffon vulture in winter is independent of the area's suitability for livestock grazing.

Ha: The observation of the griffon vulture in winter is associated with the area's suitability for livestock grazing.

Ho: The observation of the griffon vulture in summer is independent of the area's suitability for livestock grazing.

Ha: The observation of the griffon vulture in summer is associated with the area's suitability for livestock grazing.

2.3.3.2. Preparation of NDVI maps for seasonal livestock density estimations

To estimate the density of livestock, average NDVI values of each NDVI class were used by converting the NDVI map to a polygon file. The annual NDVI map is divided into summer and winter maps according to the distinction of seasons made before. Images starting with the second image of April (composite 11) and ending with the second image of November (composite 32), in total 187 images, were classified as summer while the remaining images (composite 32-36, 1-12), in total 113 images, were classified as winter. Average NDVI values of each suitable NDVI class for livestock grazing were re-calculated for each season separately. New average NDVI values were calculated for each map according to Equation 1, which sums the average NDVI values for each class in one season and divides them by the total NDVI value of all composites in that season. Then these seasonal average values of each NDVI class were converted to percentages representing the relative amounts of green biomass produced by each class in summer and winter. Later these "greenness fractions" were saved as features for each polygon. Greenness fraction of each polygon was used to distribute the livestock numbers within suitable polygons for grazing, according to amount of green biomass produced by each NDVI class. The aim of calculating such a "greenness fraction" was based on the assumption that within suitable areas for livestock grazing the greener the area is the higher the livestock number will be, which can graze in that area.

$$GF_i = \frac{\sum_{j=1}^{187} n_{i,j}}{\sum_{i=1}^{27}\sum_{j=1}^{187} n_{i,j}} \text{ for summer} \qquad GF_i = \frac{\sum_{j=1}^{113} n_{i,j}}{\sum_{i=1}^{27}\sum_{j=1}^{113} n_{i,j}} \text{ for winter} \qquad \text{Equation 2}$$

where; GF is greenness fraction of each polygon
n is average DN value of each NDVI class
i is the number of the NDVI class
j is the number of the decade

For example the seasonal Greenness Fraction (GF) of NDVI class 1 among all NDVI classes for summer is,

$$GF = \frac{n_{1,1}+n_{1,2}+n_{1,3}+\ldots+n_{1,187}}{(n_{1,1}+n_{1,2}+n_{1,3}+\ldots+n_{1,187})+(n_{2,1}+n_{2,2}+n_{2,3}+\ldots+n_{2,187})+\ldots+(n_{27,1}+n_{27,2}+n_{27,3}+\ldots+n_{27,187})}$$

2.3.3.3. Livestock density estimation

Livestock census data from NHMC were used to estimate the livestock density over Crete for summer and winter. To create the winter livestock density map, all livestock (i.e. sheep and goat) were considered as being kept within municipal borders during winter and registered numbers of livestock for each municipality were divided by the area (km^2) of each municipality.

The estimation of summer livestock density was made according to available information about animal husbandry in Crete and three parameters were taken into account. First parameter was the altitude according to which the areas higher than 600 meters were considered as suitable for grazing of transhumant livestock during summer. For this, DEM-SRTM map of Crete was used. This altitude is also a threshold for transition from summer to winter, when livestock is moved back to the pens in lowlands during late October – early November. This is also the average altitude of winter roosts, while griffon vultures forage during winter in Crete (Xirouchakis and Mylonas, 2004). This means 600 meters is their upper limit for being close to livestock during winter. According to this fact, 600 m was set as a seasonal barrier for livestock and seasonal densities of livestock over Crete were calculated with respect to this barrier. That is, the transhumant livestock was assumed to be located above 600 m in summer.

The second parameter was the suitability for grazing according to NDVI classification. For this, suitable NDVI classes for grazing in Crete map, which is determined as described in section 2.3.3.1, was used.

These two maps were combined with the municipality borders to get one map showing the suitability according to altitude (higher or lower than 600m), suitability according to NDVI class and the administrative unit (municipality). This resulted in 4994 polygons of a combination of NDVI class, altitude and municipality different from their neighbouring polygons.

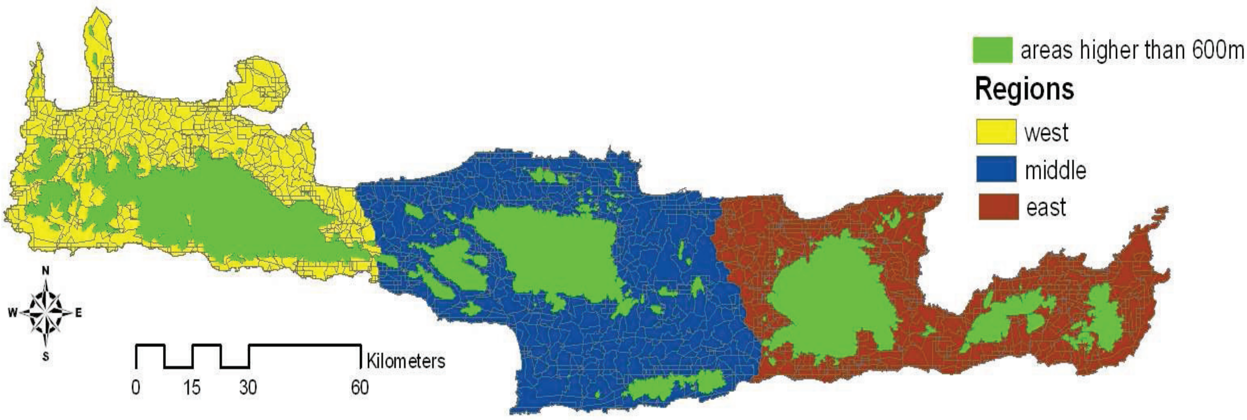


Figure 5: Uplands and the three regions of Crete

The spatial distribution of transhumant livestock numbers, which is 77% of the total number of livestock in each municipality (section 2.2.1.2) was based on the livestock census of Crete. While using these numbers, Crete was divided in three regions, as west, middle and east (Figure 5), based on the assumption that transhumant livestock moves to the nearest suitable area for grazing in summer, which means that 77% of the total number of livestock registered in the west part of Crete was considered as moving to the suitable grazing areas in highlands of the west part rather than moving to highlands of the middle part. 23% of total livestock number was assumed to be kept within municipal borders. To estimate the livestock density in each polygon, only the polygons with suitable altitude and polygons of suitable NDVI classes were taken into account and the three regionswere treated separately.

For each region transhumant livestock numbers were calculated separately by taking the 77% of total livestock number in each region. The number of transhumant livestock for each region was redistributed within each region according to Equation 3, in which a distribution fraction was calculated for each region. The distribution fraction was calculated by dividing the total number of transhumant livestock for each region by the total greenness fraction of each region.

$$\text{Livestock distribution fraction} = \frac{\Sigma\, n_{TL}}{\Sigma\, GF} \qquad \text{Equation 3}$$

where; Σn_{TL} is the total transhumant livestock number in each region
GF is the greenness fraction of each polygon within the region (calculated from NDVI value of each polygon)

Then this fraction was multiplied by the greenness fraction of each polygon found within each region to get the number of transhumant livestock assumed to be transported to that area for grazing. Then these numbers were added to the 23% of the original livestock number of each polygon to get final livestock number in each polygon. Dividing this livestock number by the area of the polygon gave the livestock density of the polygon.

2.3.3.4. Carcass density estimation

To estimate the carcass density over the whole island at seasonal base, carcass density estimation made for ten regions in Crete obtained from NHMC was used (Xirouchakis, 2003). The map showing ten regions where field observations were made was digitized and combined with map of Crete resulting 11 polygons, or regions 10 polygons representing the carcass density estimated areas and 1 representing the areas remaining between outside of these regions and coastline of the island. To estimate the ratio of carcass density for winter and for summer monthly estimations were used. Monthly estimations were grouped as winter and summer based on the previously described distinction between seasons. Estimated carcass densities of five months (November – March) were summed to get the total estimated carcass density for winter while the densities of the remaining seven months (April – October) were summed to get the total estimated carcass density for summer according to this distinction. Then percentages of estimated carcass densities for winter and for summer were calculated to use in the next step. The carcass density estimation was made for each polygon, which were created during livestock density estimation process in section 2.3.3.3. In the second step, estimated carcass densities of ten regions were used to recalculate carcass densities for each polygon within the ten regions. For this, estimated carcass densities (carcass/km^2, Table 2) for each region were converted to total estimated carcass numbers for each region, by multiplying the density of each region with the total area of each region. Then estimated total numbers of carcass for each region were distributed to the seasons according to seasonal percentages, which were calculated in the first step. This resulted in two values for each of the ten regions, one representing the total number of estimated carcass number for winter and one for summer. The total number of livestock for each region for each season was estimated by using the estimated livestock numbers for each polygon, which was calculated in section 2.3.3.3. The numbers of livestock of all polygons within each region were summed to get the total estimated number of livestock for each region for winter and for summer. By dividing the estimated total number of carcass for each region by estimated total number of livestock for same region two fraction values for each of the ten regions were calculated (in total 20 fraction values), one for winter and one for summer. Then these seasonal fraction values for each region were multiplied by the previously estimated seasonal livestock density (livestock/km^2) of each polygon within those ten regions, to estimate the carcass density for winter and for summer for each polygon within those ten regions.

For the remaining polygons, which were not within any of ten regions, carcass density estimation was made by generalizing the total numbers of carcasses calculated for each region. They were summed to get a total number of carcasses for ten regions. Then this total number of carcasses for ten regions was distributed seasonally as winter and summer based on the previously calculated seasonal percentages. After splitting the total number of carcasses of ten regions for winter and summer, total number of livestock for ten regions was also calculated based on the estimated livestock numbers in section 2.3.3.3.. Then by dividing the seasonal total number of carcasses of ten regions by the seasonal total numbers of livestock for ten regions two more fraction values were calculated, one for winter and one for summer. These new fractions were multiplied by the seasonal estimated livestock densities of all polygons found outside of the ten regions, to estimate the carcass density for winter and summer.

At last the seasonal livestock densities and seasonal carcass densities polygons were plotted to examine if there is strong linearity between livestock density and carcass density in winter and summer. If the carcass density was following a different distribution, it was used as second variable with together estimated seasonal livestock density representing the seasonal distribution of potential prey for griffon vulture in Crete.

The livestock and carcass density estimation approach is also shown schematically in Figure 6.

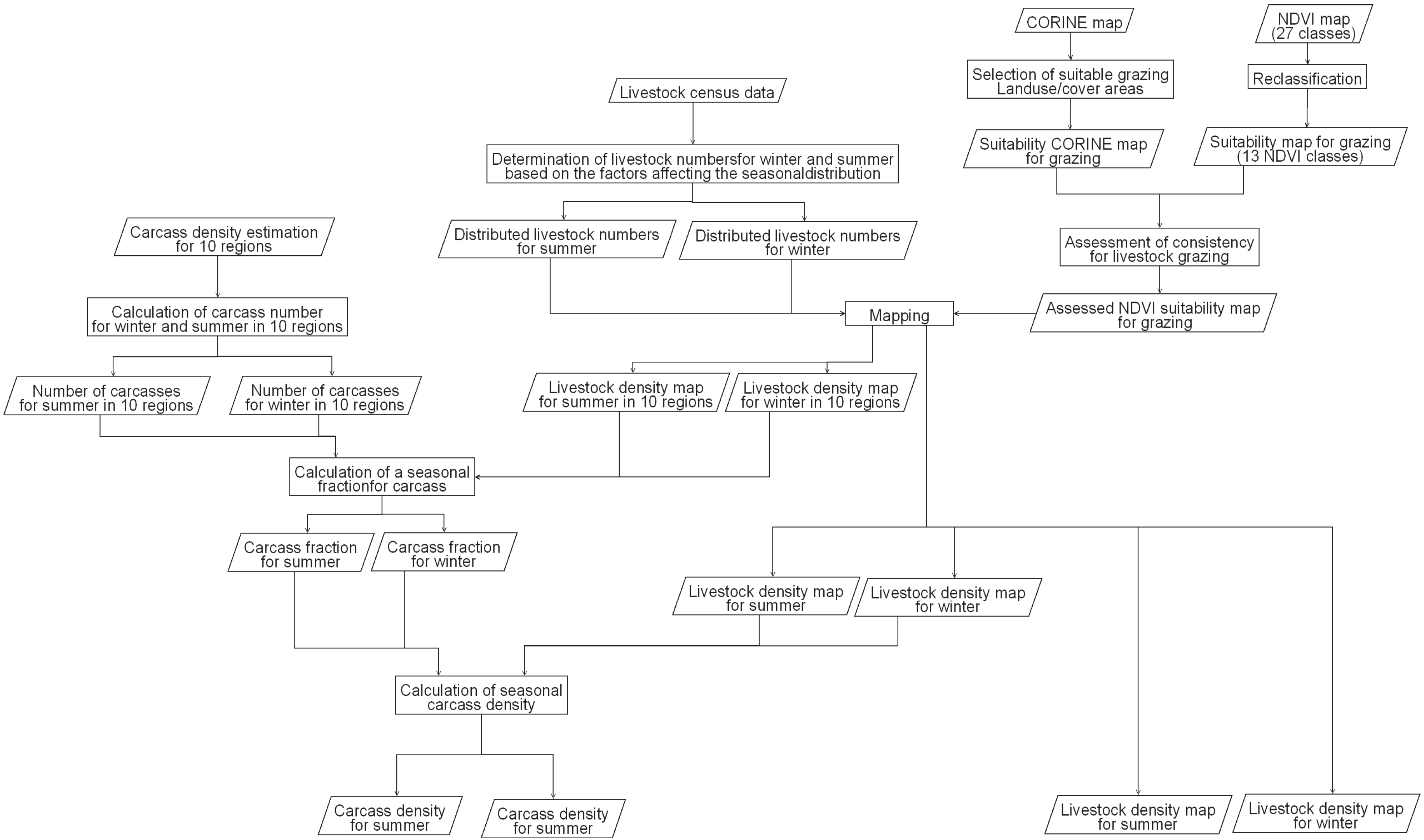


Figure 6 General Approach, Flow Chart

2.3.4. Statistical Analysis

Linear regression was implemented in SPSS 14.0 to establish the relation between seasonal distribution of potential prey (livestock and carcass) and seasonal foraging distribution of griffon vulture in Crete. It was also implemented to examine the same relation within two different age classes to see whether the regression was different for adult and juveniles separately during winter and summer.

Linear regression is used to model the value of a dependent scale variable based on its linear relationship to one or more predictors. The model assumes that there is a linear relationship between the dependent variable and each predictor. This relationship is described in the following formula:

$$y_i=b_0+b_1x_{i1}+...+b_px_{ip}+e_i \qquad \text{Equation 4}$$

where y_i is the value of the ith case of the dependent scale variable

p is the number of predictors

b_j is the value of the jth coefficient, j=0,...,p

x_{ij} is the value of the ith case of the jth predictor

e_i is the error in the observed value for the ith case

A number of tests are available to determine if the relationship between two categorical variables is significant. One of the more common tests is chi-square. One of the advantages of chi-square is that it is appropriate for almost any kind of data. The Chi Square (X^2) statistic is used to investigate whether distributions of categorical variables differ from one another. In this study the Chi Square test was used to compare grazing suitability maps from two different sources, to test whether the presence or absence of vultures was related to the suitability or unsuitability of the area for grazing and to test whether there is a significant difference between the distribution of adult and juvenile vultures.

The Independent samples t-test is used to test the difference between two groups on the basis of the means of a continuous variable. In this study, the independent samples t-test is used to test the difference between adults and juveniles based on the distance of their observation points to the nearest colony, considering the change occurs in the colony occupancy between seasons to test whether this change was caused by the difference in seasonal distributions of two age class between. The observations from different age classes were assumed to be independent off the age class of individuals.

All the statistical tests were implemented with a 95% confidence interval.

3. Results

3.1. Seasonal Griffon Vulture distribution maps

According to the summer-winter distinction made as described in 2.3.1, the presence only data for the vultures were divided at seasonal base (Figure 7). 813 points were recorded in summer and 562 points were recorded in winter.

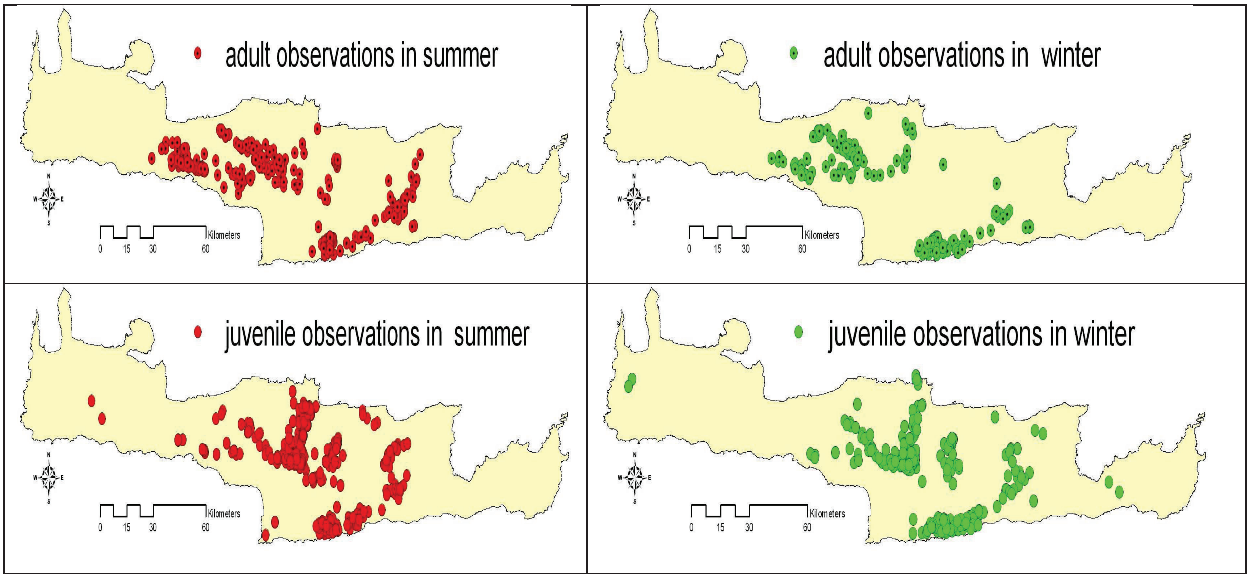


Figure 7: Seasonal distribution of griffon vultures in Crete (in total 1375 observations). Seasonal distribution maps of adults and juveniles were constructed according to age class. 474 points were classified as distributions of adults (186 winter and 288 summer) while 901 points were classified as distributions of juveniles (525 summer and 376 points winter).

Within a total of 1375 number of observation points, 1191 points were considered as representative of foraging individuals while the remaining 184 points were considered as not foraging based on the distance from colonies (1 km). Within the 1191 observations of foraging individuals (791 juvenile, 400 adult), 477 points were recorded during winter while remaining 714 points were recorded during summer (Table 3).

Table 3: Number of foraging adult and juvenile griffon vulture observations recorded during winter and summer periods in Crete.

Season	Frequency	Percent	Age class	Frequency	Percent
winter	477	40.1	juvenile	331	27.8
			adult	146	12.3
summer	714	59.9	juvenile	460	38.6
			adult	254	21.3
Total	1191	100		1191	100

After producing the seasonal potential prey (i.e. livestock and carcass) density maps, which were composed of polygons each representing a different density from its surrounding polygons, seasonal and yearly distribution maps of foraging griffon vulture were overlaid with these maps. By dividing the number of foraging vulture observations in each polygon by the polygon's area vulture densities for different combinations of age classes and seasons were estimated such as yearly vulture density and summer juvenile density maps. Then these vulture densities were exported with ascending prey densities to examine their relation.

3.2. Suitable areas for livestock grazing based on landcover / use

The differences in the size of polygons representing the suitable and unsuitable suitable areas for livestock grazing between NDVI-based and CORINE-based maps can be noticed easily from visual comparison of two maps shown in Figure 8. The polygons of suitable and unsuitable areas in the CORINE based map are look like smaller in size and more in number.

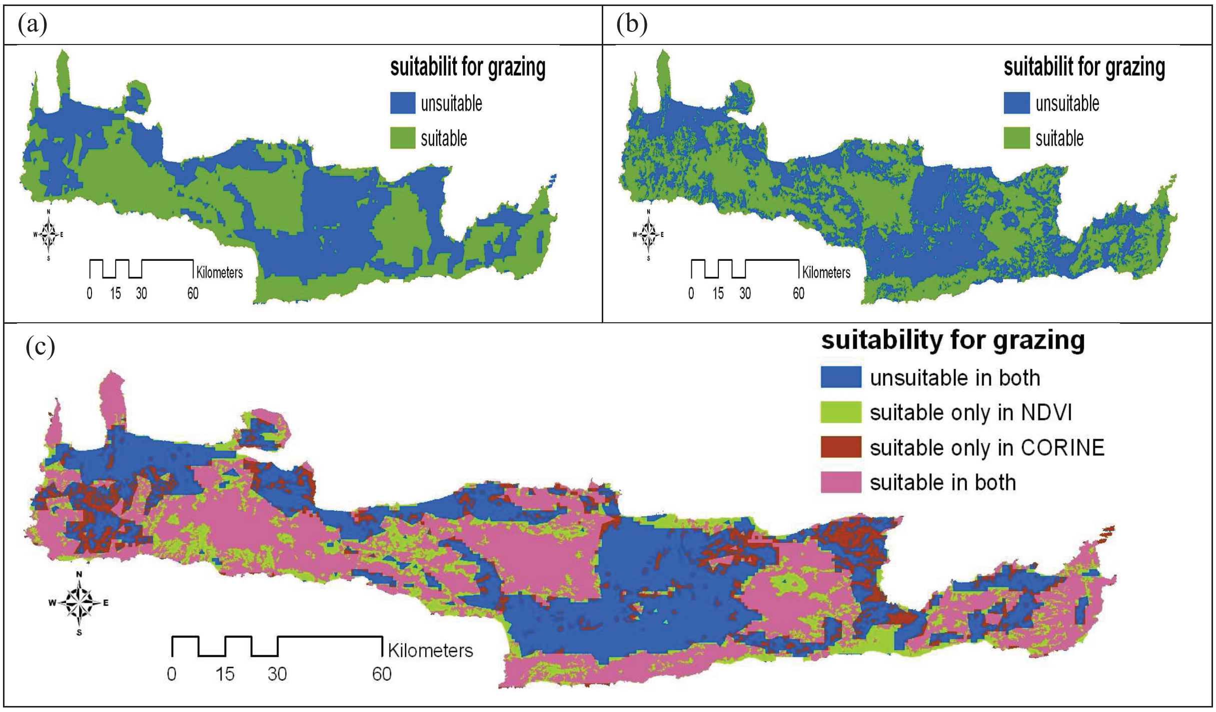


Figure 8: Suitable grazing areas according to reclassified NDVI map (a), CORINE map (b) and NDVI-CORINE maps together.

The visual interpretation was not enough to explain the difference between two maps and examining the numerical representations of the difference was necessary. Classified areas in the two different maps were consistent with each other at 75.31% (35.01% unsuitable in both + 40.3% suitable in both) while

13.54 % and 11.15% of the remaining 24.69% were classified as suitable for only NDVI and only CORINE, respectively (Table 4). The number of griffon vulture observations that fall on suitable areas for livestock grazing only in NDVI based map was 59 (4.95% of total number of observations) while the number of vulture observations for the same condition only in CORINE based map was 35 (2.94%). According to these numbers, the difference between two maps was not bigger then 25 % for whole island and it was not bigger than 8 % for the areas where griffon vultures were observed.

Table 4: The degree of matching between grazing suitability according to reclassified NDVI map and CORINE map.

Suitability	Km^2	Percentage (%)	No. of vulture observation	Percentage (%)
unsuitable in both maps	2920.83	35.01	59	4.95
suitable only in NDVI map	1129.54	13.54	59	4.95
suitable only in CORINE map	929.87	11.15	35	2.94
suitable in both maps	3361.86	40.3	1038	87.15
Total	8342.09	100	1191	100

To analyze the significance of this difference, Chi-square statistics were used (Tables 5 and 6) and the result was that the difference between classified areas in the two maps was not significant with a Chi-square value of 3.6131 smaller than 3.841 (Chi square for α=0.05). The null hypothesis that there is no significant difference between reclassified NDVI and CORINE maps in suitability for livestock grazing could not be rejected.

Table 5: Chi-square test statistics for the difference between classified areas in two maps.

total areas suitable in NDVI map	total areas (km^2) suitable in CORINE map	total area (km^2) of Crete
5456.93	5214.34	10135.43

Chi-square statistic	Degree of freedom	P value
3.6131	1	0.057

The second hypothesis (There is no significant difference in classifications of the areas where foraging griffon vultures were observed between the NDVI based and CORINE based suitability maps for livestock grazing) was also verified with a P value smaller than the P value for 95% significance level. This means that the difference was not significant for the places where observations were made. So, the suitability map for livestock grazing produced according to NDVI classification was as relevant as the CORINE Landcover/use map for Crete.

Table 6: Chi-square test statistics for the difference between classified areas where griffon vulture observations were made in two maps.

total number of vulture observations in suitable areas in NDVI map	total number of vulture observations in suitable areas in CORINE map	total number of vulture observations

1097	1073	1191
Chi-square statistic	Degree of freedom	P value
0.1389	1	0.709

3.3. Suitable areas for livestock grazing based on altitude

The suitable areas for livestock grazing in Crete based on NDVI classification and based on altitude are shown in Figure 9. In Figure 9 (c), the combination of the two maps, the final suitability map used in livestock density estimation, is shown representing the areas classified as suitable and unsuitable in both maps.

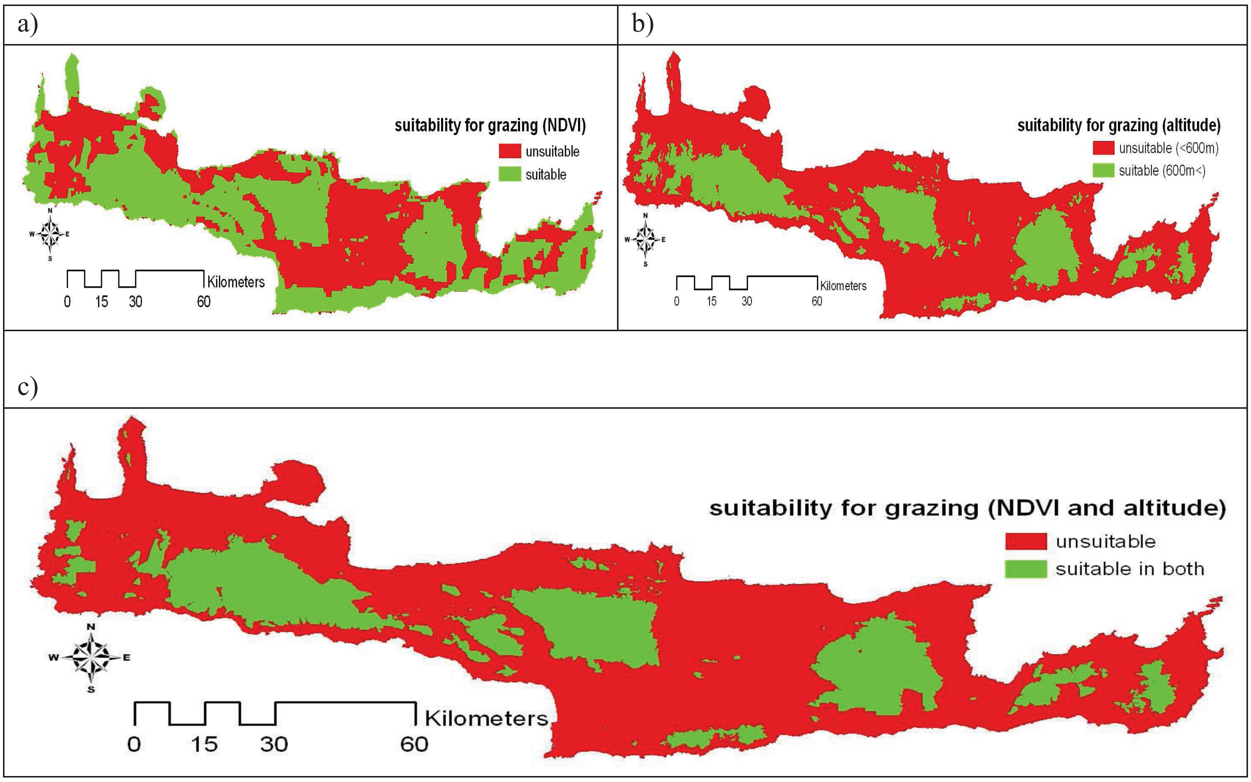


Figure 9: a) Suitability map for grazing based on NDVI map, b) suitability map for grazing based on altitude (DEM) and c) combination of two suitability maps showing the final map of suitability for livestock grazing in Crete.

The total area classified as suitable (2297.88 km^2) according to altitude was smaller; approximately half of the total area classified as suitable (4449.30 km^2) according to NDVI classification, as shown in Table 7. This big difference should be considered as a result of natural phenomena of the Earth that the acreage decreases with increasing altitude and the fact that the suitability for livestock grazing follows a similar pattern in both classifications in general should be considered as a sign of consistency of two classifications. As shown in the Table 9, 203.20 km^2 (8.84%) of the total suitable areas in the uplands (based on the altitude only) was excluded (classified as unsuitable) by the NDVI classification all around Crete.

Table 7: Suitable and unsuitable areas for livestock grazing in NDVI map, altitude (DEM) and in combination of both.

Suitability	Km^2	Percentage (%)

suitable in NDVI map	4449.30	53.34
unsuitable in NDVI map	3892.80	46.66
total	8342.09	100.00
suitable in DEM (altitude)	2297.88	27.55
unsuitable in DEM (altitude)	6044.22	72.45
total	8342.09	100.00
unsuitable in NDVI map and suitable in DEM	203.20	
total area of Crete	8342.09	

3.4. Livestock density estimation

The estimated seasonal densities of livestock are shown in Figure 10 with seasonal distribution of griffon vulture. The estimated livestock density was the highest in the middle region of Crete while the lowest was in the east part and the density of west region was moderate with varying values between 0 and 2864 livestock per km^2 for winter. Same pattern was followed in the summer density map with varying values between 0 and 3550 livestock per km^2.

The winter livestock density reflects the relation between official number of livestock in the municipalities and the area of each municipality, since this map was produced by dividing total number of sheep and goat per municipality in the livestock census data by the area (km^2) of each municipality. On the other hand, in summer the distribution of livestock and hence the density of livestock was more aggregated. The aggregation occurred in the areas which were classified as suitable based on the NDVI map and altitude. The areas with aggregated high densities of livestock were the areas found in places higher than 600 meters with suitable NDVI class for livestock grazing (one of the 13 NDVI classes). In the areas where livestock density was aggregated in the summer map, the quantity of livestock density was a result of the relation between NDVI value, altitude and number of transhumant livestock (77% of total) found in each one of three regions (west, middle and east, Figure 5). This is because livestock densities for these areas were calculated based on those three factors for summer. For the remaining areas where livestock density was mostly lower, the values were representing the relation between number of livestock registered to each municipality and its area like in winter, because the livestock density was calculated for these areas by using non-transhumant livestock number (23% of total) and area of each municipality.

It could be easily noticed from a visual interpretation of seasonal estimated density maps that the winter density of livestock in Crete showed a smoother distribution than the summer density. This was because of the assumption made in methodology that livestock are kept within municipal borders during winter. According to this assumption, livestock was not able to prefer any spatial distribution but it was kept within settlement areas during winter. On the contrary the summer livestock density showed more aggregated distribution over the suitable grazing areas because of the same assumption.

Figure 10 (b) and (d) show the seasonal livestock distribution maps together with the vulture distributions. Based on visual interpretation of two maps produced by overlaying estimated seasonal density of livestock and seasonal distribution of griffon vulture it can be said that observations of griffon vulture in winter and summer coincides with the areas where estimated livestock densities were high (yellow to green, indicating livestock densities from middle to high). The only difference between winter and summer is that the summer distribution of griffon vulture is more dispersed on the areas where estimated livestock density is aggregated. This could be caused by the difference between the numbers of griffon observations made during summer (N=813, 714 foraging and 99 resting) and during winter (N=562, 477 foraging and 85 resting).

Although it looks like the vultures are mostly present in areas with high livestock density, they are not evenly distributed within all the areas where livestock density is high, but they are rather mainly concentrated in three areas. One of these areas is in the inlands in the middle of the island, the second is in the inlands in the middle-east of the island, and the third is in the south coast.

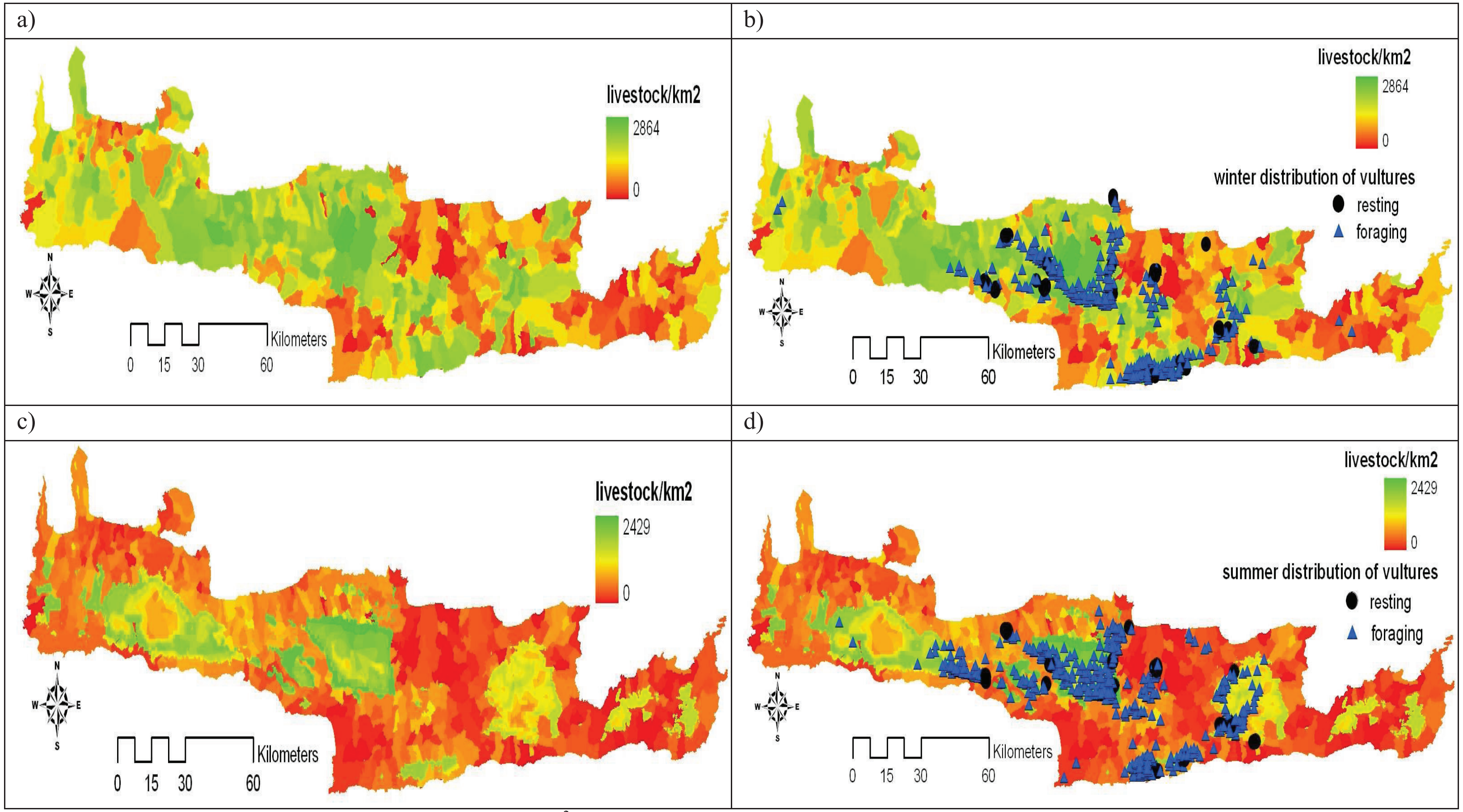
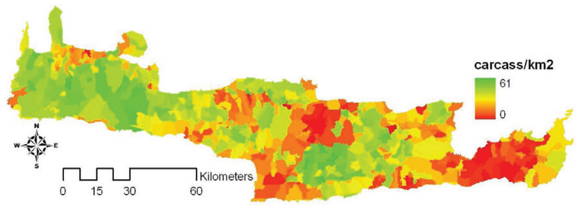


Figure 10: Estimated seasonal density of livestock as livestock per km^2 and seasonal distribution of griffon vulture in Crete. Where in a and c winter and summer densities of livestock were shown respectively while in b and d seasonal livestock densities were overlaid with winter and summer distributions of griffon vultures respectively. Griffon vultures were represented as resting and foraging means distance to the nearest colony was smaller and bigger than 1km respectively.

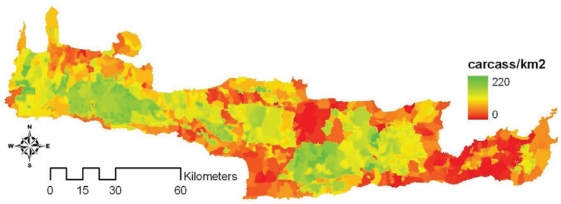
3.5. Carcass density estimation

Seasonal carcass density estimations for Crete produced by using carcass estimation data for ten regions and the livestock density estimation were shown in Figure 11 with the graphs representing the relation between seasonal livestock density and seasonal carcass density. For winter the highest carcass density was estimated 61 carcasses/km^2 while it increased to 220 carcasses/km^2 for summer.

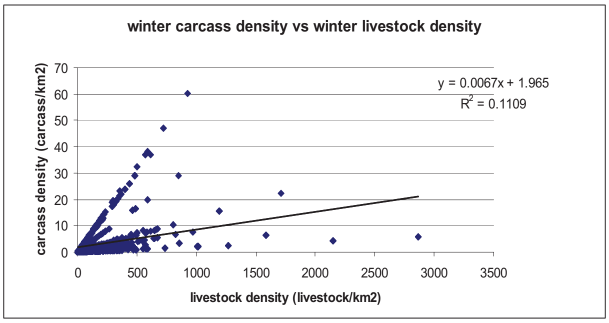
(a)



(b)



(c)



(d)

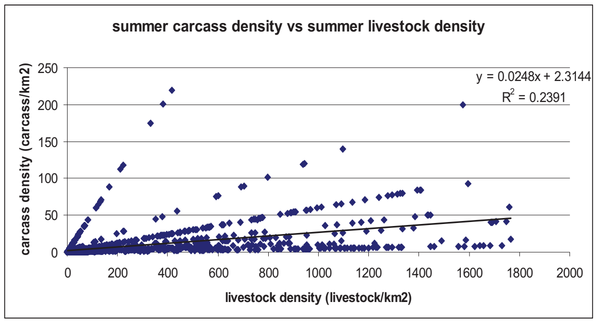


Figure 11: Carcass density estimations for (a) winter, (b) summer, carcass density versus livestock density for (c) winter and (d) summer

The strong linearity might be expected between seasonal livestock density and seasonal carcass density because estimated livestock numbers for each area were used as representing the seasonal distribution of livestock. Assuming the R^2 smaller than 0.5 does not indicate meaningful relation, the linearity between seasonal livestock density and seasonal carcass density was not considered as significant. The data showed linear trends in groups, which is caused by the calculation methodology of carcass density estimation, i.e. to calculate the carcass density for each area found within 11 different regions the estimated livestock density was multiplied by a different fraction for each one of 11 regions. Since the calculated carcass fractions for each region were different there was not an overall linear relation between estimated seasonal carcass densities and estimated seasonal livestock densities. Based on this conclusion estimated seasonal carcass densities were included as the second variable in analysis of relation between seasonal foraging distribution of griffon vulture and seasonal distribution of food in Crete. This was done in contemplation of two things, first if the estimated livestock density not explaining the seasonal distribution of griffon vulture and the second to improve the regression between estimated livestock density and griffon vulture foraging distribution because the seasonal livestock density estimated in this study was based on mainly NDVI classification, the carcass estimations based on the generalized ground observations of potential food.

3.6. Relation of suitability of the area for livestock grazing to observation of foraging Griffon Vulture

Chi-square test was implemented to test the relation between suitability of the areas where foraging griffon vultures were observed all the year, during winter and during summer.

Table 8: Relation of suitability of a polygon for grazing to observation of griffon vulture all the year.

	With vulture observation	Without vulture observation	Total
Number of suitable polygons for grazing	306	2920	3226
Number of unsuitable polygons for grazing	40	1726	1766
Total	346	4646	4992

Chi square	Degree of Freedom	P value
92.2358	1	0.000

Table 9: Relation of suitability of a polygon for grazing to observation of griffon vulture during winter.

	With vulture observation in winter	Without vulture observation in winter	Total
Number of suitable polygons for grazing	180	3043	3349
Number of unsuitable polygons for grazing	19	1748	1767
Total	199	4791	4992

Chi square	Degree of Freedom	P value
60.6166	1	0.000

Table 10: Relation of suitability of a polygon for grazing to observation of griffon vulture during summer.

	With vulture observation in summer	Without vulture observation in summer	Total
Number of suitable polygons for grazing	236	2995	3231
Number of unsuitable polygons for grazing	28	1739	1767
Total	264	4728	4992

Chi square	Degree of Freedom	P value
74.6919	1	0.000

All of the P values (X^2 : 92.236, 60.616 and 74.6919) were above the conventionally accepted value for the significance level of 0.05 with significance 0.000. So, three null hypotheses that observation of the griffon vulture is independent of the area's suitability for livestock grazing all the year, during winter and during summer were rejected. In other words, the probability of observing griffon vultures is dependent on the area’s suitability for livestock grazing both yearly and seasonally. According to the analysis of the relation between suitability of the area for livestock grazing and observation of griffon vulture, the high number of griffon vulture observation in the suitable areas and low number of griffon vulture observation in the unsuitable areas during the year, winter and summer was not due to chance and strongly related to suitability for livestock grazing.

3.7. Relation of estimated seasonal livestock and carcass density to observed seasonal density of foraging Griffon Vultures

a) b)

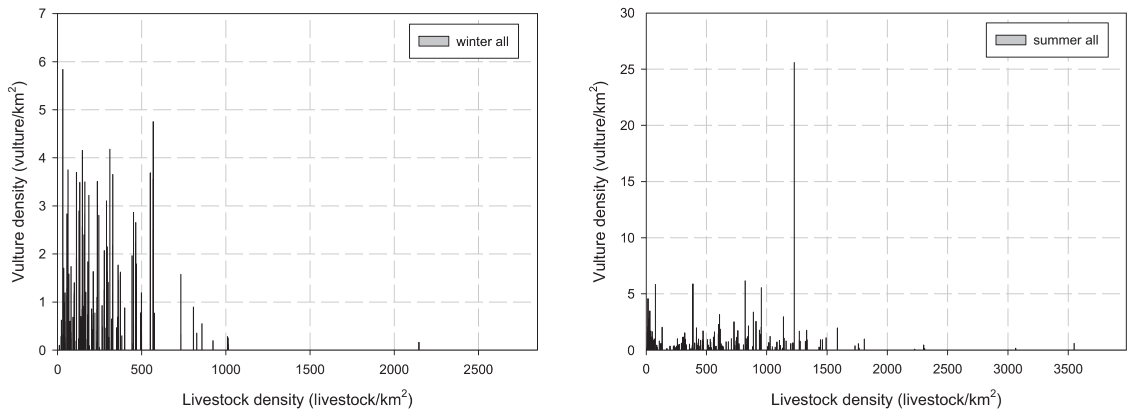


Figure 12: Relationship of vulture density and livestock density for (a) winter and (b) summer

The relation between seasonal densities of griffon vulture and estimated seasonal densities of livestock were shown in Figure 12, where the winter (a) and summer (b) densities of foraging griffon vulture was shown on y axis against the estimated winter and summer densities of livestock on x axis. By a visual interpretation of graphs both of them do not imply any significant relation between datasets.

a) b)

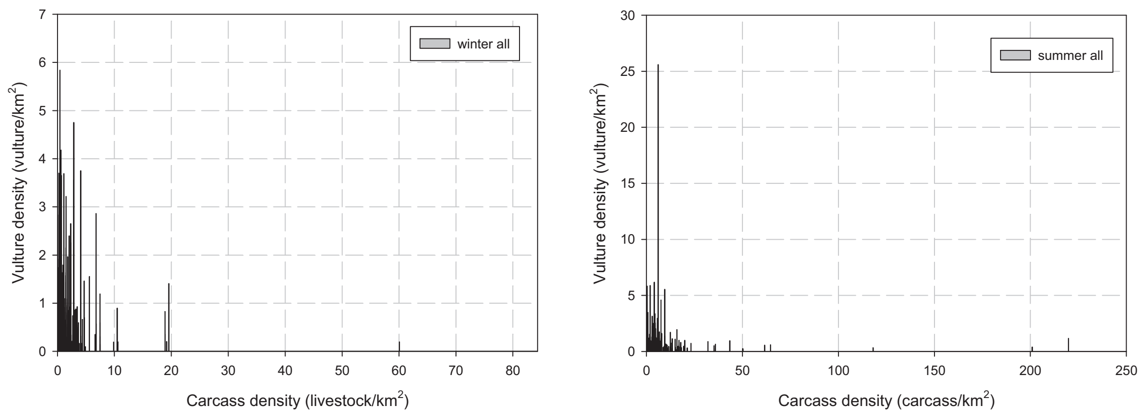


Figure 13: Relationship of vulture density and carcass density for (a) winter and (b) summer

The seasonal foraging griffon vulture densities were plotted against seasonal carcass densities are shown in Figure 13, following an aggregated pattern close to 0 on the X axis. The same think with the previous figure can be said that the distributions of data do not look like imply any relation. All four relations were tested if there is a regression between variables and results were shown in Table 11 and 12 respectively. Model 1 stands for relation of livestock density in both seasons and Model 2 represents the test results for relation of seasonal carcass density to seasonal vulture density.

Linear regression was implemented to detect the relation between estimated seasonal densities (km^2) of livestock and seasonal densities of griffon vulture observations and the relation between estimated seasonal densities (km^2) of carcass and seasonal densities of griffon vulture observations in Crete. Linear regression was executed in SPSS for winter and summer separately. For each season, two analyses were made to test the regression between griffon vulture densities with livestock density and carcass density.

Table 11: Relation between livestock density and vulture density and carcass density and vulture density in winter

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	Sig.	R Square
1	(Constant)	0.979	0.100		0.000	
	livestock density in winter (livestock/km2)	0.000	0.000	-0.013	0.844	0.000
2	(Constant)	1.009	0.072		0.000	
	carcass density in winter (carcass/km2)	-0.020	0.014	-0.097	0.138	0.009

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Table 12: Relation between livestock density and vulture density and carcass density and vulture density in summer

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	Sig.	R Square
1	(Constant)	0.707	0.163		0.000	
	livestock density in summer (livestock/km2)	0.000	0.000	0.091	0.151	0.008
2	(Constant)	0.881	0.120		0.000	
	carcass density in summer (carcass/km2)	- 0.001	0.002	-0.018	0.776	0.000

The results from linear regression shown in Table 11 and Table 12 indicated that the density of foraging griffon vulture was not related to estimated density of livestock for winter ($R^2 = 0.000$) and for summer ($R^2 = 0.008$) and estimated density of carcass in winter ($R^2 = 0.009$) and for summer ($R^2 =0.000$).

3.8. Comparison of foraging distributions of adult and juvenile Griffon Vultures

3.8.1. Relation of estimated seasonal livestock and carcass density to observed seasonal density of foraging adult and juvenile Griffon Vultures

a) b)

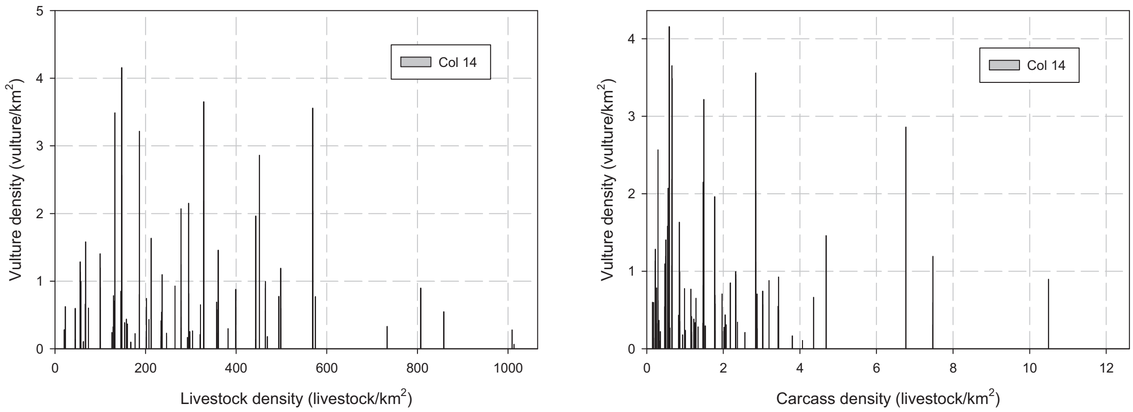


Figure 14: Relation between livestock density and adult vulture density and carcass density and adult vulture density in winter

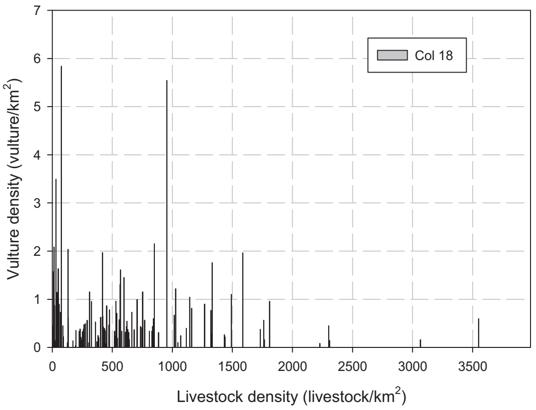
The winter density of adult griffon vulture observations was plotted in Figure 14 against the estimated winter livestock density (a) and estimated winter carcass density (b) and the linear regression test statistics are shown in table 13, where Model 1 represents the test statistics for winter livestock density and Model 2 for winter carcass density with relation to winter adult vulture density.

Table 13: Relation between livestock density and adult vulture density and carcass density and adult vulture density in winter

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	Sig.	R Square
1	(Constant)	0.828	0.149		0.000	
	livestock density in winter (livestock/km2)	0.000	0.000	0.016	0.875	0.000
2	(Constant)	0.839	0.120		0.000	
	carcass density in winter (carcass/km2)	0.005	0.048	0.010	0.923	0.000

The results from linear regression shown in Table 13 indicated that the density of foraging griffon adult vultures was not related to estimated density of livestock (R^2 = 0.000) and estimated density of carcass (R^2 = 0.000) in winter.

a) b)



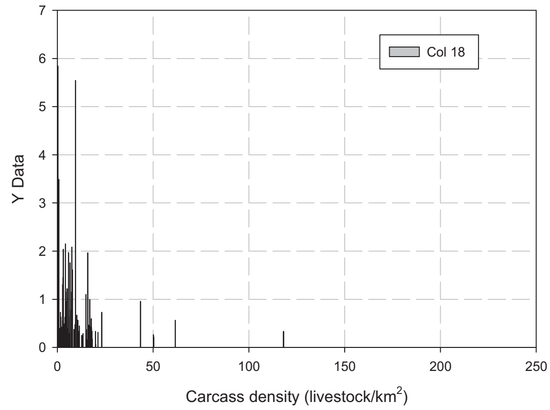


Figure 15: Relation between livestock density and adult vulture density and carcass density and adult vulture density in summer

Table 14: Relation between livestock density and adult vulture density and carcass density and adult vulture density in summer

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	Sig.	R Square
1	(Constant)	0.692	0.103		0.000	
	livestock density in summer (livestock/km2)	0.000	0.000	-0.025	0.777	0.001
2	(Constant)	0.671	0.077		0.000	
	carcass density in summer (carcass/km2)	0.000	0.001	0.006	0.119	0.000

The results from linear regression shown in Table 14 indicated that the density of foraging griffon juvenile vultures was not related to estimated density of livestock (R^2 = 0.001) and estimated density of carcass (R^2 = 0.018) in winter.

The summer density of adult griffon vulture observations was plotted in Figure 15 against the estimated summer livestock density (a) and estimated summer carcass density (b) and the linear regression test statistics are shown in table 14, where Model 1 represents the test statistics for summer livestock density and Model 2 for summer carcass density with relation to summer adult vulture density. The following figures (Figure16 and 17) with following tables (Table 15 and 16) are shown to represent the same sequence of relations for juveniles.

a) b)

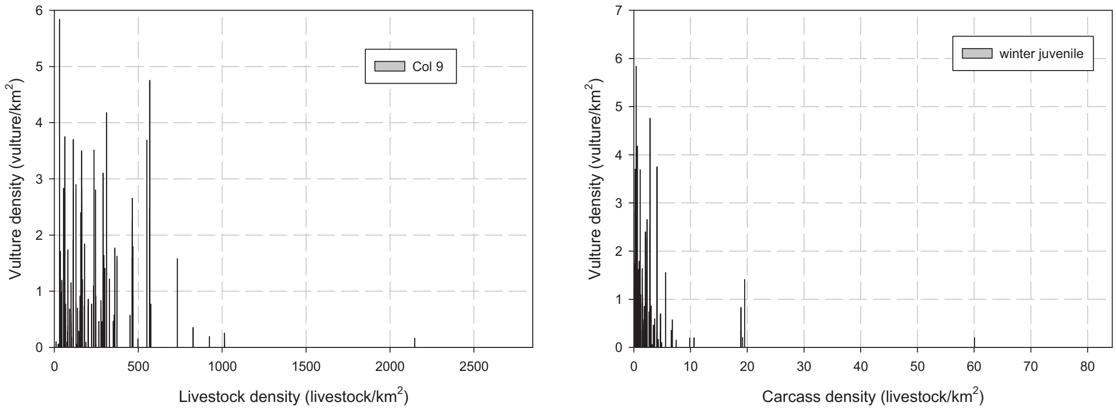


Figure 16: Relation between livestock density and juvenile vulture density and carcass density and juvenile vulture density in winter

Table 15: Relation between livestock density and juvenile vulture density and carcass density and juvenile vulture density in winter

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	Sig.	R Square
1	(Constant)	1.075	0.135		0.000	
	livestock density in winter (livestock/km2)	0.000	0.000	-0.021	0.814	0.000
2	(Constant)	1.115	0.101		0.000	
	carcass density in winter (carcass/km2)	- 0.024	0.015	-0.136	0.119	0.018

a) b)

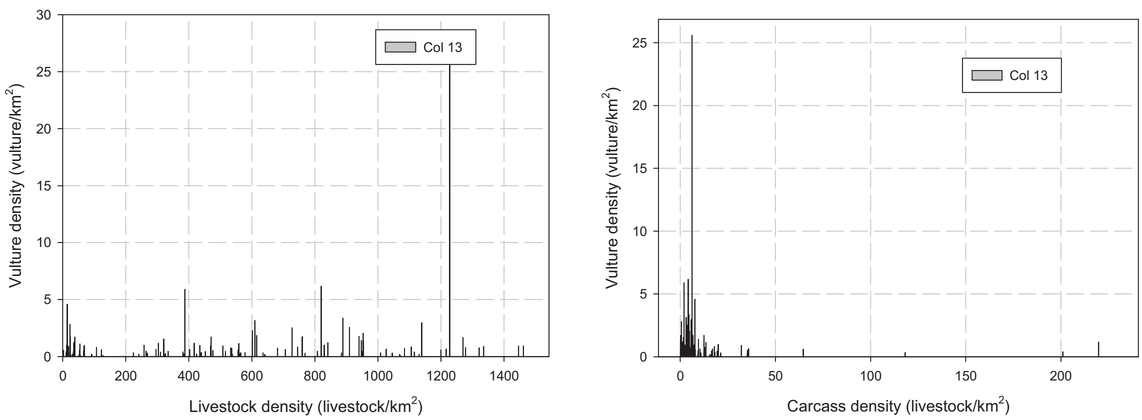


Figure 17: Relation between livestock density and juvenile vulture density and carcass density and juvenile vulture density in summer

Table 16: Relation between livestock density and juvenile vulture density and carcass density and juvenile vulture density in summer

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	Sig.	R Square
1	(Constant)	0.484	0.327		0.142	
	livestock density in summer (livestock/km2)	0.001	0.001	0.215	0.017	0.001
2	(Constant)	1.119	0.239		0.000	
	carcass density in summer (carcass/km2)	-0.004	0.008	-0.043	0.634	0.002

Table 17 shows the results of the t-test carried out if there is a significant difference between the means of the livestock and carcass densities where adult and juvenile vultures were observed, in summer and in winter. According to the test statistics, none of the pairwise comparisons showed a significant difference between adult and juvenile vultures in this respect. So there was not any significant difference between the seasonal foraging distribution of adults and juveniles with respect to the seasonal density of potential prey.

Table 17: Comparison of the means of the livestock and carcass densities where adult and juvenile vultures were observed, in summer and in winter

	t	df	Sig.
livestock density in winter (livestock/km2)	-1.249	475	0.212
carcass density in winter (carcass/km2)	1.516	475	0.13
livestock density in summer (livestock/km2)	-1.145	712	0.253
carcass density in summer (carcass/km2)	-0.198	712	0.843

The Chi-square test was implemented to test spatial distribution of foraging adult griffon vultures and foraging juvenile griffon vultures. Numbers of polygons with only adult observations and with only juvenile observations were used to construct a Chi-square statistic. The polygons were resulted during suitability for grazing and livestock density estimation processes. These processes based on NDVI, livestock census (municipal borders) and altitude maps resulting in total 4992 polygons covering whole Crete.

H_0: There is no significant difference in spatial distribution of adult and juvenile vultures while foraging all year.
Ha: There is significant difference in spatial distribution of adult and juvenile vultures while foraging during all year.

Table 18: Chi square statistics comparing the foraging distribution of adult and juvenile griffon vultures

	Only Adult	Only Juvenile	Adult-Juvenile Together

Present	123	138	86
Not present	4783	4768	4645
Total	4906	4906	4731
Chi square	df	P value	
0.8856	1	0.5<P<0.05	

With this Chi-Square statistic the corresponding probability was 0.8856 (< 0.05), which was below the conventionally accepted significance level of 0.05 so the null hypothesis that there is no significant difference between spatial distribution of adult and juvenile vultures while foraging during the year could not be rejected. In other words X^2 statistic (0.8856) did not exceeded the critical value for a 0.05 probability level, so spatial distribution a foraging juvenile vulture was not significantly different than the spatial distribution of a foraging adult.

Before testing the hypotheses with Chi square test that probability of observing a foraging adult griffon vulture is equal to the probability observing a foraging juvenile vulture all year, in summer and in winter, average observation number / individual/ age class was calculated. The griffon vulture data was consisted of observation points of 15 individuals, 10 juveniles and 5 adults. The observed values were tested against the hypothetical expected distribution that probability of observing a juvenile is equal to observing an adult during whole year, during summer and during winter. Within total number of foraging griffon vulture observations (1191) during whole year, 791 observations were recordings of juveniles while the remaining 400 were recording of adults. Observed average observation numbers for each bird within each group were 79.1(=791/10) for juveniles and 80.0 (=400/5) for adults. For winter numbers of adult and juvenile observations were 146 and 331 respectively within total 477 observations, while 254 adult and 460 juvenile observations resulting in total 714 observations were recorded during summer.

Table 19: Chi square test statistics to test if probability of observing a foraging adult griffon vulture is equal to the probability observing a foraging juvenile vulture all year, in summer and in winter.

	X2 (Chi-Square)	Degrees of Freedom	P Value
During whole year	0.0032	1	<<0.05
During summer	0.246		<0.05
During winter	0.3918		<0.05

With this Chi-Square statistics the corresponding probability were 0.0032, 0.246 and 0.3918 (< 0.05) for all year, summer and winter respectively. Three of them were below the conventionally accepted significance level of 0.05 so the hypotheses that probability of observing foraging individuals from each of the two age classes was equal during the year, summer and winter could not be rejected. In other words X^2 statistics did not exceed the critical value for a 0.05 probability level, so probability of observing a juvenile vulture was not different than the probability of observing an adult during the year and both seasons. Since the chance of observing individuals from one of two age classes was equal to the chance of observing individuals from other age class any time interval of the year, it was concluded that there is no difference between foraging distribution of juveniles and foraging distribution of adults.

3.8.2. Relationship between age class of griffon vulture and the distance to the colony

The hypothesis that there is no significant difference between mean distance to the colony of adult and mean distance to the colony of juveniles was tested by implementing independent samples t-test.

Ho: In any defined distance with respect to the nearest griffon vulture colony the probability of observing a foraging juvenile griffon vulture is equal to the probability of observing a foraging adult griffon vulture.

Ha: In a defined distance with respect to the nearest griffon vulture colony the probability of observing a foraging juvenile griffon vulture is not equal to the probability of observing a foraging adult griffon vulture

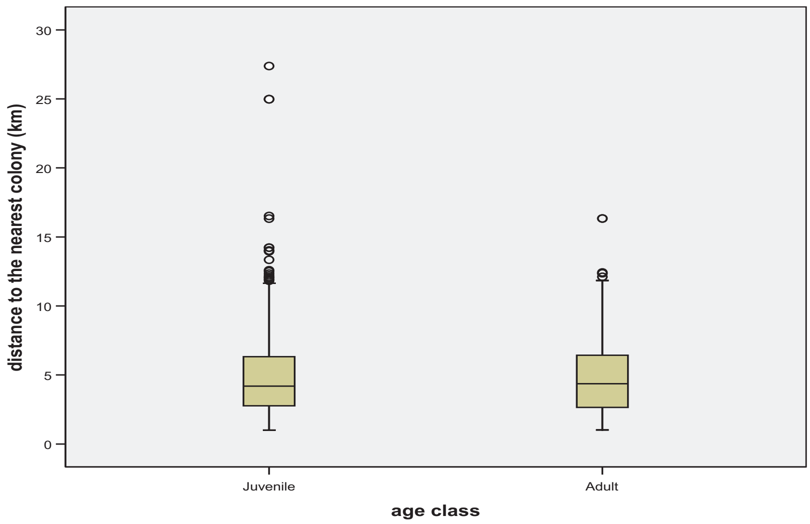


Figure 18: The distance to colony for juvenile and adult griffon vultures

Independent samples t-test was applied to examine the relationship between age class of griffon vulture and the distance to the nearest colony all year.

Table 20: The distance to colony for juvenile and adult griffon vultures

				age class	N	Mean	Std. Deviation
t	df	P	distance to the nearest colony (km2)	juvenile	791	4.9283	3.1079
0.6553	1189	0.5123 (0.05<)		adult	400	4.8074	2.7943

With a significance value of 0.5123 which is bigger than 0.05, the null hypothesis could not be rejected, that there is no difference between foraging adult and juvenile griffon vultures in relation to distance to the nearest (km) colony all year. In other words the relationship between distance to the nearest colony and distribution of foraging adult and juvenile griffon vultures does not differ significantly all year and the small difference between mean the distance to the nearest colony where observations were made was due to chance.

Same analysis was implemented to test the same relation in seasonal base and its results were consistent with the above test results, with P values 0.0082 and 0.2810 for winter and summer respectively. According to these results null hypothesis, which were in a distance from a colony probability of observing a foraging juvenile vulture is equal observing a foraging adult vulture, were verified for all year, winter and summer periods.

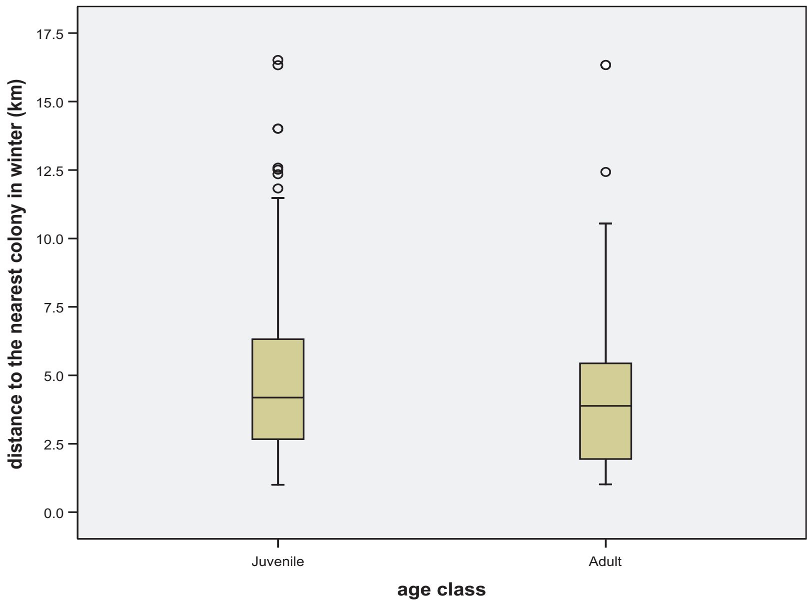


Figure 19: The distance to colony for juvenile and adult griffon vultures in winter

Independent samples t-test was applied to examine the relationship between age class of griffon vulture and the distance to the nearest colony in winter.

Table 21: The distance to colony for juvenile and adult griffon vultures in winter

				age class	N	Mean	Std. Deviation
t	df	P	distance to the nearest colony in winter (km2)	juvenile	331	4.9676	2.9974
2.6524	475	0.0082 (<0.05)		adult	146	4.1989	2.7245

With a significance value of 0.0082 which is smaller than 0.05, the null hypothesis was rejected, that there is no difference between foraging adult and juvenile griffon vultures in relation to distance to the nearest (km) colony in winter. In other words the relationship between distance to the nearest colony and distribution of foraging adult and juvenile griffon vultures differs significantly in winter and the difference between mean distance to the nearest colony where observations were made was not due to chance. In other words adults were observed nearer to the nearest colony while juveniles were observed more far from the nearest colony was not due to chance.

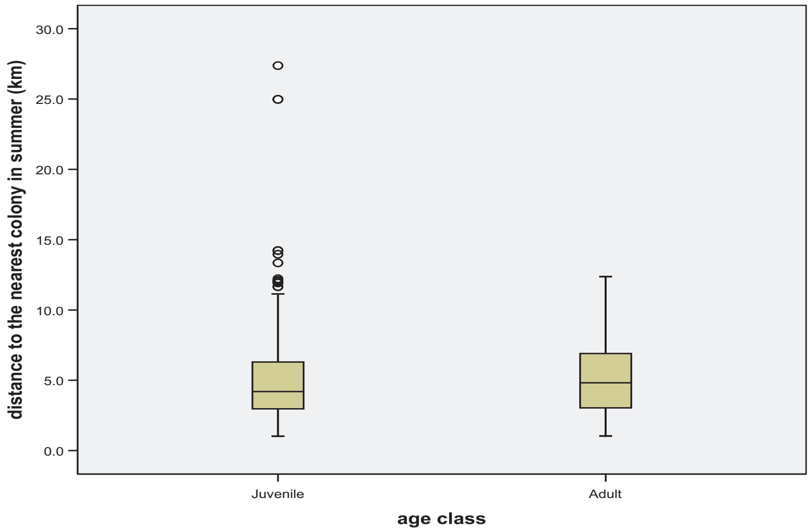


Figure 20: The distance to colony for juvenile and adult griffon vultures in summer

Independent samples t-test was applied to examine the relationship between age class of griffon vulture and the distance to the nearest colony in summer.

Table 22: The distance to colony for juvenile and adult griffon vultures in summer

				age class	N	Mean	Std. Deviation
t	df	P	distance to the nearest colony in summer (km2)	juvenile	460	4.9001	3.1880
1.0788	712	0.2810 (0.05<)		adult	254	5.1573	2.7792

With a significance value of 0.2810 which is bigger than 0.05, the null hypothesis could not be rejected, that there is no difference between foraging adult and juvenile griffon vultures in relation to distance to the nearest (km) colony in summer. In other words the relationship between distance to the nearest colony and distribution of foraging adult and juvenile griffon vultures does not differ significantly in summer and the difference between mean distances to the nearest colony where observations were made was due to chance. In other words there is no difference in relation to the distance to the nearest colony between foraging adult and juvenile griffon vultures during summer.

Since the chance of observing individuals from one of two age classes was equal to the chance of observing individuals from other age class, it was concluded that there is no difference in average distance to the nearest colony between foraging juveniles and foraging adults.

4. Discussion

4.1. Relation of landcover/use to annual and seasonal distribution of griffon vulture

The landcover/use type is considered as an important factor effecting the species distribution in general. The relation of landcover/use to griffon vulture distribution in Crete was significant during every period of the year. This significant relation was shown over the lancover/use types' suitability for livestock grazing. The significant correlation between areas classified as suitable for livestock grazing and distribution of griffon vulture can be interpreted as a sign of relation between livestock and griffon vulture distributions. Based on these results we can say that both the griffon vulture's and livestock's spatial distributions coincides with the assumption that the suitability classification was correct. The significant consistency between CORINE based classification and NDVI based classification supports this assumption.

However this coincidence might be resulted by other factors such as openness of the suitable areas. Because griffon vulture prefers open areas for foraging and the areas classified as suitable for livestock grazing were mainly open areas.

4.2. Relation of seasonal distribution of potential prey to seasonal distribution of griffon vulture

Generally food availability was considered as the most important factor related to raptors spatial and temporal distribution. On the contrary, in this study the relation between estimated seasonal distribution of livestock and seasonal distribution of griffon vulture in Crete was found not to be significant and there was no correlation. That is on the contrary what is expected, that griffon vulture's seasonal distribution is closely related to potential prey which is mainly livestock in Crete. This could be explained in more than one way.

The first one is to suspect the methodology that was applied to estimate the seasonal density of livestock, on the base of it there was the NDVI map with 27 NDVI classes. It can be said that if there is a correlation between seasonal distributions of livestock and griffon vulture in reality and this study can not explain the reality, most probably it is not caused by reclassification of NDVI map to estimate the areas for livestock grazing. Because it was proven that the reclassified NDVI map was significantly consistent with CORINE2000 Landcover map which is a conventionally excepted data source and the proven correlation between griffon distribution and the areas classified as suitable for livestock grazing based on these two maps is another reason to believe that accuracy of classification was acceptable.

The estimation of livestock number distribution might be suspected as resulting in an unrealistic livestock distribution, hence the livestock density in Crete. Then the assumption that NDVI values reflects the available green biomass for grazing should be revised. Another assumption related to livestock distribution was that 77% of total number of livestock is transported to the uplands in summer and 100% of it is kept within pens near or in the human settlement areas. Here the altitude determined as lower border for livestock grazing (600m) also might be suspected but then it should be expected the estimated winter density would have explain the distribution of griffon vulture better than estimated summer livestock density because it was based on real livestock number and did not distributed according to any assumption, but it also did not have any correlation for winter. The relation was also not explained by estimated carcass density, this can be considered as expected because carcass density estimation was based on combination of field measurements data obtained from NHMC and estimated seasonal livestock density. Then the linearity between estimated carcass density and estimated livestock density should also be expected to be significant according to this consideration, but it was not.

The second way to explain this unexpected result is the high abundance of livestock in Crete, the determining factor might not be expected as livestock in Crete, because of high density of livestock. According to official records total number of livestock found in Crete is nearly 1200,000 and total area of Crete is approximately 8,336 km2 and this results 143.9 livestock/km2 if assume that the livestock distributes evenly. This also supports the findings of this study about the relation between seasonal density of livestock and seasonal density of griffon vulture in Crete, that there is no significant relation between these two variables.

The third way to explain the finding of this study might be related to foraging behavior of griffon vulture, that they use thermals to gain altitude and glides in the air while searching visually for potential prey. This behavior that they soar in the air make them travel long distances for searching food (foraging radius is 8.4 km) and it can be speculated that their seasonal distribution might be coincide with area with high potential food (carrion) rather with the area with high density of livestock.

4.3. Comparison of foraging distributions of adult and juvenile Griffon Vultures

According to the findings of this study, there is no significant difference between the seasonal foraging distribution of juvenile and adult griffon vultures and there is also no significant difference between the distance of adult and juvenile griffon vultures to the nearest colony. The relation between livestock or carcass density and vulture density for both adults and juveniles was also not significant. This finding supports the findings in relation to the first hypothesis and also the conclusion that there is no significant difference between seasonal distribution of juveniles and adults.

5. Conclusion and recommendations

5.1. Conclusions

1. There is a significant relation between the distribution of griffon vultures and the suitability of the areas for grazing based on the landcover / use and altitude.
2. There is no significant relation between the livestock density or carcass density and the griffon vulture density at seasonal base.
3. There is no significant relation between the livestock density or carcass density and the griffon vulture density for adults and juveniles.
4. There is no significant difference between the seasonal foraging distribution of adult and juvenile vultures.
5. There is no significant difference between the distance of adult and juvenile vultures to the nearest colony.

5.2. Recommendations

1. Environmental factors can be important in the seasonal foraging distribution of the griffon vultures. For future research, this should be examined. Especially, the environmental factors related with thermal occurrence, such as wind speed and solar radiation can be significant.
2. To estimate the distribution of potential prey, the presence and location of feeding stations and illegal and legal waste dumps should be investigated and taken into account.
3. To analyze the difference between the distribution of adult and juvenile griffon vultures, continuous observations should be made rather than random sampling.

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APPENDIX

Code	Label_Level	Label Level 1	Label Level 2	suitability
111	Artificial surfaces	Urban fabric	Continuous urban fabric	0
112	Artificial surfaces	Urban fabric	Discontinuous urban fabric	0
121	Artificial surfaces	Industrial, commercial and transport units	Industrial or commercial units	0
122	Artificial surfaces	Industrial, commercial and transport units	Road and rail networks and associated land	0
123	Artificial surfaces	Industrial, commercial and transport units	Port areas	0
124	Artificial surfaces	Industrial, commercial and transport units	Airports	0
131	Artificial surfaces	Mine, dump and construction sites	Mineral extraction sites	0
133	Artificial surfaces	Mine, dump and construction sites	Construction sites	0
142	Artificial surfaces	Artificial, non-agricultural vegetated areas	Sport and leisure facilities	0
211	Agricultural areas	Arable land	Non-irrigated arable land	0
221	Agricultural areas	Permanent crops	Vineyards	0
222	Agricultural areas	Permanent crops	Fruit trees and berry plantations	0
223	Agricultural areas	Permanent crops	Olive groves	0
231	Agricultural areas	Pastures	Pastures	0
242	Agricultural areas	Heterogeneous agricultural areas	Complex cultivation patterns	0
243	Agricultural areas	Heterogeneous agricultural areas	Land principally occupied by agriculture, with significant areas of natural vegetation	1
311	Forest and semi natural areas	Forests	Broad-leaved forest	0
312	Forest and semi natural areas	Forests	Coniferous forest	0
313	Forest and semi natural areas	Forests	Mixed forest	0
321	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Natural grasslands	1
322	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Moors and heathland	1
323	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Sclerophyllous vegetation	1
324	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Transitional woodland-shrub	1
331	Forest and semi natural areas	Open spaces with little or no vegetation	Beaches, dunes, sands	0
332	Forest and semi natural areas	Open spaces with little or no vegetation	Bare rocks	1
333	Forest and semi natural areas	Open spaces with little or no vegetation	Sparsely vegetated areas	1
512	Water bodies	Inland waters	Water bodies	0
523	Water bodies	Marine waters	Sea and ocean	0