# Application of Geographic Information Systems to assess the environmental suitability for reintroduction of Griffon Vulture (*Gyps fulvus*) in Retezat National Park, Romania.

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by

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# Abstract

This study presents an application of Geographic Information Systems (GIS) to a raptor conservation problem: Retezat National Park (Romania) was evaluated for its environmental suitability to support a new population of Griffon Vulture (*Gyps fulvus*).
Existing and derived geo-data were used together with a set of biological and ecological criteria relevant for the target species. Additionally, experts' knowledge provided support to compensate for lacking information.

The suitability was assessed in relation to two main biological activities: breeding (nesting/breeding) and feeding.
Main objectives were the evaluation of the park's area in relation to the probability to be chosen as nesting/breeding places and the estimation of the size of the population sustainable by the park's resources.

Mahalanobis Distance was used to derive the suitability of the area in relation to topographic parameters.
The analysis identified 7 zones with positive probability to act as nesting/breeding sites.
The maximum population size was estimated after developing three different scenarios, each corresponding to a particular feeding behaviour. Each scenario gave a different value for the maximum carrying capacity, but two zones always stood out for relative highest values. Due to the performance of the zones mentioned above, to their extent and to the fact that they are close to the known suitable nesting places, they were suggested as areas where the reintroduction could start.

The maximum value for the carrying capacity showed that the number of vultures sustainable solely from the park resources is lower than the number suggested by similar projects.
This finding, suggests the investigation of available resources in the area surrounding the park, before making any final decision on the opportunity to start the conservation programme.

Although limited by the amount of available data, the model presented here shows how GIS can be adapted to different assumptions and requirements, giving a powerful tool to support planning and management activities aiming at conservation of natural resources.

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# Table of contents

# List of figures

# List of tables

# Acronyms

DEM: Digital Elevation Model

ETM+: Enhanced Thematic Mapper Plus

GIS: Geographic Information Systems

NP: National Park

RGB: Red Green Blue

RS: Remote Sensing

UTM: Universal Transverse Mercator

# 1. Introduction

## 1.1. Background

Species, genera and families have been lost in the past, and new ones have replaced them. Usually three types of extinction can be identified: *global extinction* for species which does not have any members alive (including cases of individuals of a species remaining alive only in human-controlled situations), *local extinction* for species no longer found in a part of its former distribution range, but still found elsewhere in the wild, and *ecological extinction* for species persisting at such reduced numbers that its effects on its community are negligible (Primack, 1993).
The natural rate of extinction, defined as the extinction in absence of human influence, has been estimated through the study of the fossil record, and compared with the current observed rate of extinction for bird and mammal species (0.01% per year). The result shows that the actual rate of extinction is 100 to 1000 times greater than would be predicted based on the background rates (Primack, 1993; Meffe & Carroll, 1994).

The different types of extinction processes are related with different types of rarity, which are determined by species' patterns distributions. A species can therefore be rare because of highly restricted geographic range, because of high habitat specificity, because of small population size, or because of various combinations of these characteristics. Human-caused rarity may be more devastating than natural rarity if the species is not adapted to have low numbers, driving very abundant species to or near extinction.
Additionally, long-lived species developed characteristics such as delayed sexual maturity, low fecundity, and reliance on juveniles' survivorship, not favourable to rapid response to a human-disturbed environment (Meffe & Carroll, 1994).
Finally, when a species goes globally extinct, its chances for further evolution are lost; if the rate of speciation is lower than the rate of extinction, the biological diversity, resulting from the evolutionary process, is itself also rapidly declining.

With the increasing awareness on the value of the biodiversity and on the necessity to establish conservation priorities, methods of population viability analysis with focus on population trends and habitat conditions, have been developed and used to classify known species based on their probability of extinction over a period of time (Primack, 1993).

Captive breeding programs and consequent releases of captive-bred animals, have been adopted as measure to counteract species decline. Nevertheless, numerous problems are associated with the restoration of animals to the wild. In the following paragraph some of them are presented.

## 1.2. Problem statement

One accepted goal of captive breeding programs, is the eventual introduction of captive-bred animals to their wild habitat, for example to restore the species to a former range, or to strengthen the breeding nucleus of a decreasing population (Soulé & Wilcox, 1980).
Although literature gives evidence of successful programs, numerous problems are encountered. Some of them are here listed (Primack, 1993; Negro & Torres, 1999):

- Introduced animals sometimes leave the release area and migrate to a place they are not supposed to be.
- Animals to be released may carry diseases that can be transmitted to wild populations of their own or other species.
- Law and bureaucratic procedures often complicate efforts to release captive bred animals.
- Animals resulting from several generations of captive breeding are less likely to be successful than animals that are translocated or first-generation captive-bred animals.
- Long-generation captive-bred populations may have lost much of their genetic component, due to inbreeding.
- Source population may not be genetically close to the original native stock.
- Finally, restoration programs are unlikely to work effectively, if the factors leading to the decline of the original wild population are not clear understood and/or still exist, and if the social context does not support the program.

A sound feasibility study may increase the possibility of successfully accomplishing a reintroduction program. To minimize the effects of unforeseen events, efforts should be directed towards an accurate analysis of all relevant elements; some of the common elements worthy of attention are the biological characteristic and the ecologic requirements of concerned species, its genetic position and the veterinary aspect; elements not species-specific, but related with the human and therefore important to increase the possibility of a success, are the social context, the economic cost and the legal situation.

This study is an attempt to evaluate the environmental suitability of Retezat National Park, on the basis of Griffon Vulture ecology and biology. The use of Geographic Information Systems (GIS) is meant to emphasize the spatial component of the analysis, and to act as an example of the application of GIS within the field of conservation.

# 2. Objectives

## 2.1. Introduction

The following study fits in the frame of a conservation programme aiming at the reintroduction of Griffon Vulture (*Gyps fulvus*) in Retezat National Park (NP), Romania.
Focus of this study is the exploration of the spatial suitability, through the use of Geographic Information System.
Assessment of the attitude of local people towards the project, timing and animals' care, are other important aspects of the feasibility study but they are mainly under the responsibility of the project's partners[1]; therefore they will not be included in this report.

## 2.2. Objectives of the study

This study specifically aims at the application of GIS tools to:

- Find suitable nesting/breeding sites for Griffon Vulture, in Retezat NP
- Quantify and spatially characterize feeding sources, namely those species inhabiting the park and potentially supporting Griffon Vulture
- Derive from these findings the number of vultures sustained by Retezat NP

## 2.3. Leading questions

The objectives of the study are supported by the following questions:

- Do suitable sites for Griffon Vulture nesting/breeding exist in Retezat NP? If so, where are they?
- What is the food availability and how is it distributed?
- What is the size of the Griffon Vulture population sustained by the park, on the basis of trophic resources?
- Finally, if the final stage of release phase is marked by the reintroduction of a minimum of 60 birds (Choisy, 2002), will this number be sustained by the existing park's resources?

[1] Carpathian Wildlife Foundation (Fundatia Carpati) (a.mertens@libero.it), Milvus Group (www.milvus.ro), Forest Research and Management Institute Brasov - Wildlife Unit (www.icaswildlife.ro)

## 2.4. Assumptions and justifications

This study is based on the following assumptions, sustained by the mentioned references:

- Griffon Vulture disappeared from Retezat area due to poison and not due to changes in its habitat (Tewes et al., 2002; Slotta-Bachmaryl et al., 2004)
- Cause of the extinction is no longer present in the area [2]
- Legal conditions support the program, particularly:
  - Law forbids poisoning (Slotta-Bachmaryl et al., 2004)
  - Monitoring and penalty empower the law
  - Where presence of vultures is ascertained, livestock carcasses are left untouched
- The general viability of the group is seriously compromised if the number of its components falls below 7 or 8 individuals. To buffer the inevitable losses, a minimum number of 12 individuals at the same time should be released (Choisy, 2002); this will be considered as the minimum size of birds to be sustained
- Possibilities of dispersal and migration from the release site are negligible (Choisy, 2002).[3]

[2] This assumption is supported by local experts and conservation organizations (see here above)

[3] Gregarious nature of Griffon would incline them to batch to existing colonies. In Romania not breeding Griffon are recorded (see below).

# 3. Literature review: habitat modelling

## 3.1. Introduction

One field of application of models is ecology and, in the frame of nature conservation, models have often been applied to gather knowledge and give guidelines for management (Jørgensen, 1994).
One application of modelling in ecology is to characterize species distribution. Here is presented a review of some literature related to this topic.

## 3.2. Habitat distribution models in ecology

Analysis and quantification of species-environment relationship represent the core of predictive geographical modelling in ecology (Guisan & Zimmermann, 2000).
The collection of resources and conditions necessary for an animal to live has been adopted as a definition of *habitat* and the differential use of habitat types is understood as habitat *selection* and *preference*. Although they are often used interchangeably in the wildlife literature, the two terms have subtly different meanings: selection has been described as "the process of choosing resources" and preferences as "the likelihood of a resource being chosen if offered on an equal basis with others" (Garshelis, 2000). The purpose for determining preferences is to evaluate habitat quality or suitability, defined as the ability of the environment to sustain and support specific population growth.
Although selection and preference can be clearly defined, they may not easily be measured in the real world; yet, knowledge of the area in which a species occurs is fundamental for the implementation of adequate conservation strategies and specific management actions (Corsi et al., 2000).

One way to derive species' distribution range is from the presence or the absence of the species; this approach is nevertheless prone to ambiguity, since no presence can be either related with lack of information or with true absence. As described by Corsi et al. (Corsi et al., 2000), the concept of distribution range has moved toward one of area of occupancy, which aims at the description of the species' presence in terms of correlated environmental variables.
The assessment of species' preferred ranges of values is the first phase in species distribution modelling and it has often been called habitat suitability index analysis; the identification of locations fulfilling these preferred ranges is the second-one and involves the true distribution model (Corsi et al., 2000).
While assessing the suitability, the large amount of data, often from different sources and scales, raises the difficulty of the process: insofar, the use of GIS has enhanced the potential of ecological modelling, through its capability to handle large amounts of spatial data.

## 3.3. Inductive and deductive models

Two broad categories can be identified in habitat modelling: inductive and deductive models (Poirazidis et al., 2004; Store & Jokimaki, 2003; Corsi et al., 2000).
Inductive models follow empirical methods, investigating the relationship between the collected occurrence data and appropriate background variables; deductive models are based on the former knowledge of the species concerned in the study area. In both cases, GIS can be used to handle the data and to display the results of the analysis. The use of raster format is often adopted: each habitat factor is transformed in a raster format map layer, and different kinds of spatial analysis are applied to produce the final suitability map.

As summarized by Store and Jokimaki (Store & Jokimaki, 2003), in response to the model procedure that has been adopted, two different ways of producing suitability maps can be identified: maps based on empirical models use cartographic modelling, in which the raw score map is transformed to correspond to the units used in the models; maps based on expert knowledge, result from the combination of standardised score maps, which are often also weighted; the process of standardisation is necessary in order to make the raw scores commensurable, and the final result is a standardised score map in which the values range between 0 (not suitable) and 1 (most suitable).

## 3.4. Statistics

Different statistical techniques are applied to generate GIS models simulating potential geographic distribution of concerned species. Three of them are here summarized in relation to their application in prediction distribution models: (Wilds et al., 2000):

- Multiple linear regression
- Multiple logistic regression
- Mahalanobis distance

### 3.4.1. Multiple linear regression

Assumption of this technique is the existence of linear relationship (or relationship easily represented mathematically) between multiple predictor variables and dependent variable.
It is an appropriate modelling technique for numerical data, but often results in limited applicability towards biological data.
Its main advantage is the generation of predictive equations, which allow it to determine the influence of one variable while adjusting for the others.
In the case of *Cornus florida*, a common understory tree species threatened by the fungal disease, modelling efforts revealed that the distribution of the species is difficult to model with any great accuracy (a maximum coefficient of determination of 0.4 was reached) (Wilds et al., 2000). The incorporation of complex variables is thought to be the reason for the observed variation, which perhaps reflects the influence of complex interactions in determining the distribution of the species.

### 3.4.2. Multiple logistic regression

Assumption of this statistic is that predictor variables are either true or false (Boolean).
It is suitable to predict the probability of dichotomous events, such as presence or absence for any given location.
In modelling the presence of heath balds, an evergreen shrub community that occupies exposed ridge tops, a high over prediction rate was noticed (Wilds et al., 2000). Although that community has a limited range of occurrence, the mechanism influencing their formation and persistence in the landscape are not well understood.
Conversely an example of successful application is found in Brown Bear (*Ursus arctos*) habitat modelling, in central Apennines (Posillico et al., 2004). The success is expressed by 95.5% of presence squares correctly classified, and 93.8% of absence ones.
Another successful example is found in the prediction of Black Vulture (*Aegypius monachus*) potential nest sites (Poirazidis et al., 2004), in which various measures of classification accuracy for validation and calibration are also presented.

### 3.4.3. Mahalanobis distance

This statistic is based on the mean, variance and covariance for the variables used as input. In its application to model species distribution, Mahalanobis distance describes the landscape in terms of its similarity to the ideal parameters associated with the species presence.
Small values of Mahalanobis distance represent therefore habitat conditions similar to those for known locations of concerned species, whilst large values represent dissimilar, presumably unsupportive conditions (Corsi et al., 1999; Clark, 1993; Farber & Kadmon, 2003; Cayuela, 2004; Wilds et al., 2000).

Main assumption of this statistic is that the quality of the habitat exist as a continuum from highly suitable to unsupportive; additionally, in Clark (Clark, 1993) is assumed that species locations are representative of the population segment or character being targeted; habitat character and location data are sufficiently accurate and significant to bear ecology; past habitat use patterns are indicative to those in the future.
Main advantage of this techniques is that only presence locations are required for input, therefore assumptions on the distribution of the species are not made; moreover, it corrects for correlation among variables including variance-covariance matrix (Wilds et al., 2000).
In the application to habitat use of female Black Bear (*Ursus americanus*) (Clark, 1993), the model and the chosen habitat variables showed good predictive value. In large-scale modelling of Wolf (*Canis lupus*) distribution in Italy (Corsi et al., 1999), Mahalanobis distance statistics is applied to construct an actual and potential spatial distribution of Wolf for the entire country, and its contribution and limitations to conservation planning are also presented.
In modelling habitat of *Cardamine clematitis*, a perennial herb restricted to high-elevation seeps and boulder fields in the Southern Blue Ridge (Wilds et al., 2000), the model performs successfully in distinguishing suitable from unsuitable habitat, but the occurrence of the species in the available habitat results low (18% of the potential). Authors cannot assess whether low rate of habitat occupancy is due to a failure to include significant variables or reflects biotic factors, but they emphasize the necessity to consider validation as integral part of the modelling.
An application of Mahalanobis statistic to bio climatic modelling is found in relation to woody plant distribution (Farber & Kadmon, 2003). Results obtained with this technique are compared with rectilinear modelling, in the context of climatic envelope models[4]. After validating the model, results show that Mahalanobian models are superior to rectilinear ones, although reasons are only suggested and not yet proved.

## 3.5. Application to vultures conservation

### 3.5.1. Introduction

Four species of vultures are living in Europe: Griffon Vulture (*Gyps fulvus*), Egyptian Vulture (*Neophron percnopterus*), Black Vulture (*Aegypius monachus*) and Bearded Vulture (*Gypaetus barbatus*) (Tewes et al., 2002).
Since the 20$^{th}$ century their number has dramatically declined, and nowadays the stronghold of all vulture species is Spain.
In the Balkan countries, once hosting all the four species, they are present in few numbers, in decline or even locally extinct. At present, the main threat to all four species is the wide use of different kinds of poison. Poisoning is generally utilized against the revitalised populations of mammalian predators and mustelids but can also be caused by agrochemicals. In most cases, the target animals are not vultures, so secondary poisoning is the dominant problem (Slotta-Bachmaryl et al., 2004).
Other occurring threats have been identified in:

- Loss of habitat, related to food availability (changes in livestock rearing) and breeding sites
- Electrocution

Due to the delicate status of vultures in Europe and to their important ecological role as scavengers, modelling habitat and particularly modelling nesting habitat, has been a useful tool in conservation programmes (Liberatori & Penteriani, 2001; Poirazidis et al., 2004).
As already mentioned, reintroduction programmes should assess beforehand whether causes of extinctions are no longer present, and only then the restoration of a viable population could start.
In the case of Griffon in Romania, locally extinct from 1950, the cause of extinction has been identified as poisoning, most likely affecting the bird as indirect targets; whereas changes in habitat and food availability have not been recorded. The species was very common in the area of Carpathian

[4] Envelope models generate predicting maps of species distributions, using data on the climatic characteristics of the sites where the species are located.

Mountains, but its extinction was fast, due to its feeding behaviour: Griffons feed together, and a poisoned carcass can therefore kill many birds at the same time (Slotta-Bachmaryl et al., 2004).

### 3.5.2. Biological information

(Eurasian) Griffon Vulture is a huge bird (wingspan 230-255cm), mainly resident in mountains of Mediterranean area, Turkey, Caucasus. Less than 19,000 pairs are estimated to be left in the all Europe, and almost all (17,000) are living in Spain (Tewes et al., 2002).
They nest on cliff-ledges or in caves on steep mountainsides, often in loose colonies of 10-20 pairs. Griffons pair for life and the female lays 1 or 2 eggs 2 months after mating. Incubation lasts from 48 to 52 days and the sexual maturity is reached at the age of 7 years. They live around 40 years.
Griffons cannot smell and they find food by soaring high, scanning the land for signs of a kill, or for stationary bodies. They can soar for 6 to 7 hours, for more than 100 km (Oaklandzoo, 2004).
They often require steep cliffs or mountains to aid them in taking off: their wing muscles are rather weak in relation to body weight (7 kg) and wing surface, thus they depend on thermals to take off and are generally not active in the morning hours (Mullarney et al., 2004).

### 3.5.3. Modelling spatial suitability for Griffon Vulture

Since the reintroduction of Griffon Vulture is still largely experimental, the exchange of information is essential. Reports on reintroduction attempts (Choisy, 2002; Slotta-Bachmaryl et al., 2004), action plans (Tewes et al., 2002; Slotta-Bachmaryl et al., 2004) and local expert knowledge therefore represent important sources of information to generate models and increase the possibility of success for reintroduction actions.
In the specific case, spatial suitability is derived by integrating expert knowledge and locations of possible nesting places, in a raster environment. The results are meant to support mainly the initial phase of the release, when birds have to adapt to the wild and are therefore considered vulnerable (Choisy, 2002).
The model is therefore based upon the species requirements and the landscape parameters, derived mainly from remote sensing. The use of satellite imagery (and supervised classification) to derive landscape parameters has been widely described and tested in the field of habitat modelling; in many cases the prerequisite for spatial modelling is the Digital Elevation Model (DEM), constituting the basis for generating new maps of environmental variables (e.g. slope and aspect) and often determining the spatial resolution for the derived maps.
Criteria adopted are related to topographic parameters (altitude, slope and aspect) and ecological characteristics (abundance and distribution of livestock and wildlife). Simple carrying capacity is estimated on the basis of available literature (Bretagnolle et al.) and expert knowledge (Choisy, 2004; Genero, 2004).
Mahalanobis statistic is adopted, as method of measuring how similar some set of conditions is to an ideal set of conditions, here represented by the locations of nesting sites. For the rationale of this statistic refer to 3.4 and 3.6.

### 3.5.4. Limitation

The main limitation of this study is the absence of data on former presence of the species in the area: suitable places for nests, as indicated by the experts, have been visited and located and assumed as representative for ideal conditions.
The high adaptability of the species and the fact that the park has not changed over years should compensate for the lack of data on former presence. Additionally, the institutional state of the area chosen for the reintroduction (National Park) should finally increase the success of the program, limiting the potentially adverse factors.

## 3.6. Conclusion

Topics common to most of the articles were found in the literature review.
Two aspects particularly stand out, one related to the source of information (and therefore to the model approach), the other to the data processing.
Sources of information for the species distribution can either be known locations of the species or expert opinions. In the latter case, the assumption is that experts are able to select environmental parameters relevant to the species. This may not fully correspond to the truth and may introduce bias into the model. Additionally, experts might disagree.
The aspect associated with data processing, includes limited availability of detailed GIS data layers, issues of scale, difficulty in creating models (which information to use, where to find that information), and validity of prediction. Additionally, difficulties encountered with discriminant functions and logistical regression, which require a correct classification of both, presence and absence data, are often mentioned. In this regard, one of the advantages of using Mahalanobis distance statistic is that it involves only the presence data, therefore avoiding problems related to misclassification of used versus non used.

# 4. Study area

## 4.1. Introduction

As a consequence of its geographical location, the meeting point between bio-geographic regions, Romania has a unique and high level of biodiversity. Flora diversity includes more than 3,700 species, and fauna diversity is estimated to more than 33,800 species, including numbers of endemic species. Consequences of human activities are nevertheless affecting Romania: general pollution, river damming, hydro technical works, industrial agriculture, overexploitation of natural resources and inappropriate forms of tourism have each had their particular role in decreasing Rumanian biodiversity. In order to address these problems, Romania has adopted the National Strategy and Action Plan for biological diversity conservation and sustainable use of its components, both of which integrate the principles and objectives of the most significant conventions in the field of nature and biodiversity conservation (Biodiversity Conservation Division et al., 2004; UNDP, 1996).

## 4.2. Retezat National Park

Retezat National Park (Figure 1) has been gazetted in 1935 and covers 38,000ha, of which 1,800ha are strictly protected area (“Gemenele”). Altitude ranges between 790m and 2500m above sea level.
From phyto-geographical point of view the area belongs to the Euro-Siberian region, East-Carpathian central-European sub-region, and Middle Carpathians unit.
Vegetation of Retezat NP is represented by broad-leaved and coniferous forests, mixed forests and alpine and sub alpine pastures with dwarf-pine. Gemenele shelters a natural primary forest.
24 species on the list of European threatened vertebrates are found in the park, which plays a role also in terms of the ecological corridors existence, to facilitate species migration and dispersal (Pronatura, 2004).

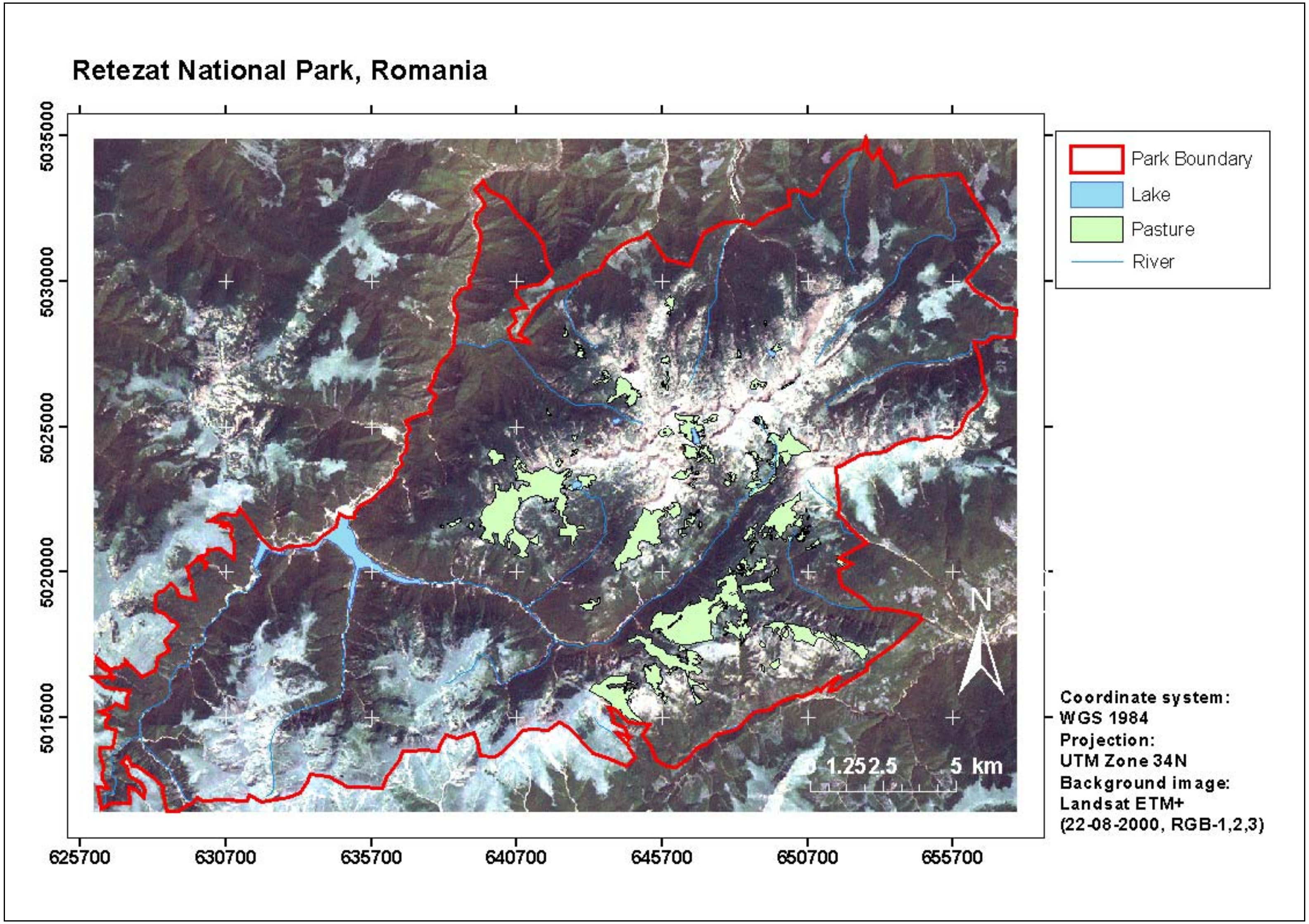


**Figure 1: Retezat National Park, Romania.**

# 5. Methods and materials

## 5.1. Introduction

Since environmental suitability depends on the requirements of a given species (see 3.2), GIS layers to be used as input for the model need to be selected. Some of the most commonly used layers in habitat suitability models include DEMs and data derived from them. Vegetation layers and variables like distance to disturbance features (for instance roads or settlements, according to the sensitivity of the species) and to water sources are often also considered. In the specific case, the suitability was derived from:

- Topographic variables (altitude, slope and aspect)
- Food abundance and distribution (livestock and big and medium size wildlife)

Variables associated with the disturbance (mainly electrocution as mentioned is 3.5) were not included because power lines are not present in the park.
Parameters associated with altitude, slope and aspect were used to assess the suitability for nesting sites, whereas food abundance and distribution were used to assess the carrying capacity of the park, calculated as grams of food per pixel and then converted in number of vultures sustainable by the park area (Bretagnolle et al.).
The extent of the analysis was limited to the park area, since data on resources in its surroundings were not available.
Due to the characteristics of the analysis, raster environment was adopted.

## 5.2. Nesting/breeding sites suitability

### 5.2.1. Assumptions

Following assumptions were made:

- Expert opinions are correct and therefore visited sites are representative for a set of conditions Griffon would also select
- Elevation, slope and aspect are the main variables influencing the suitability of nesting sites
- Home range[5] of Griffon Vulture depends on the availability of food (Robertson & Boshoff, 1986): an *a priori* delimitation of the area used for daily activity cannot be done and different thresholds are instead considered
- The resolution of the DEM (90m pixel size) is adequate to analyse the suitability for nesting sites[6]

[5] The local area occupied by an individual during a normal day's activities, which may or may not be completely defended by the individual, depending upon the species and the season (Northonline, 2004).
[6] Similar studies done in Italy used a minimum size of 50 by 50m, for the selection of the suitable cliffs (Genero, 2004).

### 5.2.2. Input data

Input data are:

- Suitable sites selected by experts[7] and visited during fieldwork in June 2004
- DEM obtained from Shuttle Radar Topography Mission

Detailed information on input data are contained in Appendix 1.

### 5.2.3. Data preparation and processing

Data preparation:

- ERDAS 8.6 was used to project the DEM in UTM Zone 34N, using Datum WGS 84
- ArcGis 8.3 - N-bands raster clipper extension was used to clip the area of interest

Data processing:

- ArcView 3.2 – Spatial Analyst extension was used to derive slope and aspect from the DTM; Mahalanobis distance extension (Jenness, 2003) was used to calculate probability surface reflecting suitability for nesting places.
- ArcGis 8.3 - Spatial Analyst was used to assemble suitable single pixels in zones and create a distance map for every zone.

<u>Generation of Mahalanobis Distance Surface Grid</u>

Flowchart in Figure 2 summarizes main steps followed to generate Mahalanobis Distance Surface Grid and how that grid has been used to derive potential nesting sites.

Point theme corresponding to visited suitable sites was used to generate a vector of mean elevation, slope and aspect values, plus a covariance matrix.

Independent variables grids (elevation, slope and aspect) were used, with exact cell values at each point.

The resulting grid expresses Mahalanobis distance from the vector of the mean values of independent variables (see Appendix 2); since Mahalanobis distances have not upper limit, values are usually rescaled to 0-1 (0-100 for the analysis). New values (p-values) express the probability of seeing a Mahalanobis value as large or larger than the actual Mahalanobis value, assuming the vector of predictor values that produced that Mahalanobis value was sampled from a population with an ideal mean (i.e. equal to the vector of mean predictor variable values used to generate the Mahalanobis value). P-values close to 0 reflect high Mahalanobis distance values and are therefore very dissimilar to the ideal combination of predictor variables. P-values close to 1 reflect low Mahalanobis distances and are therefore very similar to the ideal combination of predictor variables. The closer the p-value is to the upper limit, the more similar that combination of predictor values is to the ideal combination (Jenness, 2003).

[7] 1 Ornithologist (D.Szilard, from Milvus Group – www.milvus.ro ) and 1 biologist (C.Hodor, from Retezat NP)

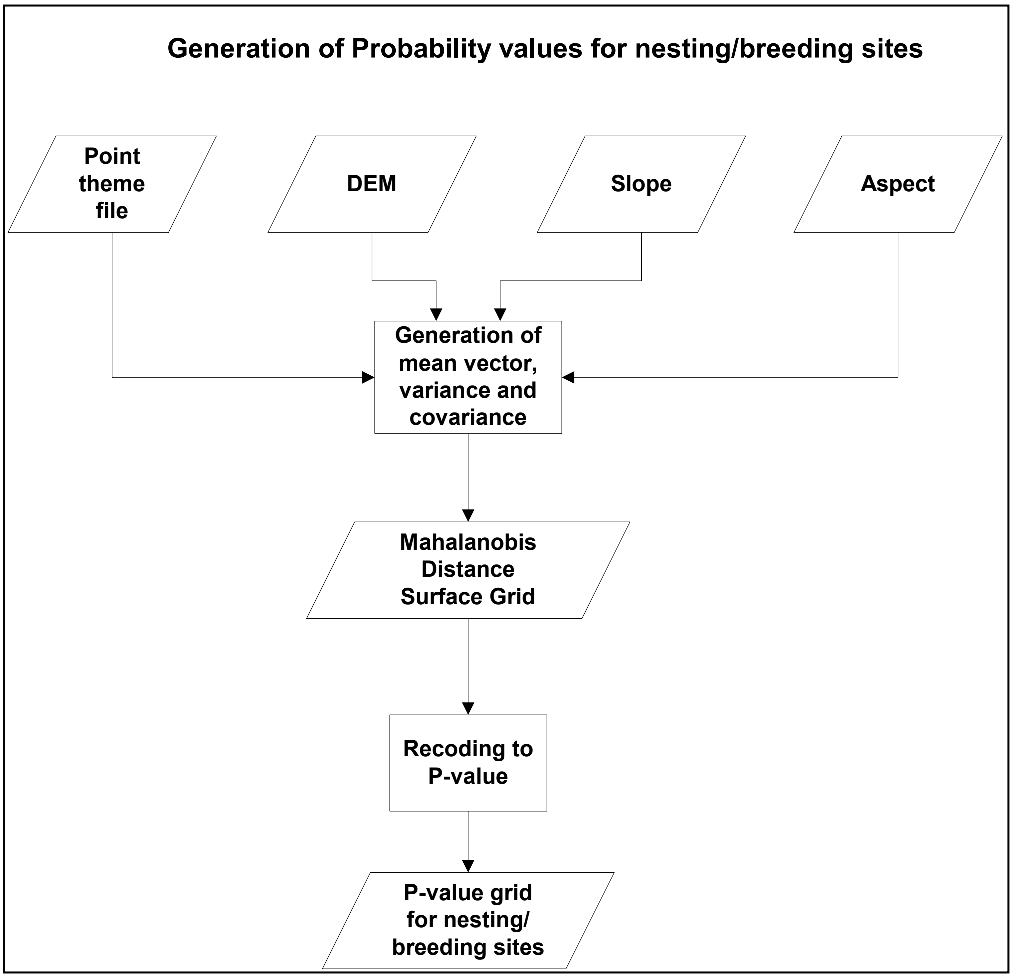


**Figure 2: Flowchart of main steps to obtain probability value grid for nesting/breeding sites.**

<u>Clustering single pixels in zones</u>

Flowchart in Figure 3 summarizes main steps done to create nesting zones from single suitable pixels.
Pixels with p-value equal or greater than 50 were selected and Spatial Analyst was used to create a density layer around these points. Simple and Kernel density were calculated and after visual inspection Kernel[8] was selected due to its better approximation of points distribution. Density clouds with density equal or greater than 10 points/sqkm were selected as potential nesting zones (see Appendix 3).
As mentioned above (5.2.1), the home range depends upon the resource abundance, therefore for zones containing highest number of suitable nesting points, a distance layer was calculated, and distances were sliced in intervals of biological values (threshold values were based on literature review and expert knowledge).
Distance were calculated as straight lines, since a flight model for the vulture would require data on thermal occurrence as well as bird physiological information, not available and not obtainable in due time.
Distance layers were later used to evaluate the carrying capacity, as described below.

[8] In the Kernel density calculation the points or lines lying near the centre of a raster cell's search area are weighted more heavily than those lying near the edge (see Spatial Analyst On-Line Guide).

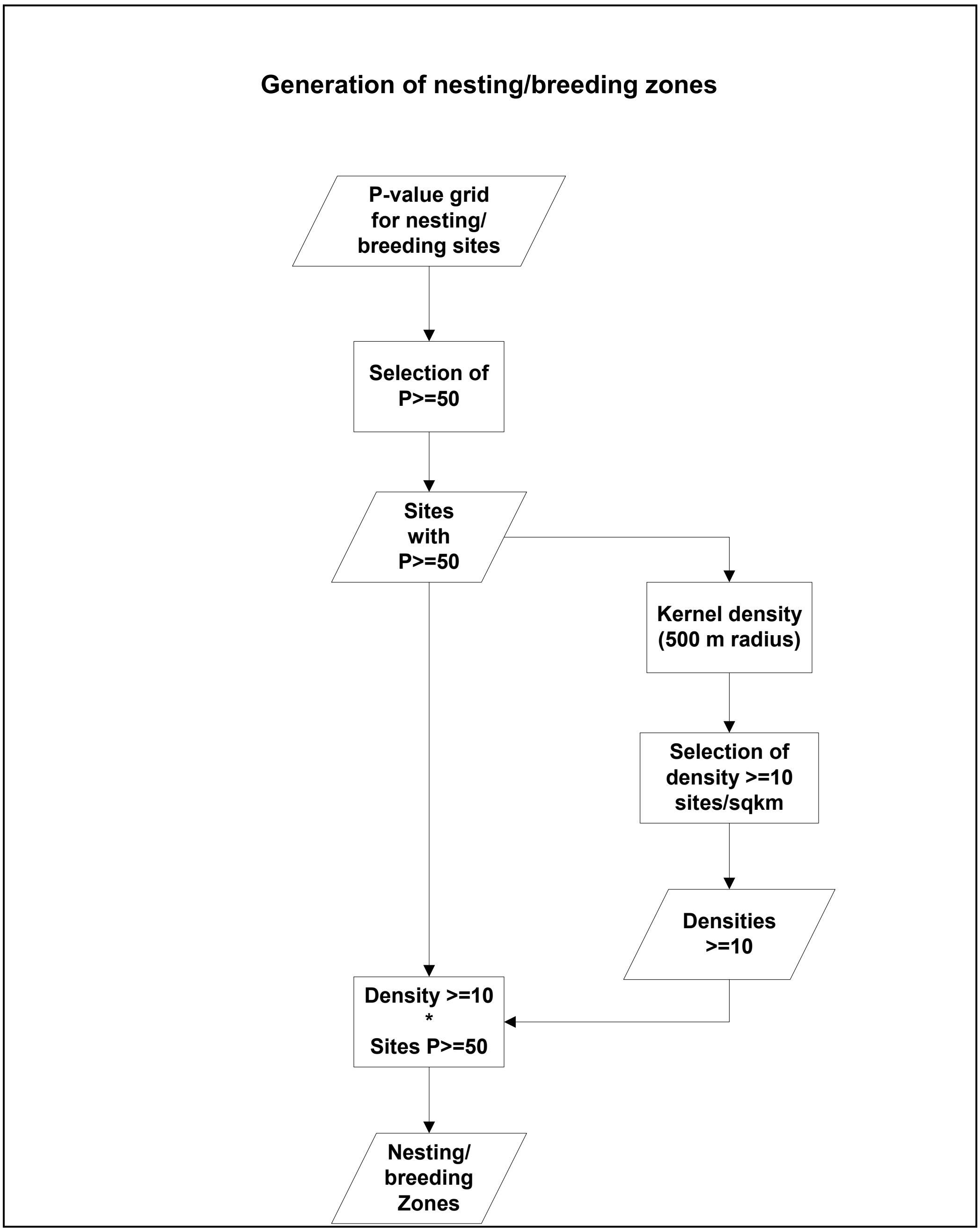


**Figure 3: Flowchart of main steps to obtain nesting/breeding zones from suitable single sites.**

## 5.3. Food availability and distribution

Resource abundance and distribution were used to assess the carrying capacity, expressed as number of vultures sustainable on the basis of different distances from the nesting area. After reviewing literature and consulting experts, three scenarios were developed, each related with a particular feeding behaviour (diet based on “Sheep and wildlife”, on “Sheep and cattle”, and on “Sheep, cattle and wildlife”). Below is the description of assumptions, parameters and data used to model the three different scenarios.

### 5.3.1. Assumptions

Following assumption were made:

- Griffon Vulture diet is based mainly on livestock (with sheep dominating)(Robertson & Boshoff, 1986; Bretagnolle et al.)
- In the study area, poisoning does no longer represent a threat
- Large and medium size wildlife mammals might be included in the diet (Choisy, 2004; Bretagnolle et al.)
- Livestock carcasses are left untouched[9]
- Wildlife is evenly distributed over the entire park
- Livestock is present on pasture areas only
- Annual mortality rate is 1% for livestock and 4% for wildlife (Bretagnolle et al.)
- An adult vulture needs 400g of meat per day, which gives a figure of 292kg of meat per year, per breeding pair (Choisy, 2004; Bretagnolle et al.)
- 20% of the gross weight of each dead animal is available to the vulture (Bretagnolle et al., ; Robertson & Boshoff, 1986)

### 5.3.2. Input data

Input data are:

- Wildlife census data (year 2004)
- Livestock census data (year 2003)
- Land cover/use map of Retezat NP

All the mentioned data were obtained from Retezat NP[10]. Detailed information on input data are contained in Appendix 1.

### 5.3.3. Food base: sheep and wildlife

Parameters used to model the distribution of food under a feeding behaviour dominated by sheep and wildlife are presented in Table1.

**Table 1: Parameters used to assess food abundance, on the basis of sheep and wildlife presence in the diet.**

| Species | Average weight (kg) | Presence in the diet (%) | Presence in the diet (kg/year) |
|---|---|---|---|
| Sheep (*Ovis aries*) | 50 | 80 | 234 |
| Wildlife[11]: Wild Boar (*Sus scrofa*), Chamois (*Rupicapra rupicapra*), Roe Deer (*Capreolus capreolus*), Red Deer (*Cervus elaphus*) | 150 | 20 | 59 |

[9] At present, rules prescribe to bury livestock carcasses; exceptions related to vultures’ presence seem to be possible (C. Hodor, pers. Comm.; M. Kelemen, pers. Comm.).
[10] Census data were givern by C. Hodor, GIS layers by L. Canacheu.
[11] Average weights per species: 200kg (Wild Boar), 45kg (Chamois), 26kg (Roe deer), 330kg (Red Deer).

### 5.3.4. Food base: sheep and cattle

Parameters used to model the distribution of food under a feeding behaviour dominated by sheep and cattle are presented in Table 2.

**Table 2: Parameters used to assess food abundance, on the basis of sheep and cattle presence in the diet.**

| **Species** | **Average weight (kg)** | **Presence in the diet (%)** | **Presence in the diet (kg/year)** |
|---|---|---|---|
| Sheep | 50 | 80 | 234 |
| Other livestock, mainly cattle (*Bos taurus*) | 250 | 20 | 59 |

### 5.3.5. Food base: sheep, cattle and wildlife

Parameters used to model the distribution of food under a feeding behaviour dominated by sheep, cattle and wildlife are presented in Table 3.

**Table 3: Parameters used to assess food abundance, on the basis of sheep, cattle and wildlife presence in the diet.**

| **Species** | **Average weight (kg)** | **Presence in the diet (%)** | **Presence in the diet (kg/year)** |
|---|---|---|---|
| Sheep | 50 | 60 | 175 |
| Other livestock (see 5.3.4) | 250 | 20 | 59 |
| Wildlife (see 5.3.3) | 150 | 20 | 59 |

### 5.3.6. Data preparation and processing

Livestock census was conducted on pastures, therefore land cover/use map was used to locate pastures and spatially characterize the data.

A raster layer corresponding to each scenario was calculated and used as food-base distribution (g/pixel). Each scenario was then used to evaluate, for each nesting zone, the abundance of food in relation to increasing distance from the nesting zone. This value was obtained as the sum of the quantity available in each pixel belonging to the considered distance zone.

Obtained grams of food, were finally converted in carrying capacity, expressed as number of vultures sustainable by each nesting zone. Parameters adopted are listed in 5.3.1 – 5.3.5.

# 6. Results and discussion

## 6.1. Introduction

Biological criteria, GIS-based model, expert knowledge and information derived from literature, have been integrated in this study to explore the spatial suitability of Retezat NP as an attempt to support the reintroduction of Griffon Vulture.
Presence of nesting/breeding places, distribution and quantification of trophic resources, estimation of number of individuals potentially sustained, are the main factors considered to evaluate the suitability of the area.
Nevertheless, spatial suitability is only one of the aspects to be considered during a reintroduction programme and the output of the analysis should not be used as unique criterion to support decision-making processes.
At least other two factors can be identified as relevant:

- Attitude of local community towards the programme
- Existence of institutional support

Moreover, the results here presented depend on the accuracy and precision of the input data, supposed to be representative of the reality, and are the consequence of the biological/ecological assumptions listed in previous chapters.

## 6.2. Results

As expected from the objectives and leading questions, three major findings have been obtained:

- Identification of suitable nesting/breeding sites
- Food availability and distribution
- Carrying capacity

### 6.2.1. Identification of suitable nesting/breeding sites

Figure 4 shows the probability for a cell to be suitable for Griffon Vulture nesting/breeding site (background satellite image is displayed to facilitate the orientation).
Values range from 0 to 100, resulting from the rescaling of Mahalanobis distance. Since Mahalanobis distance has no upper boundary, the recoding has the advantage of placing the values between two limits.
As described in 5.2.3, single cells were clustered in zones, on the basis of their Kernel density. Bounded areas represent zones with a number of single suitable sites ranging from 40 (zone 7) to 264 (zone 1), and an area ranging from 1214 to 141ha. Zone 2 accounts for a greater number (185) than zone 3 (180), although its extent is slightly smaller.

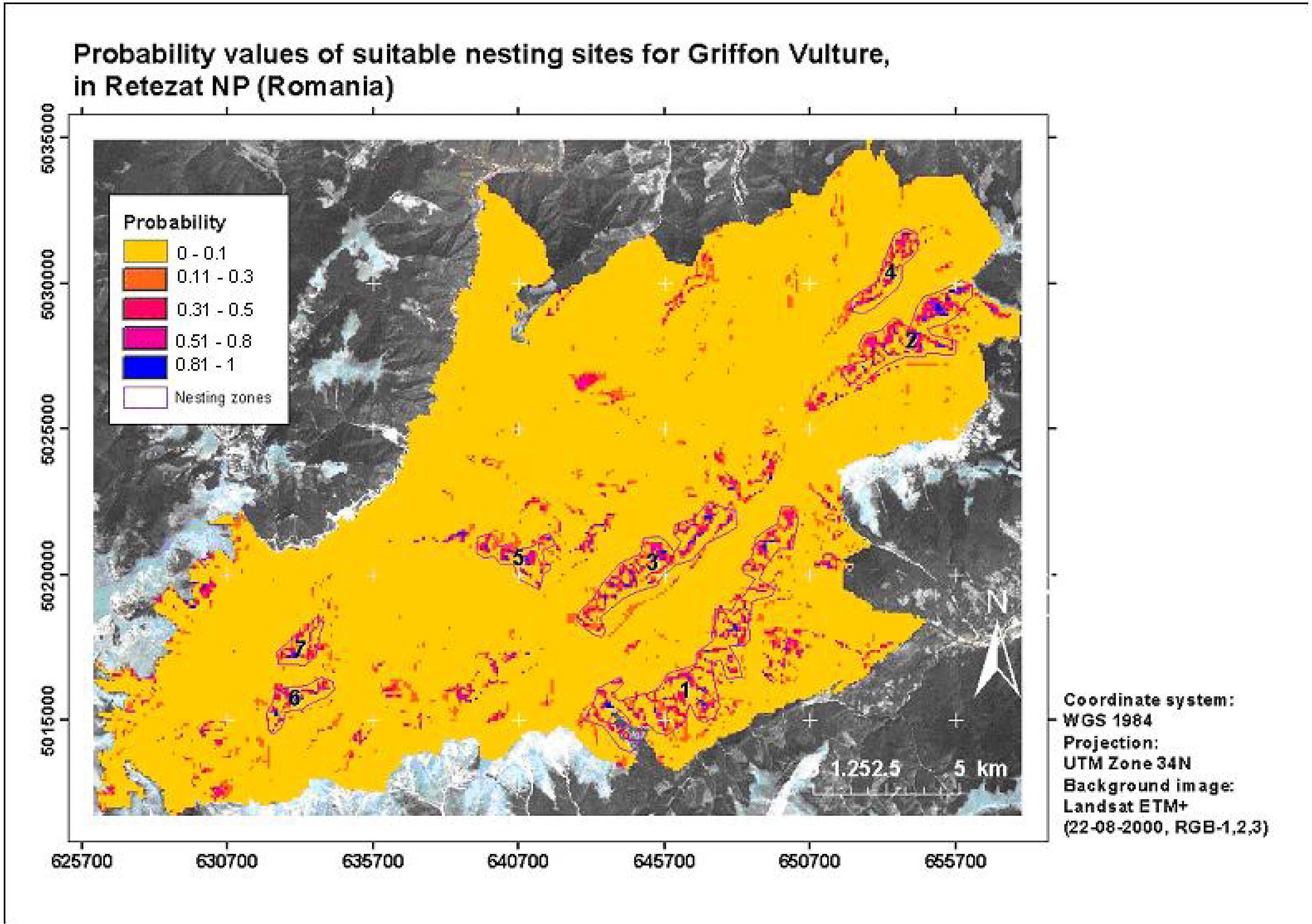


**Figure 4: Probability values of suitable nesting sites for Griffon Vulture in Retezat NP.**

### 6.2.2. Food availability and distribution

Figure 5, 6, 7 represent the food availability obtained per each scenario, namely considering three feeding behaviours: sheep and wildlife (Figure 5), sheep and cattle (Figure 6), sheep, wildlife and cattle (Figure 7).
Values are expressed as grams/hectare per year, after converting values obtained per grid cell (90 m pixel size).
Food availability ranges are:

- From 50 to 2500 g/ha per year for feeding behaviour based on sheep and wildlife
- From 0 to 2700 g/ha per year for feeding behaviour based on livestock only (sheep and cattle)
- From 50 to 2800 g/ha per year for feeding behaviour based on livestock and wildlife

Presence of wildlife in the diet adds 50 grams of food per hectare.
Presence of cattle in the diet extends the resources availability to those areas where sheep are not present.

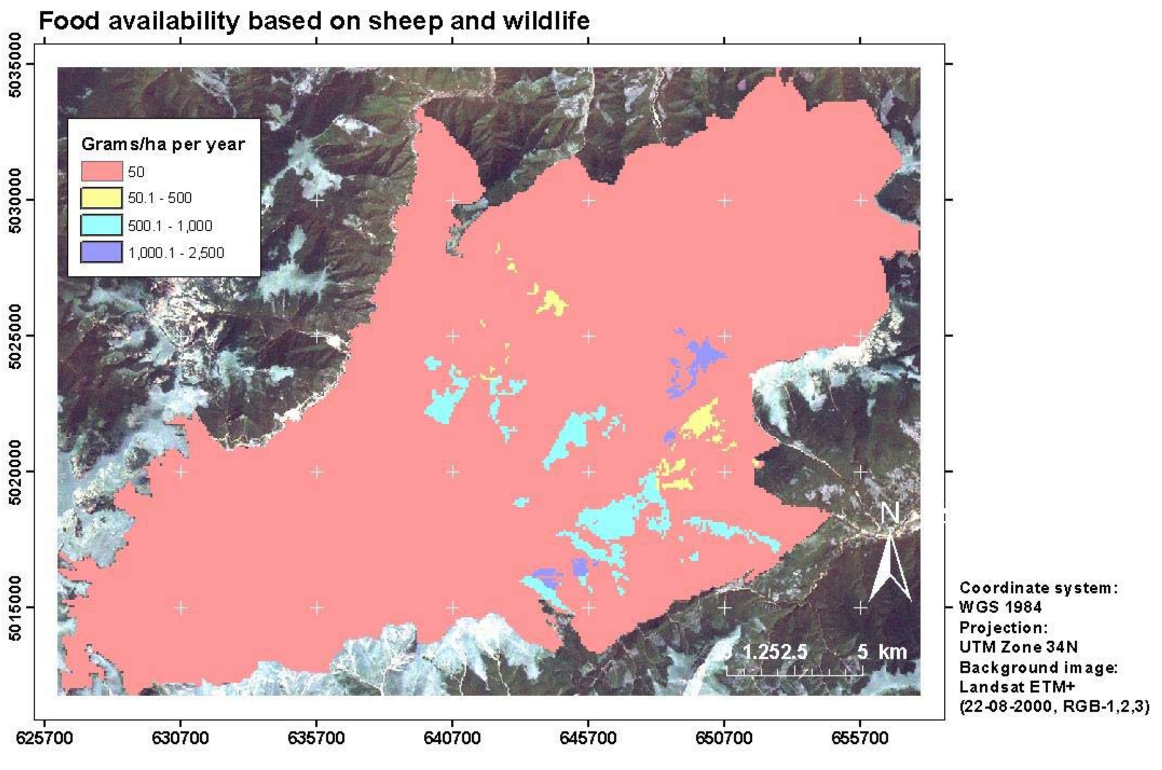


**Figure 5: Annual availability of food (g/ha) on a diet based on sheep and wildlife.**

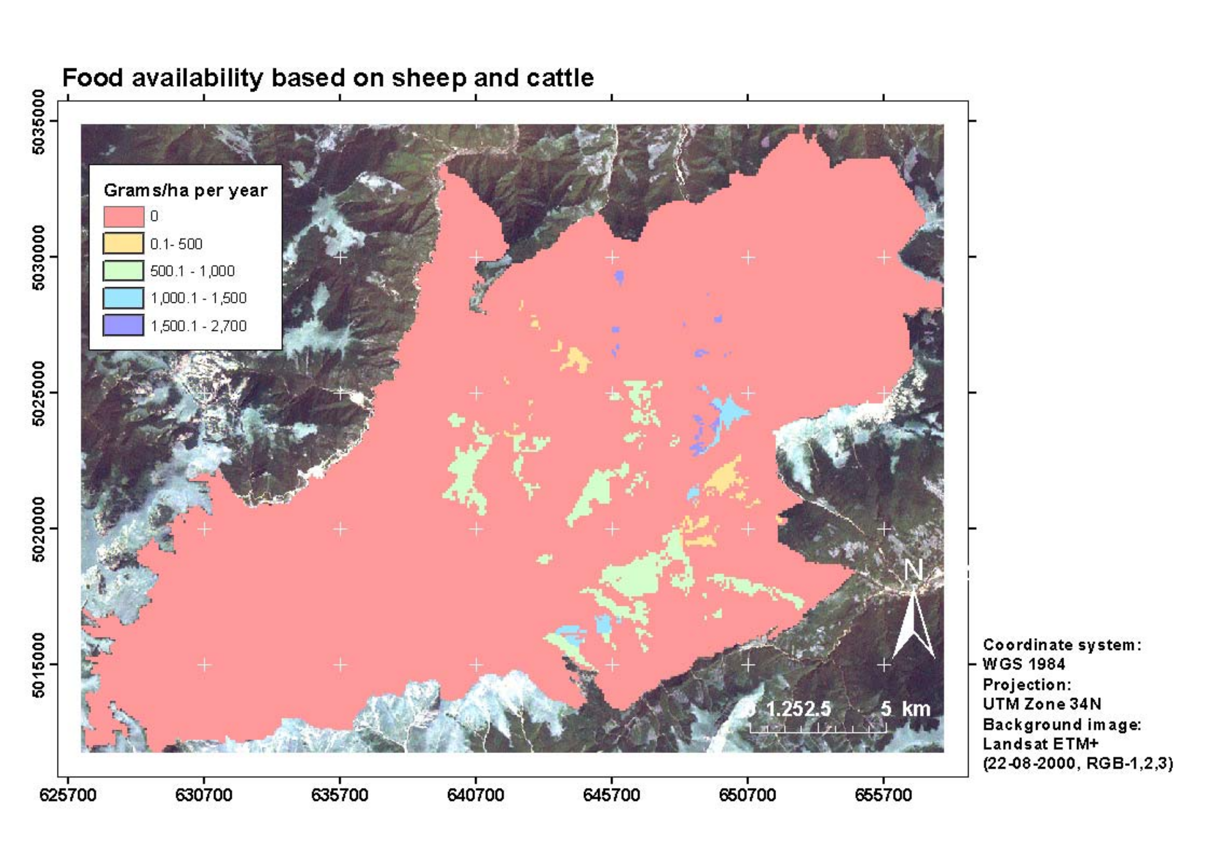


**Figure 6: Annual availability of food (g/ha) on a diet based on sheep and cattle.**

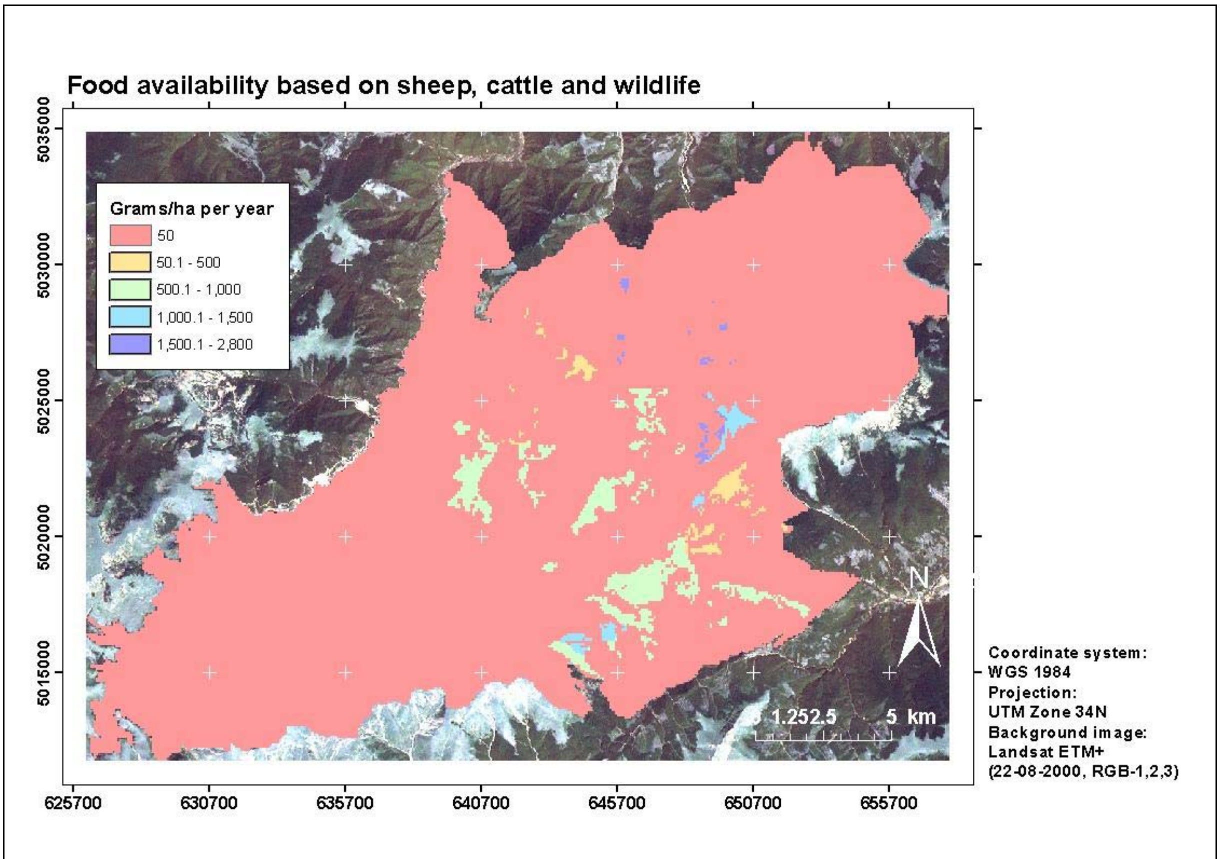


**Figure 7: Annual availability of food (g/ha) on a diet based on sheep, cattle and wildlife.**

### 6.2.3. Carrying capacity

The evaluation of food presence and distribution might be used to assess the size of population sustained by available resources (here considered as carrying capacity)(Bretagnolle et al.).
Species-specific requirements are necessary to convert the availability in carrying capacity.
Additionally, many other factors determine the size of the population sustained; here the daily distance flown to search for food has been considered.
Cumulative food availability at increasing distances from each nesting zone was evaluated and converted in number of individuals, using parameters listed in 5.3.
Figures 8, 9, 10, represent the carrying capacity of each zone, as derived from the three feeding behaviours. As shown by the charts, the additional food derived from feeding behaviour that includes wildlife, increases significantly the size of the population sustained by the park.

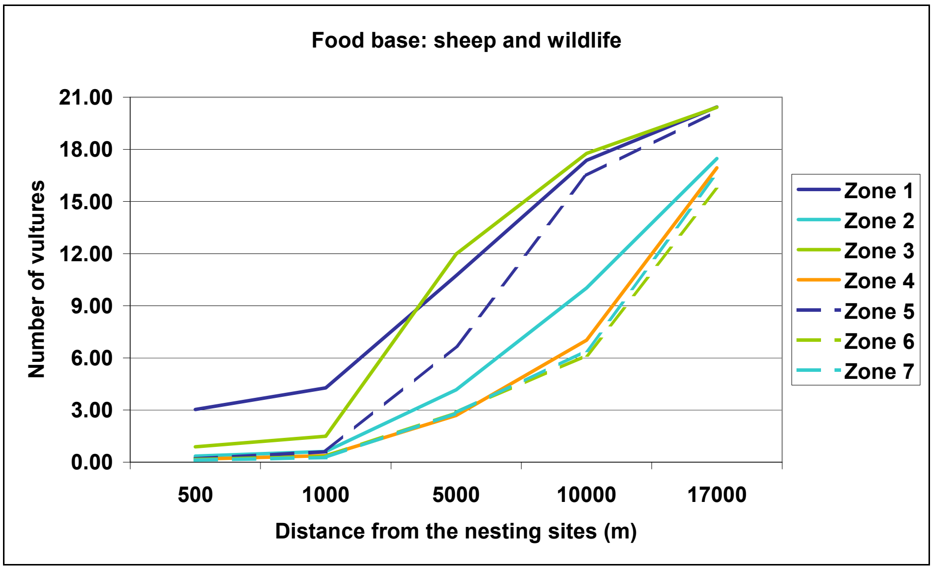


**Figure 8: Annual carrying capacity, estimated from a diet based on sheep and wildlife.**

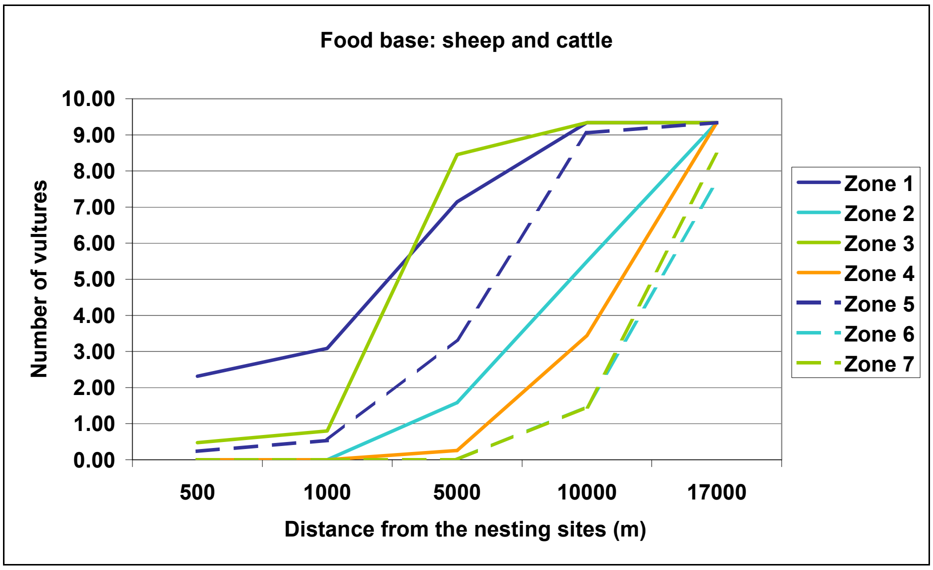


**Figure 9: Annual carrying capacity, estimated from a diet based on sheep and cattle.**

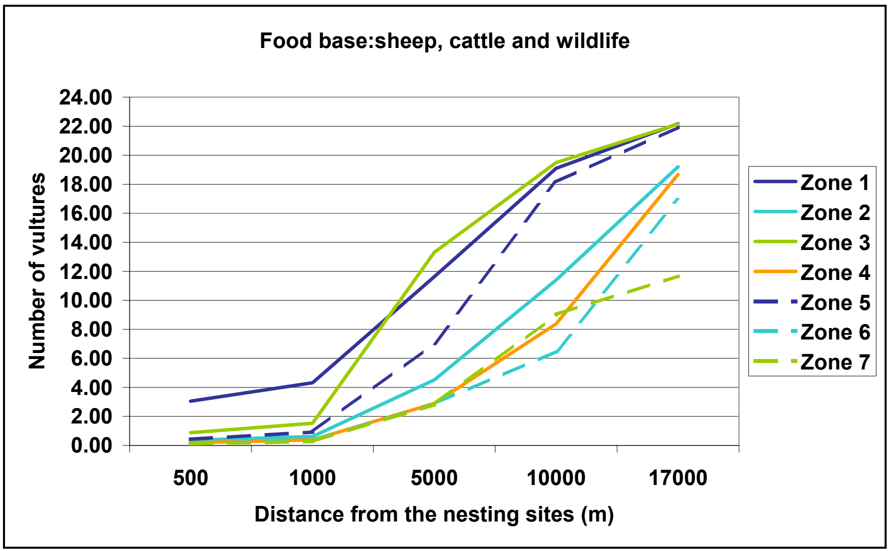


**Figure 10: Annual carrying capacity, estimated from a diet based on sheep, cattle and wildlife.**

The highest carrying capacities have been obtained from zone 1 and 3. Figure 11 shows zone 1 and 3 together with the visited sites. These points appear to be in the area (or on its boundary) selected as suitable for nesting/breeding and named as 1.

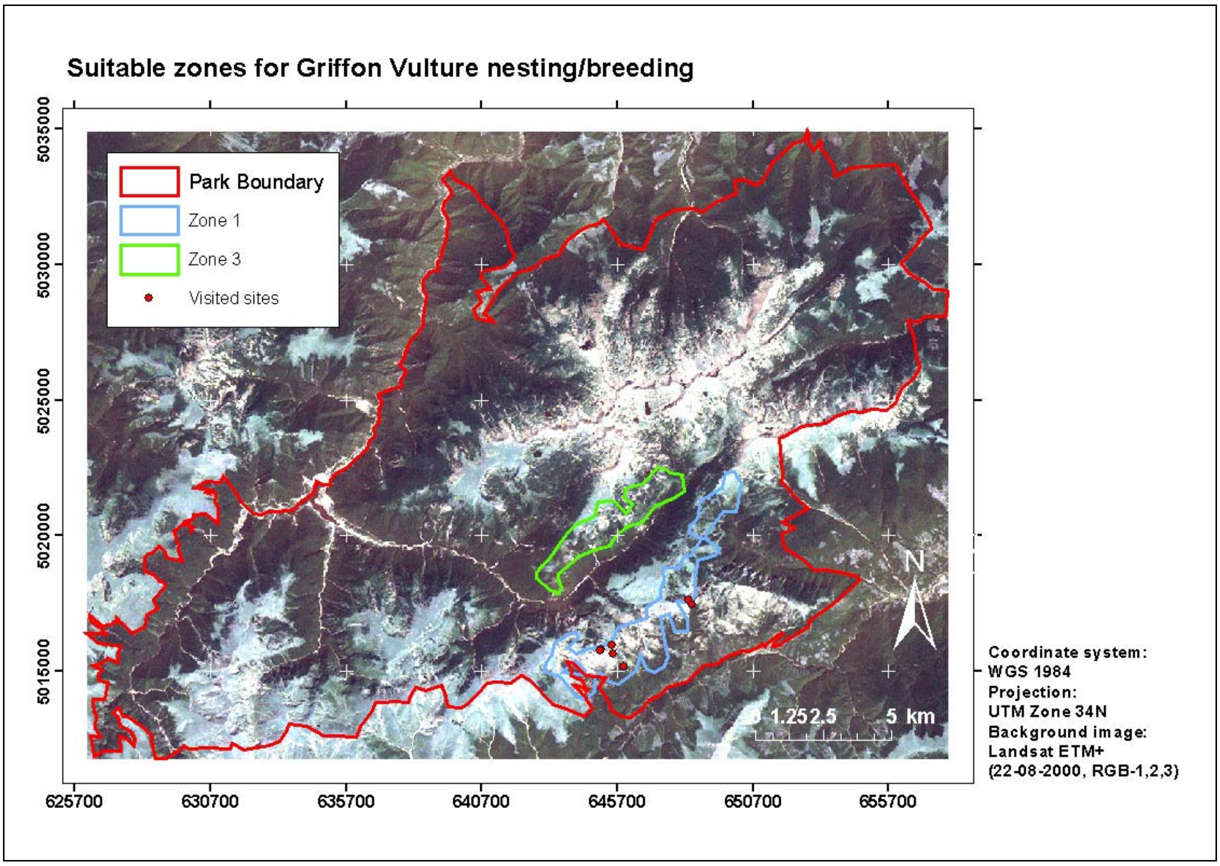


**Figure 11: Map depicting nesting areas accounting for the highest carrying capacities.**

## 6.3. Discussion

This study was intended as an application of GIS tools to evaluate the spatial suitability of Retezat NP in supporting the restoration of a Griffon Vulture population.
To accomplish this goal, biological criteria, expert knowledge and information available in literature (particularly from similar projects) have been used to create the specific environment for the application of the GIS.

Three objectives were formulated, as a consequence of a number of questions phrased to assess the overall suitability.

The first objective was to find the location of suitable places for Griffon Vulture nesting and breeding. The inductive approach was chosen: from the location of known existing suitable sites, the suitability was derived using the Mahalanobis Distance on the basis of altitude, slope and aspect, selected as relevant parameters to characterize the visited locations.
To avoid biased conclusions, the selection of the environmental variables to include in the statistic has to be done with care. For the specific case, visited locations were selected out of a set of known suitable places, on the basis of their accessibility from our camp, considering the limited time available. If main roads were present in the area, and the parameter “Distance from roads” was included in the analysis, the result would likely be biased.
In the case of Griffon, electric pylons usually represent a negative factor, but they are not present in the area and therefore they were not included in the analysis.
The suitability was expressed in terms of probability for a site to be chosen as nesting/breeding place, on the basis of its similarity to the known suitable sites.

From the single sites, zones were derived, on the basis of the single sites density: a total of 7 suitable zones were defined and provided a basis for the analysis pertaining to the third objective. These are the two main rationales for clustering the nesting points into nesting sites:

- From the species social behaviour point of view, a “zone” (made upon a number of neighbour sites) provides more space to shelter a colony, than isolated sites
- From a reintroduction strategy point of view, a suitability extended to the surrounding areas where the pre-release phase cages are kept, helps the birds to not move away once they are released (see also consideration here below, under third objective)

The second objective was the estimation of food availability.
Census data obtained from the park were used to characterize wildlife and livestock presence, and assumptions derived from literature were used to assess the annual number of carcasses. The results obtained are strictly dependent on the assumptions: therefore, conservative values were used for mortality rate and effective percentage of meat obtained from the carcass. Experience from previous works (Bretagnolle et al., ; Choisy, 2004) and the “least optimistic view” were adopted to justify the assumptions.
The first step to derive the availability of food was the selection of species relevant to Griffon diet; then the effective food obtainable from each species was determined; therefore, the result derived (grams of food per hectare of park), is based on the target species requirement.

The third objective was the evaluation of the carrying capacity, on the basis of food abundance and distribution in relation to the identified nesting/breeding zones.
A set of assumptions based on biological criteria was adopted. The main assumption is that the home range of Griffon Vulture is limited by food availability rather than territorial behaviour. Griffons cannot smell: they soar and search for food; once carrion is found they gorge themselves and feed together. On the basis of this social behaviour, interactions between birds belonging to different colonies are possible. Therefore the carrying capacity was evaluated based on the food available at increasing distances from the nesting zones, assuming possible overlaps. Linear distance, rather than “area around the nest” was used to express the daily movement from the nests, based on literature reviewed.

Due to the characteristics of the data set, maximum distance was necessarily set at the boundary of the park, for which was therefore expected the same value for all the zones. More interesting results were obtained with intermediate thresholds, as detailed presented in Table 4.
At the distance of 10km from the nesting/breeding zone, maximum carrying capacity ranges from 9.34 vultures per year (scenario “sheep and cattle”) to 19.49 vultures per year (scenario “sheep, cattle and wildlife”).
Zone 1 and 3 account for the highest carrying capacity, in all the three scenarios. These findings should be taken into consideration during the captive phase, which normally lasts 3 to 5 years (Choisy, 2002); in fact during that period, birds get familiar with the area surrounding their cages. Therefore, suitable conditions contributing to their survival decrease the possibility of migration once they are released.

**Table 4: Summary table showing carrying capacity (annual number of Griffon supported) at increasing distances from nesting sites.**

| Number of Griffon Vulture supported | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Food base: sheep and wildlife** | | | | | | | |
| **Distance (m)** | **Zone 1** | **Zone 2** | **Zone 3** | **Zone 4** | **Zone 5** | **Zone 6** | **Zone 7** |
| 500 | 3.03 | 0.35 | 0.89 | 0.18 | 0.19 | 0.15 | 0.11 |
| 1000 | 4.27 | 0.61 | 1.49 | 0.37 | 0.60 | 0.33 | 0.27 |
| 5000 | 10.74 | 4.17 | 11.98 | 2.69 | 6.69 | 2.85 | 2.83 |
| 10000 | 17.37 | 10.03 | 17.76 | 7.02 | 16.49 | 6.16 | 6.44 |
| **Food base: sheep and cattle** | | | | | | | |
| **Distance (m)** | **Zone 1** | **Zone 2** | **Zone 3** | **Zone 4** | **Zone 5** | **Zone 6** | **Zone 7** |
| 500 | 2.32 | 0.00 | 0.48 | 0.00 | 0.24 | 0.00 | 0.00 |
| 1000 | 3.08 | 0.00 | 0.80 | 0.00 | 0.54 | 0.00 | 0.00 |
| 5000 | 7.14 | 1.58 | 8.45 | 0.26 | 3.34 | 0.00 | 0.00 |
| 10000 | 9.34 | 5.49 | 9.34 | 3.44 | 9.06 | 1.48 | 1.47 |
| **Food base: sheep, cattle and wildlife** | | | | | | | |
| **Distance (m)** | **Zone 1** | **Zone 2** | **Zone 3** | **Zone 4** | **Zone 5** | **Zone 6** | **Zone 7** |
| 500 | 3.05 | 0.35 | 0.89 | 0.18 | 0.43 | 0.15 | 0.11 |
| 1000 | 4.31 | 0.61 | 1.53 | 0.37 | 0.93 | 0.33 | 0.27 |
| 5000 | 11.62 | 4.51 | 13.30 | 2.90 | 7.05 | 2.85 | 2.83 |
| 10000 | 19.10 | 11.40 | 19.49 | 8.37 | 18.15 | 6.49 | 9.02 |

From these findings the park it is not suitable for a population of 60 vultures released at the same time and depending only on the park’s resources. Instead, the initial phase of the programme, when 12 individuals (Choisy, 2002) should be released, is sustainable for two out of three scenarios.
To assess what would be the carrying capacity irrespective of the nesting site, the food available in the entire park for each of the three feeding behaviours, was also evaluated[12]. A maximum carrying capacity of 9.34 vultures (diet based on sheep and cattle), 20.45 vultures (diet based on sheep and wildlife), and 22.17 vultures (diet based on sheep, cattle and wildlife) was derived from the all park, adding evidence to the conclusion that the park cannot support by itself a viable population (considering viable a population of at least 60 individuals). Nevertheless, before any final conclusion is drawn, an investigation on the resources abundance should be done for the surroundings of the park and included in the model. In fact, due to the characteristics of the area (mountains and forests), suitable food for Griffon will likely be found outside of the park.

[12] Only results are presented here.

# 7. Conclusion and recommendation

Increasing awareness on the value of biodiversity drove the necessity to gather knowledge on the relevant conditions helping to preserve biodiversity components. The viability of its components would indeed ensure the existence of the overall community, which is one of the elements used to evaluate the biological diversity.
A GIS-based approach is here presented, as a contribution to better understand the potential of Retezat Mountains area, to support a Griffon Vulture reintroduction programme.

The general aim of GIS-based modelling here is to represent the reality in a useful way to obtain relevant information for the target species; therefore, a selection of elements to include in the model to guide the analysis and help to interpret the results was necessary.
Here, a number of information based on biological, ecological and institutional/management criteria have been considered and included in the model.
Although data availability and the possibility to retrieve new information limited the extent of the model, additional elements could be included, following the same approach.

The environmental suitability of Retezat area was evaluated on the basis of:

- Presence of potential nesting/breeding sites
- Number of vultures sustainable based on food abundance and distribution

Whilst the first element of the suitability gave positive results, the second one showed a maximum population size smaller than the suggested from literature for similar projects.
Nevertheless, due to the sensitivity of the model to the assumptions, this finding should be further investigated. Particularly, due to the extent of available information, the analyses were limited to the park boundary, which is unlikely to be recognised by the species of any biological meaning. Data on food abundance and distribution outside the park should be gathered and included in the model, to increase its biological character.

Experience and contact with similar projects should be considered as an important source of information to improve the capability of the model to predict the suitability. Additionally, higher percentages of food obtainable from a carcass and the possibility to get additional food from vulture restaurants (Slotta-Bachmaryl et al., 2004) should be explored before taking any management decisions.

# References


Biodiversity Conservation Division, Ministry of Waters, Forests & Environmental Protection, 2004. Biodiversity in Romania. http://ariiprotejate.ngo.ro/docs/biodiversity/robiodiv.htm.

Bretagnolle, V., Inchausti, P., Seguin, J.-F. & Thibault, J.-C. Evaluation of the extinction risk and of conservation alternatives for a very small insular population: the bearded vulture Gypaetus barbatus in Corsica. *Biological Conservation*, **In Press**.

Cayuela, L. 2004. Habitat evaluation for the Iberian wolf *Canis lupus* in Picos de Europa National Park, Spain. *Applied Geography*, **24,** 199-215.

Choisy, J. P. 2004. Pers. comm.

Choisy, J. P., Tessier, C. & Henriquet, S. 2002. Reintroduction of Griffon Vulture *Gyps fulvus*. Current state of the method in France. Parc Naturel Regional du Vercors, France.

Clark, J. D., Dunn, J.E. & Smith, K.G. 1993. A multivariate model of female black bear habitat use for a geographic information system. *J. Wildl. Manage.*, **57,** 519-526.

Corsi, F., De Leeuw, J. & Skidmore, A. 2000. Modeling Species Distribution with GIS. In: *Research techniques in animal ecology: controversies and consequencies.*: Boitani, L. and Fuller, T.K. Eds.

Corsi, F., Dupre, E. & Boitani, L. 1999. A Large-Scale Model of Wolf Distribution in Italy for Conservation Planning. *Conservation Biology*, **13,** 150-159.

Farber, O. & Kadmon, R. 2003. Assessment of alternative approaches for bioclimatic modeling with species emphasis on the Mahalanobs distance. *Ecological Modelling*, **160,** 115-130.

Garshelis, D. L. 2000. Delusions in Habitat Evaluation: Measuring Use, Selection, and Importance. In: *Research techniques in animal ecology: controversies and consequencies*: Boitani, L. and Fuller, T.K. Eds.

Genero, F. 2004. Pers.Comm., pp. Progetto Grifone, Forgaria nel Friuli, Italy.

Guisan, A. & Zimmermann, N. E. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling*, **135,** 147-186.

Jenness, J. 2003. Mahalanobis distances (mahalanobis.avx) extension for ArcView 3.x. Jenness Enterprises.

Jørgensen, S. E. 1994. *Fundamentals of ecological modelling*. Amsterdam etc.: Elsevier.

Liberatori, F. & Penteriani, V. 2001. A long-term analysis of the declining population of the Egyptian vulture in the Italian peninsula: distribution, habitat preference, productivity and conservation implications. *Biological Conservation*, **101,** 381-389.

Meffe, G. K. & Carroll, C. R. 1994. *Principles of conservation biology*. Sunderland, Massachusetts: Sinauer Associates, Inc.

Mullarney, K., Svensson, L., Zetterstrom, D. & Grant, P. J. 2004. *Bird Guide*. Vicenza: HarperCollins.

Negro, J. J. & Torres, M. J. 1999. Genetic variability and differentiation of two bearded vulture *Gypaetus barbatus* populations and implications for reintroduction projects. *Biological Conservation*, **87,** 249-254.

Oaklandzoo. 2004. Griffon Vulture. http://www.oaklandzoo.org/atoz/azgrvult.html.

Poirazidis, K., Goutner, V., Skartsi, T. & Stamou, G. 2004. Modelling nesting habitat as a conservation tool for the Eurasian black vulture (*Aegypius monachus*) in Dadia Nature Reserve, northeastern Greece. *Biological Conservation*, **118,** 235-248.

Posillico, M., Meriggi, A., Pagnin, E., Lovari, S. & Russo, L. 2004. A habitat model for brown bear conservation and land use planning in the central Apennines. *Biological Conservation*, **118,** 141-150.

Primack, R. B. 1993. *Essentials of conservation biology*. Sunderland, Massachusetts: Sinauer Associates, Inc.
Pronatura. 2004. http://www.pronatura.ro/en/retezatnp/importance.htm.
Robertson, A. S. & Boshoff, A. F. 1986. The Feeding Ecology of Cape Vultures *Gyps coprotheres* in a Stock-Farming Area. *Biological Conservation*, **35,** 63-86.
Slotta-Bachmaryl, L., Bogel, R. & Camina Cardenal, A. 2004. Status report and Action plan. The Eurasian Griffon Vulture (*Gypus fulvus*) in Europe and the Mediterranean. http://www.gyps.org/download/Action_plan_Griffon_vulture.doc
Soulé, M. E. & Wilcox, B. A. 1980. *Conservation biology : an evolutionary - ecological perspective*. Sunderland, Massachusetts: Sinauer Associates, Inc.
Store, R. & Jokimaki, J. 2003. A GIS-based multi-scale approach to habitat suitability modeling. *Ecological Modelling*, **169,** 1-15.
Tewes, E., Terrasse, M., Frey, H., Sanchez, J. J. & Fremuth, W. 2002. Action plane for recovery and conservation of vultures on the Balkan peninsula. In: *Planning workshop*. Sofia.
UNDP, U. N. D. P. 1996. The national strategy and action plan for the biological diversity conservation and sustainable use of its components in Romania http://www.undp.org/bpsp/nbsap_links/NBSAP_Romania.htm
Wilds, S., Boetsch, J. R., van Manen, F. T., Clark, J. D. & White, P. S. 2000. Modeling the distributions of species and communities in Great Smoky Mountains National Park. *Computers and Electronics in Agriculture*, **27,** 389-392.

# Appendix 1

**Table 5: Input data.**

| Name | Data type | Geometry type | Coordinates System | Datum |
|---|---|---|---|---|
| Wildlife census data | Excel spreadsheet | | | |
| Livestock census data | Excel spreadsheet | | | |
| Visited sites | Shapefile Feature Class | Point | GCS WGS 1984 | WGS 1984 |
| Lake | Shapefile Feature Class | Polygon | WGS 1984 UTM Zone 34N | WGS 1984 |
| River | Shapefile Feature Class | Line | WGS 1984 UTM Zone 34N | WGS 1984 |
| Area of interest clip | Shapefile Feature Class | Polygon | Double Stereographic | Dealul Piscului 1970 |
| Retezat NP Boundary | Shapefile Feature Class | Polygon | Double Stereographic | Dealul Piscului 1970 |
| Retezat NP Land Cover | Shapefile Feature Class | Polygon | Double Stereographic | Dealul Piscului 1970 |
| Digital Elevation Model (Shuttle Radar Topography Mission) | Raster; 90m pixel size | | GCS WGS 1984 | WGS 1984 |
| Bands 1-5 Landsat 7 Enhanced Thematic Mapper Plus (22 August 2000) | Raster; 28.5m pixel size | | WGS 1984 UTM Zone 34N | WGS 1984 |

# Appendix 2

Mahalanobis distances are calculated as (Jenness, 2003):

$$D^2 = (\mathbf{x}-\mathbf{m})^{\mathrm{T}} \mathbf{C}^{-1} (\mathbf{x}-\mathbf{m})$$

where:

$D^2$ = Mahalanobis distance

$\mathbf{x}$ = Vector of data

$\mathbf{m}$ = Vector of mean values of independent variables

$\mathbf{C}^{-1}$ = Inverse Covariance matrix of independent variables

$\mathbf{T}$ = Indicates vector should be transposed

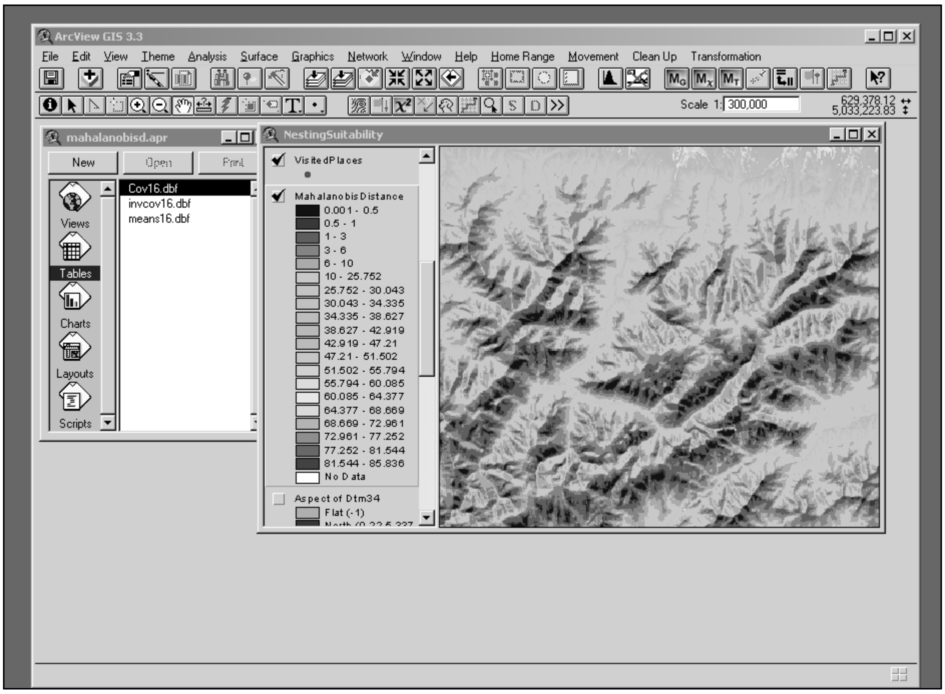


**Figure 12: Screenshot of Mahalanobis Distance Surface Grid representing the similarity of input environmental variables (Aspect, DEM and Slope grids) in relation to the known suitable sites (Visited places).**

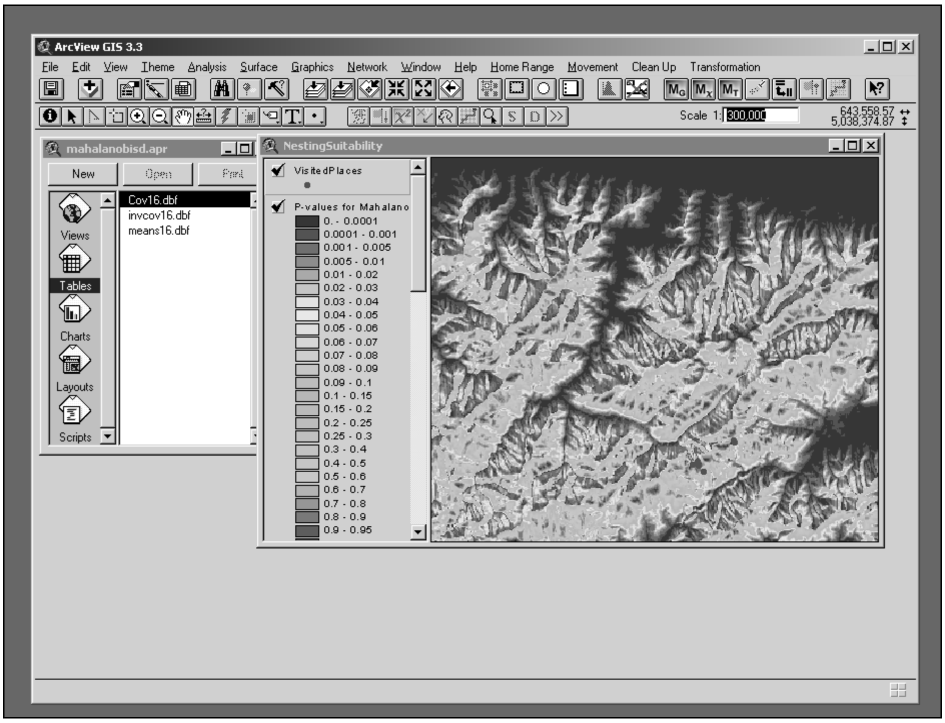


**Figure 13: Screenshot of probability of the area to be used as nesting/breeding sites, obtained after rescaling Mahalanobis Distance Values.**

# Appendix 3

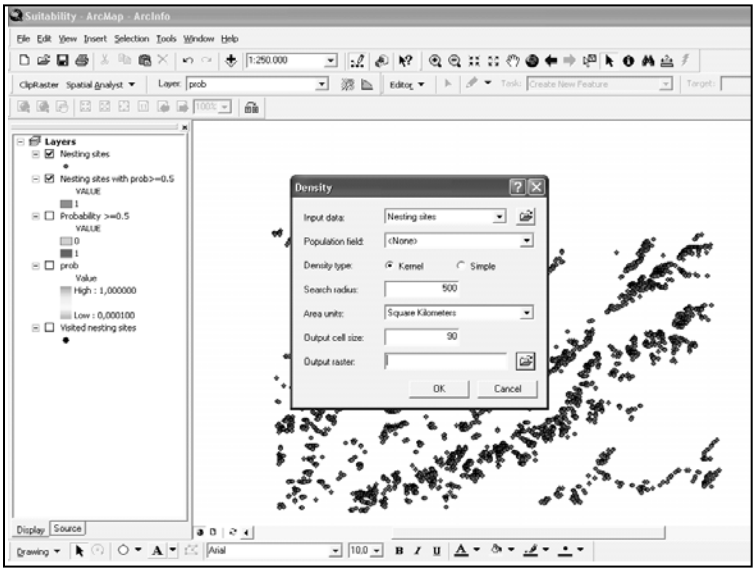


**Figure 14: Screenshot of derivation of Kernel density grid around suitable single nesting sites.**

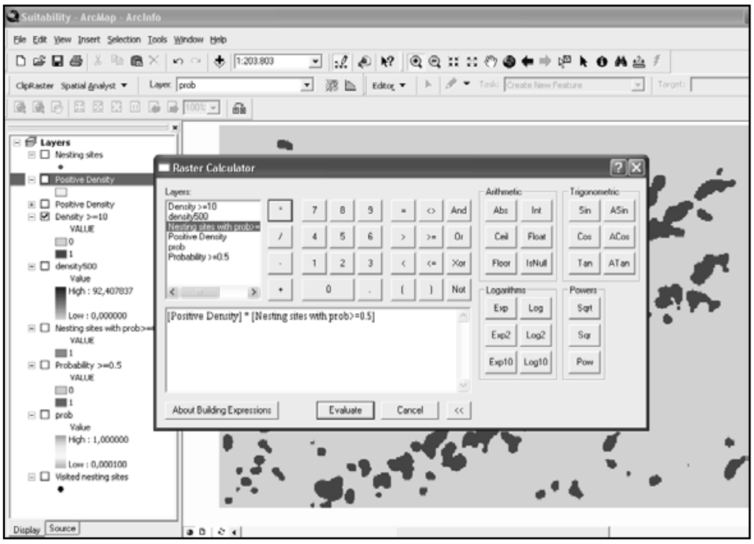


**Figure 15: Screenshot of derivation of a grid, representing number of nesting sites per each density cluster.**