European Ground Squirrel (*Spermophilus citellus*) conservation: a potential distribution approach

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Content

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Summary
The European Ground Squirrel (*Spermophilus citellus*) is a rodent species which is currently distributed through central and south-eastern Europe (between 12° 40’-29° 00’ E and between 40° 20’-51° 00’ N), where it occurs at altitudes of 0-2.500 m. Its distribution is generally limited by climatic conditions and the existence of step-like habitats with low vegetation layers. The dispersion of EGS in Europe followed the development of landscape deforestation and its conversion to cultural steppe 3000 to 2000 years ago, beginning in its Balkan refuge.

Between 1947-1952 EGS was so abundant, that they were seen as a pest species which caused considerable damage to small farmers. Since this time EGS abundance started to decrease. EGS was hunted as pest and, through a change in the agricultural system, landscape conversion occurred with a loss of suitable habitat and a rapid disappearance of an essential part of the EGS’s biotope.

The EGS went extinct in 1960 in Germany and in the 1980’s in Poland. Today, EGS is a protected species. Within the European legislation the EGS is listed on Appendix II of the Bern Convention and Annexes II and IV of the EU Habitats and Species Directive. On the IUCN red list the conservation status for the whole range of its distribution is listed as vulnerable. On national scale the EGS is protected in the Czech Republic, Slovakia, Austria, Hungary and Poland. There is no information on protection status in the other range countries.

Today changes in landscape use and loss of biotope still play a role but the endangering factors for the EGS are more heterogenic and differ from habitat to habitat. Genetic isolation, absence of appropriate grass cover management, random weather events, construction development, and natural enemies and diseases are important ones.
Distribution of EGS switched for a considerable percentage to human made areas such as airports, golf courses or vineyards.

To investigate current distribution and potentially needed conservation actions, an ArcGIS based analysis with Maximum Entropy (MaxEnt) species distribution modeling was performed. This revealed that EGS potential occurrence (based on apparent preference and limitation patterns derived from modeling based on current distribution data) are scattered throughout Europe and within the range countries Slovenia, Romania, Greece, Macedonia, Croatia, Bulgaria, Moldova, Montenegro, Turkey, Germany and Poland, but that a reasonably interconnected core area of EGS distribution appears to occur in Austria, Slovakia, Hungary and the Czech Republic.

An overlap of Natura 2000 areas and areas of potential EGS occurrence, showed that most of the areas where EGS potentially occur are not protected by these areas (0.14% overlap), also in the core area (0.65% overlap). Reintroduction programs took place in Poland, Germany, Slovakia, and the Czech Republic. Some of them were unsuccessful, for various named reasons such as inadequate management of the target localities, a too small or too high amount of individuals transferred, too high predation pressure or unsuitability of the release site. Our potential distribution model showed that the reintroduction sites were generally located outside of areas with suitable environmental conditions for EGS occurrence.

The Maxent species distribution modeling showed 3.4% of core area range countries to be suitable habitat for EGS occurrence, of which 0.65% is currently located in Natura 2000 areas. Suitable habitat thus appears to be an important issue and potentially limiting factor for EGS occurrence and conservation. For this reason and because of the ongoing landscape conversion to artificial and agricultural areas, it appears crucial to connect existing suitable

habitats and start to extend the Natura 2000 network to grass steppe habitats with EGS as key species.

To prevent extinction on international scale, the general conservation strategy should be:

- Prevent reduction of future habitat loss by habitat protection and restoration.
- Compensation for farmers for EGS appropriate habitat management. Connectivity between EGS sites, to facilitate passing railroads, roads, urban developments between locations.
- Conservation breeding and reintroduction in suitable core areas, not in marginal habitat.
- Enhance public awareness: Undertake efforts to educate and inform the public to increase the acceptance and facilitation of the species.
- Intensify and support research on population ecology, dynamics and genetics, as well as on the efficiency of conservation measures
- Update the knowledge on the status, distribution, population density and vitality in countries where it is uncertain, and suffering from a lack of data.
- Updating legal protection in range countries where EGS is still not protected.
- Ideally generating a network of protected core areas under Natura 2000 areas.

1. Introduction

The European Ground Squirrel (*Spermophilus citellus*) is an endemic, non-social, hibernating rodent, distributed through several Pan- European countries. Its habitat is semi-arid grass steppes and analogical man-made landscapes with short vegetation layers, such as meadows and golf courses (Komárek, 1950; Koshev, 2008).

Since 1996, the European Ground Squirrel (EGS) is categorized by IUCN as vulnerable, and population numbers are decreasing (IUCN, 2008). It is included in the Bern Convention on Appendix II, and in the European Habitat and Species Directive on Appendix II and IV (Koshev, 2008). Main threats on populations are converting steppes to forestry or cultivated areas with higher vegetation layers (Kryštufek, 1999; Spitzenberger, 2002). Another threat to populations is the lack of knowledge concerning its current distribution and legal conservation status.

The EGS is supposed to be an indicator species with international importance for the conservation of steppe habitats in the scope of installing a Pan- European ecological network (Bloemmen & v.d., Sluis, 2004).

Currently, EGS status has received attention in several countries of its distribution area, but there is no international plan for its conservation. There is however an ad hoc informal network of conservation research on EGS, the European Ground Squirrel Group, with representatives from the majority of the range countries, which has regular meetings. This group has an interest in conservation issues, but currently lacks coherence and a good overview of distribution data over the species range throughout Europe.

This investigation has the objective to get an overview of currently existing recent species distribution data, in order to indicate current distribution characteristics and potential habitat, as basis to emphasize the importance of international cooperation in EGS conservation.

The objective will be established by (1.) identifying current life history issues and limitations to EGS occurrence (Chapter 3 and 4), by (2.) displaying current status and distribution of EGS on a national and international scale in ArcGIS (Chapter 5), by (3.) predicting potential EGS range by using Maximum Entropy (Maxent) species distribution modeling (Chapter 6), by (4.) evaluating the Natura 2000 network concerning legal protection of EGS and reintroduction initiatives (Chapter 6.2.2. till 6.2.4.), and by (5.), as a consequence, defining appropriate conservation measures (Chapter 9).

2. Approach

This study is written to provide a report accessible for all parties active in the conservation and protection of the European Ground Squirrel on a European scale. It shows a recent view on the distribution and status of the EGS and a potential distribution of EGS in Europe based on important factors concerning the habitat, such as land use, soil type, temperature and elevation.

Within the framework of a Bachelor thesis, we accumulated existing and available distribution data of EGS of all range countries to prepare current distribution maps and status reports, and to generate a potential distribution of EGS in Europe.

Combining the findings with present conservation measures, we aimed for generating recommendations for future conservation activities concerning the EGS, and suggestions for future research are needed before these recommendations can be executed.

The existence of the EGS research group proved to be very helpful. Every two years there is a meeting in one of the range countries. This year, in 2012 it will be in Poland. The first EGS meeting took place in 2006 in Felsőtárkány, Hungary. An initial idea of a regular expert meeting originates from the international conference "Ecology and conservation of the European souslik (*Spermophilus citellus*)" in 2002 in Madjarovo, Bulgaria, organized by Bird Life Bulgaria and the Bulgarian-Swiss Biodiversity conservation program. The EGS research group meeting represents a possibility for researchers and nature conservationists to share experiences and data on the species on an international scale (Matějů 2012). Several publications related to these meetings have been produced since and some have been consulted regularly to fulfil our present task.

In addition to the study of scientific papers and publications, direct contact by email was sought with the participants of the EGS research Group. With the co-operation of several of their members in providing data, it was possible to cross-check and updates the available information on distribution and status of the species for several of the range countries. Unfortunately, not all countries were able to provide information, so there are still gaps in the analyses.

The methodology used for the whole process of analyzing available Literature and distribution data of EGS can be described in five main steps. 1) Summarize literature about natural history of EGS, 2) Consult experts of the EGS research group, 3) Analyse obtained distribution data in ArcGIS, 4) Combine the maps with other mapped habitat aspects and analyse the distribution data using maximal entropy (Maxent) species distribution modeling, and 5) Formulate recommendations. A flow model of the process can be found in Appendix VII. This model provides a guideline through the report.

3. Conservation status

European level

Within the European Legislation the EGS is listed on Appendix II of the Bern Convention (strictly protected fauna species) and Annexes II (fauna and flora species in the interest of the Communities whose protection requires that special protection areas are declared) and IV (fauna and flora species in the interest of the Communities that require strict protection) of the EU Habitats and Species Directive. (IUCN 2011, Matějů et al 2010) On the IUCN red list the conservation status for the whole range of its distribution is vulnerable. (IUCN 2011)

National level - Protection status in other countries

Czech Republic: Specially protected animal species pursuant to provisions of section 48 of the Czech National Council No 114/1992 Coll. on nature and landscape protection declared by means of Decree No. 395/1992 Coll. against killing, destroying of its habitat and disturbing by human activities (Matějů 2012) and is because of the level of risk in the EGS included in the list of critically endangered species (Matějů et al. 2010).
Slovakia: Protected species of European importance pursuant to Act No. 345/2002 and Decree No. 24/2003 (Ministry of Environment of the Slovak Republic 2003)
Austria**:** Every federal state in Austria has its own legal regulation providing for conservation so there is no uniform legislation in this country. In the federal states where the EGS occurs, (Wien, Niederösterreich and Burgenland) it is protected by legal regulations. (Umweltdachverband, 2008)
Hungary: Protected species pursuant to Act No. 13/2001 (European Commission 2009)
Poland: Strictly protected species (Act of 16. April 2004, Coll. 2004, Item no 92/880; Decree of 24th September 2004, Coll. 2004 Item no. 220/2237) (Matějů et al. 2010). The species got extinct in Poland in the 1980s (Meczynski 1985). Recently it has been introduced near the town Kamień Śląski (Matějů et al. 2010, Matějů et al. 2011).

EGS notations in national Red lists of endangered species

Czech Republic: EGS, originally considered as a pest, was in 1988 included in the Red List of endangered vertebrate taxa in former Czechoslovakia as critically endangered.
Slovakia: Endangered
Austria: Endangered
Hungary: Not included in the red list (The red list was published 1989)
Poland: Extinct species, however the red list has not been updated since 2001.
Greece: Vulnerable (Legakis et al. 2009)
Romania: Vulnerable (Animal info 2004)

4. Natural History

4.1. Appearance

EGS is a stout-bodied species adapted for fully quadruped movement and semi-fossorial life. Front limbs have 4 and hind limbs 5 fingers (Matějů 2012). The EGS is about as large as a small rat. The males are a little larger than females. On average, the body length of the EGS is 17-23 cm. The hind foot length is 33-41mm and the ear 7-10mm. The fury tail is relatively short with 38-74mm. The weight lies generally between 170g and 430g. The pelage of the back is yellow grey. The fur is somewhat brown yellow mottled, but not spotted. The belly and the throat are whitish. In spring time (winter coat) the fur is lighter and more grayish. The outer ears are almost not present only small auricles are visible. (Mac Donald & Barrett 1993, Twisk, 2010) In proportion to the rest of the body the paws are short. The EGS has big light framed eyes on the side of the head. It frequently stands erected in alarmed "begging" posture (Mac Donald & Barrett 1993).

4.2. Fossil records and taxonomy

Fossil records of squirrels suggest that they originate in the Northern Hemisphere, particularly North America, around 36 million years ago. The first fossil record of a squirrel (*Douglassciurus jeffersoni)* ranges from approximately 37.5 to 35 million years ago. The appearance of this squirrel is quite similar to the squirrels today with similar dental and skeletal structures but it still missed the typical sciuromorphous zygomasseteric system (characterized by attachment of the lateral masseter muscle along the side of the rostrum). (Steppan & Hamm 2006)

The name „Squirrel" originates probably from the Greek word „skioros," meaning shade tail. The philosopher Aristoteles called them like that. Later the French called them „esquirel", and in time, through other languages and interpretations, rodents with long, bushy tails became commonly known as squirrels in the English language. (Steppan & Hamm 2006)

The EGS is a member of the family Sciuridae (see Table 1) which comprises at the moment 278 species and 51 genera. It is one of the most diverse and variable families of living mammals. (Steppan & Hamm 2006)

Table 1. Taxonomic classification of the Spermophilus citellus

Kingdom	Animalia
Phylum	Chordata
Subphylum	Vertebrata
Class	Mammalia
Order	Rodentia
Family	Sciuridae
Subfamily	Xerinae
Genus	Spermophilus
Species	S. citellus

Members of Sciuridae range from the common, arboreal grey squirrel in the United States, to flying squirrels, terrestrial marmots, chipmunks, semi-fossorial prairie dogs, and various terrestrial and arboreal squirrels around the world. Sciurids can tolerate a variety of

environmental conditions and are found from the Arctic to the tropics, including most arid and humid regions. (Steppan & Hamm 2006)
Typical squirrels, such as *Sciurus carolinensis, Spermophilus lateralis,* and *Xerus inauris* have a body mass of 0.25 kg to 0.4 kg, with lengths of about 23 to 25 centimetres. But within this family there is a huge range from 7 cm of the African Pygmy squirrel up to 91 cm of the Giant Red Squirrels of Southeast Asia.

In the past squirrels where divided into 2 subfamilies comprising out of *Sciurinae*, the tree and Ground Squirrels, and *Pteromyinae*, the flying squirrels. But recent research detected that squirrels have to be divided into 5 subfamilies concerning some distinctive adaptations for gliding found in the *Pteromyinae.* So now there are *Ratufinae, Sciurillinae, Sciurinae, Xerinae*, and *Callosciurinae, Spermophilus citellus* belonging to *Xerinae.* (Steppan & Hamm 2006)

There are nine subspecies of *S. citellus* recognized in the area of its distribution. (Matějů et al. 2010).

1. *S. c. citellus* (Linnaeus, 1766) mainly distributed in the Czech Republic, Austria, Slovakia and Hungary.
2. *S. c. gradojevici* (Martino & Martino, 1929) occurs in lowlands of the river Vardar and the lake Dorjan; Macedonia
3. *S. c. karamani* (Martino & Martino, 1940) is only found in Macedonia; occurs on alpine meadows and pastures in the Patiška river-basin, Karadžica Mountains., (KRYŠTUFEK 1993, 1996).
4. *S. c. istricus* (Calinescu, 1935) Romania; Muntenie area, Danube lowland; (RUŽIĆ 1978).
5. *S. c. laskarevi* (Martino & Martino, 1940) Serbia; occurs in SE part of Panonia - southeast Banat; some Bulgarian populations also belong to this sub species.
6. *S. c. martinoi* (Pešev, 1955) in question by Ondrias (1966) who synonymises this sub-species with *S. c. karamani.* Ružić (1978) considers it as a single sub species in Bulgaria, in the Rila Mountains.
7. *S. c. balcanicus* (Markov, 1957) in question by Ondrias (1966) synonymises this sub species with *S. c. karamani.* Ružić (1978) considers it as a single sub species, Bulgarian mountains.
8. *S. c. thracius* (Mursaloğlu, 1964) occurs in European part of Turkey.
9. *S. c. macedonicus* (Fraguedakis-Tsolis, 1977) occurs in Greek Macedonia

4.3. European distribution

The EGS is endemic to central and south-eastern Europe (between 12° 40’ and 29° 00’degrees of east longitude and between 40° 20’ and 51° 00’ degrees of north latitude), where it occurs at altitudes of 0-2.500 m. Its range is divided in two main areas of occurrence by the Carpathian Mountains. The north-western portion extends from Poland through the Czech Republic, Austria, Croatia, Slovakia, Hungary, northern Serbia and Montenegro, and western Romania whilst the south-eastern portion extends from southern Serbia, Macedonia and Greece through Bulgaria and southern Romania to Turkish Thrace, Moldova and Ukraine (Panteleyev 1998, Kryštufek 1999). (IUCN 2011, Matějů 2010).

The area of *S. citellus* distribution is highly fragmented by several geographical barriers (rivers, mountain ranges, continuous forest areas etc.), which may be the cause of a relatively high number of existing subspecies (Matějů 2012). Figure 1 shows a map of *Spermophilus citellus* distribution according IUCN.

(Figure 1. Distribution of *Spermophilus citellus* in Europe, IUCN 2008)

<u>4.4. Habitat preferences and burrows</u>

EGS habitats are European grassy steppes with low vegetation layers (Mateju *et al*, 2010). Its current distribution in non-steppe habitats became facilitated by the evolving of agriculture (Komarek, 1950). Nowadays, the EGS occurs in several habitat types that differ per range country. In lower Austria only 5 different habitats were distinguished: dry grassland, fallow land, vineyards, field boundaries and grassland influenced by man (Enzinger *et al*, 2008). Durica (2008) observed EGS occurrence in 15 different habitats in Serbia.

Important habitat characteristics are short vegetation layers, associated with extensive grazing (Durica, 2008). Areas without grazing and higher vegetation layers are not viable options for EGS, because they lose orientation and get more vulnerable to predators (Hulova, 2001). By the presence of large herbivores and resulting habitat heterogeneity, EGS habitats are considered to invite high biodiversity (Carpaneto *et al*, 2011).

EGS occur at elevations below 200m, except for Slovakia, where EGS are also considered to occur in elevations above 1000m (W. Arnold, pers.comm., in Millesi *et al*, 1999).

The species occurs throughout soil types that facilitate burrow digging (Mateju *et al*, 2010). Limiting factors are ground water level and low soil conductivity. Populations locate their burrows in plain areas or small slopes (Mateju *et al*, 2010).). Two types of burrows can be distinguished: shelters and permanent burrows (Mateju *et al*, 2010).). Shelters are used only to hide from predators whereas permanent burrows are used perennial for resting, nesting and hibernation. The burrows often evolve from shelter burrows and may be connected to each other by a corridor. Permanent burrows are located in a depth of ~70cm.

Intensification of agriculture cause decreasing EGS populations throughout its range (Mateju *et al*, 2010). Also impacts such as shifting habitats by reforestation, plantations of hazelnuts and increasing oil seed fields cause habitat fragmentation and isolated populations.

A summary of habitat characteristics that appear essential for the potential occurrence of EGS are listed in table 2.

Table 2. Habitat characteristics and limitations for EGS occurrence

Habitat characteristic	**Limitations**
Habitat type/ use	Low vegetation layers, limitations of agricultural use: extensive grazing, mowing; shifting habitats
Slope	Small gradients
Elevation	<200m (>1000m Slovakia)
Soil: Texture, parent material	Must facilitate burrow digging; soil conductivity
Water management	Not >1m asl.

The general trend in Europe concerning grazed landscapes is decreasing. For this reason, several grassland habitats are categorized in Annex I of the Habitat directive that represent habitats of European community interest with the necessity of conservation (Table 3).

Table 3. European grassland habitats included in Annex I of habitat directive (Office for Official Publications of the European Communities, 2004)

European grasslands in Annex I of the habitat directive
6. NATURAL AND SEMI-NATURAL GRASSLAND FORMATIONS **61. Natural grasslands** 6110 * Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi 6120 * Xeric sand calcareous grasslands 6130 Calaminarian grasslands of the Violetalia calaminariae 6140 Siliceous Pyrenean Festuca eskia grasslands 6150 Siliceous alpine and boreal grasslands 6160 Oro-Iberian Festuca indigesta grasslands 6170 Alpine and subalpine calcareous grasslands 6180 Macaronesian mesophile grasslands 6190 Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis) **62. Semi-natural dry grasslands and scrubland facies** 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites) 6220 * Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea 6230 * Species-rich Nardus grasslands, on silicious substrates in mountain areas (and sub mountain areas in Continental Europe) 6240 * Sub-Pannonic steppic grasslands 6250 * Pannonic loess steppic grasslands 6260 * Pannonic sand steppes 6270 * Fennoscandian lowland species-rich dry to mesic grasslands 6280 * Nordic alvar and precambrian calcareous flatrocks 62A0 Eastern sub-Mediterranean dry grasslands (Scorzoneratalia villosae) 62B0 * Serpentinophilous grassland of Cyprus **63. Sclerophillous grazed forests (dehesas)**

6310 Dehesas with evergreen Quercus spp.
64. Semi-natural tall-herb humid meadows
6410 Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)
6420 Mediterranean tall humid grasslands of the Molinio-Holoschoenion
6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6440 Alluvial meadows of river valleys of the Cnidion dubii
6450 Northern boreal alluvial meadows
6460 Peat grasslands of Troodos
65. Mesophile grasslands
6510 Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)
6250 Mountain hay meadows
6530 * Fennoscandian wooded meadows

The EGS has been identified as an indicator species with international importance for the conservation of steppe habitats with the potential scope of installing a Pan-European ecological network (Bloemmen & v.d. Sluis, 2004).

Role in habitat

The species is considered to be a keystone species. Its decreasing trend may cause a threat for species within its trophic system and thereby to the biodiversity of the whole ecosystem. For example, the EGS provides dung to several scarab beetle species that live in their dens (Carpaneto *et al*, 2011). As a prey species, EGS decline may have cascade effects on their predators, such as Saker falcons, buzzards, eagles and mustelids (Carpaneto *et al*, 2011).

4.5. Reproduction

EGS is a polygynous, non-social species (Huber *et al*, 2001). Polygynous males do not contribute much to parental care, their strategy to ensure the passing of their genes is to mate with as many females as possible (Franceschini & Millesi, 2001). But EGS males do contribute to parental care in an unusual manner by helping females digging burrows, where she subsequent are raising their offspring (Huber *et al*, 2001).

In contrast to EGS males, that normally reaches sexual maturity with 2 years, females become reproductive as yearlings (Millesi *et al*, 1999, Millesi *et al*, 1998).
Reproduction in EGS is constrained by hibernation and a precise timing. Before pre hibernation fattening and after lactation EGS follicular development is induced (Huber *et al*, 1999). In smaller females, that usually have longer lactation periods, follicular development is retarded and will restart in early spring, which means that females will not reproduce early in the next season. Female body mass is influencing offsprings´ body mass and late oestrus date is linked to small litter size (Huber *et al*, 1999). During post hibernation, many females undergo a pre- emerge euthermic interval (PPEI) that start regrowth of the reproductive system and spermatogenesis (Barnes et al, 1986, 1988 in Hut et al, 2002). Because of that, mating starts early after emerging from hibernation (Strauss *et al*, 2006).

After a gestation period of four weeks, offspring is born in early May (Mascher *et al*., 2008, Strauss *et al*, 2006). Litter size varies between 2- 10 (on average 4) young with larger litter sizes at low population densities (evidence of density dependence) (Hoffmann *et al*, 2003). Females produce only one litter per year to maximize growth of the offspring and to comply with annual timing (e.g. taking up sufficient energy for winter period) (Huber *et al*, 1999; Huber *et al*, 2001; Millesi *et al*, 1999).

Offspring is reared in litter burrows that are separated from permanent burrows and after a period of 30-40 days, juveniles become independent (Huber *et al*, 2001; Hoffmann et al, 2004; Holekamp, 1984). On average, natal dispersal of juveniles is 17.7m (n=17; range 6.4–25m) (Zidarova, 2008)

4.6. Food

As in all hibernating species, obtaining energy is limited by time and seasonality. As a constraint to overwinter survival, EGS have to fatten prior to hibernation (Mateju *et al*, 2010). To ensure development and overwinter survival, and especially for juveniles, it is crucial to obtain enough energy after becoming independent (Strauss *et al*, 2006).
EGS is mainly a herbivore that forages within a range of about 30 meters from their burrows and may store collected food at certain feeding places (Mateju *et al*, 2010).

EGS diet is composed 80% of mainly dicotylic plants (Danila, 1984). Foraging choices of plants depend on availability as well as on seasonality. In spring, the EGS prefers roots and green parts of plants and shift to seeds and fruits in late summer and autumn (Danila, 1984.)

Typical food items for EGS in lowland habitats are from the genera *Poa, Euphorbia, Andropogon, Cynodon, Medicago, Festuca, Chrysopogon,* and *Stipa*. In mountain habitats EGS forage on food items of the genus *Nardus*.

Also insects, especially of the suborders *Caelifera, Ensifera, Lepidoptera, Colepotera, Hymentoptera, Elateridae* (beetle larvae), *Noctuidae* (moth worms) and *Formicidae* form part of the diet (Grunlich, 1960). Occasionally, the EGS forages on vertebrates, such as little rodents, insectivores or bird eggs (Danila 1989). Pregnant females shift to a diet with higher protein contents, by increasing predation on insects (1/3 to 2/3 of total food volume) (Grunlich 1960).

Food availability concerning preferred diet appears to set habitat limitations.

Table 4. Characteristics and limitations for EGS occurrence related to food

Characteristic	**Limitation**
Habitat type	Food availability (energy)

4.7. Hibernation

By reducing metabolism and body temperature, EGS cope with low temperatures and food shortage in winter in a state of hibernation (Körtner & Geiser, 2000). Hibernation takes place for 6-7 month between August and March and is essential for EGS winter survival (Strijkstra *et al*., 2008; Hut *et al*., 2002).

Hibernation in females starts earlier and ends later than hibernation in males and potentially causes higher female mortality rates in winter (Millesi *et al*, 1999). It takes place in solitary shelter burrows where body temperatures close to ambient temperatures are tolerated (Millesi *et al*, 1999; Strijkstra, 1999; Hut *et al*, 2002). Hibernation affects reproductive, behavioural and brain functions (Hut *et al*, 2002; Millesi, *et al*., 2001).

EGS do not hoard winter reserves, and thus overwinter survival depends on internal fat storages (Humphries *et al*, 2003, Millesi *et al*. 1999). Because of the high demand of energy needed during hibernation, increasing temperature by the environment might cause a loss of hibernation survival and decreasing in reproductive fitness (Nemeth *et al*, 2008).

During hibernation, EGS undergo different periods, including euthermic phases that resemble mainly the physiological state of sleep (Strijkstra et al, 2008, Strijkstra & Daan, 1997). Euthermic phases are very costly (86% of energy expenditure during winter) and cause body mass loss (Wang, 1979, Strijkstra, 1999). Duration and frequency of euthermic phases depend on ambient temperature and endogenous circannual rhythms. At the beginning and at the end of hibernation (usually when higher soil temperatures occur in nature), torpor phases are shorter (Németh *et al*, 2009).

Table 5. Characteristics and limitations for EGS occurrence related to overwinter survival

Characteristic	Limitation
Temperature/ climate	European temperate; climate change

4.8. Mortality

Anthropogenic factors appear to be the main cause of decline in EGS numbers. Shifting of grassland and steppe habitats to cultivated landscapes or forest areas cause EGS habitat loss and fragmentation. Also abandoned pastures and their transforming to meadows with higher vegetation layers or shrubs make former habitats unsuitable for EGS (Kryštufek 1999). Results of these effects are isolated, decreasing EGS populations that are unable to migrate to suitable habitats.

Mortality risks in EGS are likely to increase with migration over long distances because of increasing predation risk (Michener 1989; Schmutz *et al*., 1979). Juvenile males undergo a higher predation risks than females, because they are leaving their burrows earlier and have to search for a new home range (Hoffmann *et al*, 2002). Additionally, adult males have larger home ranges than females and thereby have higher predation risk (Huber, 1996).

Monocultural agriculture causes a threat to EGS in spring and after harvesting when crops are short, because of its increasing visibility to predators. Also increasing industry (e.g. habitat fragmentation, use of chemicals) and development of urban areas (e.g. fragmentation, road kills) are threats to EGS survival (Legakis *et al*. 2009).

As a small primary consumer, EGS undergo high predation risks. Depending on the home range, EGS are predated by birds of prey, mammals and reptiles. In Bulgaria, several EGS predators are listed, amongst which birds of prey, i.e. Buzzard (*Buteo buteo*), Long-legged buzzard (*B. rufinus)*, Lesser spotted eagle (*Aquila pomarina*), Sparrow hawk (*Accipiter nisus*), Kestrel (*Falco tinnunculus*) and Short–toed eagle (*Circaetus gallicus*), and also mammals, i.e. Pine marten (*Matres martes)*, Stone marten (*M. foina*), Western polecat (*Mustela putorus*), Red fox (*Vulpes vulpes*), Golden jackal (*Canis aureus*) and Domestic dog (*C. familiaris*). (Koshev, 2005)

In other countries, also mammals such as feral cats and birds, i.e. magpies and crows, are recorded to hunt EGS (Millesi *et al*, 1999).

Golemansky and Koshev (2007) recorded different species of eucoccidian parasites from the genus *Eimeria* in Bulgarian EGS populations. They considered the occurrence of the species

E. citelli (prevalence 86%), *E. callospermophilli* (71%) and *E. cynomysis* (35%) as limiting factors for EGS survival (Golemansky and Koshev, 2007). In Bulgaria, an infestation percentage with *Eimeria* parasites of 88.5% was reported, in Czech Republic and Slovakia this amounted to 100% (Golemansky & Koshev, 2009).

Adult survival rates during spring and summer (active period) range between 20-40%. Hibernation is a relatively safe behaviour since survival in winter is 70-100% (Strijkstra, 1999). Low winter mortality rates may be an indicator of the good condition in EGS, perhaps due to side-effects of predator pressure (Millesi *et al*, 1999, Hoffman, 1995). In juveniles, mortality rates are 70% in the summer period, without differences between the sexes (Hoffman, 1995).

Table 6. Characteristics related to main mortality factors of EGS

Characteristic	**Mortality factor**
Habitat	Shifting habitats, urban development, road kills, increasing predation risk, isolated and fragmented populations, food shortage
Temperature/ climate	Predation risk during summer, overwinter mortality

4.9. Population dynamics

Population fluctuations are a result of births and death rates, as well as of immigration and emigration. Reproductively, the EGS follow a r-type strategy, because they occur in variable environments throughout a wide range, have shifting population sizes, have a rapid development, have small body size and reach early reproductive maturity.

Population sizes are fluctuating greatly between years, and numbers of males are more variable and more males are lost (Millesi *et al*, 1999). Juvenile losses exceed adult losses, whereas sex ratios in juveniles are equal (Millesi *et al*, 1999; Hoffmann *et al*, 2003).

Population density is lowest before females give birth to their young in early spring where sex ratios then shift to higher numbers of females (Hoffmann *et al*, 2003), and populations increase most between May and June (Mateju *et al*. 2010).

Life expectancy of EGS is about 1-2 years, but on average male life span is shorter (Hoffmann *et al*, 2003).

Size of home ranges depends on season (activity and energy requirements), sex (behaviour) and population density (Zidarova, 2008). Females access larger territories during gestation and males occupy larger home ranges in the mating season, and during emergence of young and natal dispersal (Zidarova, 2008).

Kosnar (1979) observed densities of 46.8 individuals/ha in April and 142.6 individuals/ha in June in the Czech Republic. On average, population densities are between 18-48 individuals/ha, but also lower densities of 5-14 individuals/ ha were reported (Kryštufek, 1999).

In Greece, distances between patches / colonies are 1.03 ± 0.40 km from one another (range 0.40-1.55 km) (Alivizatos & Goutner 1997).

4.9.1. Example of population development in the Czech Republic population

Historical distribution

The dispersion of EGS in Europe followed the development of landscape deforestation and its conversion to cultural steppe 3000 to 2000 years ago, beginning in its Balkan refuge. 1000 To 900 years ago the EGS arrived in Moravia and Bohemia and 700 to 600 years ago dispersed through Bohemia after the clearing of forest area in the Českomoravská vysočina Highlands. 500 To 300 years ago deep forest clearing along the boarders opened the way for the EGS to Poland and Germany.

A first integral image of the distribution of the EGS was published by Grulich (1960) based on a questionnaire research and field investigation. EGSs at this time were widely distributed almost through the whole Bohemian basin with a few exceptions in the south Bohemian basin, the Brdy Mountain area and part of the Českomoravská vysočina Highlands. In Moravia the EGS was especially found in the south and central part. During the mid-20st century (1947-1952) EGS were so abundant, that they were seen as a pest species (Grulich 1960). Since this time EGS abundance started to decrease. (Matějů et al 2010). In 1988, Barta (1992) reviewed the 19 known locations of EGSs in the Most area and only found some individuals in 1 location. In the middle of the 1990's EGSs were only found in 37 locations in 29 grid squares in the whole Czech Republic (Anděra & Hanzal 1995). During the next 5 years the EGSs died out at 14 locations and disappeared from 6 map square grids (Hulova 2001).

Recent distribution

During EGS mapping in 2000/2001, 26 occupied localities were recorded with some not having been reported previously (Cepákova & Hulova 2002) (Matějů et al 2010). Since 2001, there has been regular monitoring of *S. citellus*. Five new sites have been found, six colonies have disappeared, one was re-established by reintroduction, and one site has been naturally colonized following conservation management. Fluctuation or stagnation of abundance has been observed at eleven sites, numbers of EGSs have steadily decreased at seven sites, and only in five colonies populations increased.

In 2006 the total number of *S. citellus* living in the Czech Republic was estimated at 2,750 individuals (Matějů et al 2010). In 2007 occurrence of the EGS was reported only from 34 sites in the Czech Republic which are more or less isolated colonies distributed irregularly through the entire Czech Republic except East Bohemia and North Moravia (Matějů et al 2010).

Future trends

Abundance of EGS colonies changes within seasons and between seasons with the highest numbers in May to June, when the new born individuals enter the population Grulich 1960). In the EGS no apparent recurring population cycles, common to some other species of rodents, were found (Danila 1982).

4.10. Population genetics

The EGS is an endangered species in decline. Populations are increasingly fragmented. There are two major ranges, one in central and south-eastern Europe (Slovakia and Hungary; Eastern), where the EGS is still relatively abundant, and one in the Czech Republic (western), where it occurs in isolated human-made habitats and several isolated patches (Říčanová 2010).

Maintaining local genetic diversity is difficult because of fragmentation and deterioration of available habitat along with the possibility of genetic drift effects at relatively low effective population sizes. (Slimen et al. 2011)

Over 50% of the western populations have fewer than 50 individuals (Kryštufek et al. 2009). In the short term, inbreeding depression might occur which might result in viability problems. In the long term loss of genetic diversity especially in small isolated populations will reduce their capability to adapt to future environmental challenges which can eventually lead to extinction (Matějů et al 2010).

Especially the data of the very fragmented Czech populations (western population) indicate low genetic variability (Říčanová 2010), a high level of inbreeding, and strong genetic differentiation among populations compared to more eastern populations, such as in Austria, Hungary and Romania (Slimen et al. 2011). The Czech populations have indeed lost genetic diversity in the recent past. But genetic variability in the eastern populations is still significantly lower than in undisturbed populations of related species such as *S. suslicus* and *S. Brunneus,* species that are quite similar to the EGS in their ecological requirements, reproductive biology, and social organization. (Slimen et al. 2011)

Gündüz et al. (2007) assume that the EGS originate from a glacial refuge in Anatolia and colonized Europe during interglacial periods between 220000-185000 years ago (Bridgland et al. 2004). Both western and eastern populations were established from the same phylogeographic lineage and are considered to offer low genetic diversity (Kryštufek et al. 2009). During the later expansion of *S. citellus* in Europe some loss of genetic diversity might also have occurred. The lack of sub-fossil records during long periods of the Holocene may indicate local population decreases in central Europe and a spread to the current western edge of its distribution range (i.e., Austria, Czech Republic) only in historical times.

Such a probable recent history might have contributed to a generally lowered level of genetic diversity in *S. citellus*, which presumably has further declined in the course of increased habitat loss and deterioration, and ensuing population fluctuations in the past 50 years (Hoffmann et al. 2003).(Slimen et al. 2011)

4.11. Population decline and endangering factors

Changes in Agriculture and Landscape use and loss of biotope

In the past EGSs were hunted (Gross et al. 2006) and until the 1950th EGS was considered a pest species with considerable damage to small farmers. EGSs were very abundant because suitable habitat like plentiful grassy balks and fields was available. Later, through a major change in the agricultural system a general landscape conversion occurred. Collectivization of fields and ploughing away most of the field's balks resulted in a rapid disappearance of an essential part of the EGS's biotope. The need for mowing the remaining balks and ditches became reduced and they became overgrown with tall vegetation, causing EGS to become an easy prey for predators. Food shortage through harvesting of large areas of agricultural crops during a relatively short time can also have added to the decrease of EGS numbers.

The changes in the landscape mosaic led to a reduction in migration among individual populations. Smaller populations that were maintained by migration of individuals from surrounding sources thus ceased to exist, and in limited time decreases in EGS numbers have been observed. (Matějů et al 2010)

The EGS is currently in serious decline. Its populations have become fragmented, and extinctions have occurred in peripheral parts of its range, for example in Germany in the late 1960s (IUCN 2011, Matějů et al 2010), and during the 1980s from Poland (Matějů 2012).

Today changes in landscape use and loss of biotope still play a role, but the endangering factors for the EGS are more heterogenic and differ from habitat to habitat (Gross et al. 2006). The following factors are the most important ones.

Isolation

Populations of EGS are quite isolated and contain low numbers. Populations can easily become extinct due to any negative impact, such as loss of genetic variation, or catastrophes, such as by disease or high predation pressure, when these factors cannot be compensated through immigration. A reason for isolation is often the loss of appropriate grass cover management. (Matějů et al 2010)

Absence of appropriate grass cover management

In tall vegetation, EGSs lose the overview of its surroundings and become an easy prey for predators. Appropriate vegetation cover management is crucial. Grazing by livestock or regular mowing is necessary to keep the grass cover low (Gross et al. 2006). In 5 of 6 extinctions of EGS populations, inappropriate grass cover management was the probable reason for extinctions between 2000 and 2005. A reduction of individuals may already be caused by a relatively short term lack of proper management for 1-2 seasons. (Matějů et al 2010). Furthermore, landscape discontinuity can inhibit gene flow between habitat patches, decrease the effective population size and may lead to inbreeding depression. Especially in small fragmented populations, the effect of genetic drift may reduce genetic variability and decrease adaptability to a changing environment, and even lead to local extinction (Řícănová 2010).

Weather variations

Random weather events such as rapid snow melting and torrential rain can cause extinction in particularly small EGS populations.(Matějů et al 2010) Fields and meadows get under water, the burrows of the EGSs get flooded and they drown or migrate to other areas (Gross et al. 2006).

Construction development

More and more populations of EGSs get extinct through the change of usage of their localities, particularly when they get used as construction sites (Gross et al. 2006). The problem is that nature and landscape protection in some cases give in to economic interests. (Matějů et al 2010)

Genetic isolation

Since rodents are not good colonists at long distances, they become caught in ‘‘islands’’ of suitable habitat once connectivity is reduced. (Řícănová 2010) Isolated populations show an increased occurrence of homozygote, reduced genetic variability and high rates of inbreeding. In the long term this means reduced viability of the individuals and of the populations which can eventually lead to extinction. But it is not known yet to what extent the process reduces the survival capability of populations of EGSs. (Matějů et al 2010)

Natural Enemies and Diseases
Diseases probably pose only a small risk. However, it can be crucial for small, isolated populations. (Matějů et al 2010)

Direct human influence
In some areas animals are caught or are chased out of their burrows or killed by human action. Sometimes poison is used. (Gross et al. 2006)
Besides many threatened populations, there are still some large and apparently stable populations. There are many reports of population's decline especially in the north-western and southern part of the species range (IUCN, 2011).

Table 7. Overview of threats to EGS

Threat	**Effect**	**Scale**
Isolation	- low individual numbers Populations can easily become extinct - loss of genetic variation,	Local, National and international
Absence of appropriate grass cover management	- EGS lose the overview - EGS become easy prey for predators - Landscape disconnectivity inhibits gene flow between habitat patches, decrease the effective population size and lead to inbreeding depression what results in reduced genetic variability and decrease adaptability to a changing environment, and even lead to local extinction	Local
Weather variations	- rapid snow melting and torrential rain, burrows of the EGSs get flooded and they drown or migrate to other areas	international
Construction development	- Habitat destruction, fragmentation, isolation, extinction	local
Natural Enemies and Diseases	- Decrease in population size, extinction	local
Direct human influence	- hunting and killing of EGS, reduced individual and population numbers	local
Changes in Agriculture and Landscape use and loss of biotope	- Landscape conversion, ploughing away most of the fields balks resulted in a rapid disappearance of an essential part of the EGS's biotope. - Food shortage - reduction in migration among individual populations	local

5.1. Geographical Information Systems (GIS)

Geographical Information Systems produce information maps. A well-known GIS program in the world is ArcGIS (Foote, 2009), supported by worldwide well organized training possibilities. With ArcGIS, distribution maps can be created and combined to visualize Geographical distributions and combinations of maps to indicate habitat use or other Geographical information. GIS is considered a very strong tool in conservation Biology.

We used GIS for processing as current as possible distribution data for as many as possible range countries. These distributions were then combined with other GIS information layers, to investigate current EGS land use for all range countries separately and for all range countries together. Furthermore environmental parameters were estimated as well in the distribution area.

5.1.1. Data

Geographical points of species occurrence were obtained by different researchers per range country. Data was sent electronically or downloaded as shapefiles at http://www.lifemapper.org. An overview of contact people that donated data is given in table 8. Records and data points were not always made available as shapefiles but as excel or kml files. Within ArcGIS 10.0, records were converted to point files and set into the projected coordinate system WGS_1972_Albers.

Table 8. List of Data providers from the range countries

Country	Data provider
Austria	Ilse Hoffmann
Slovakia	Michal Ambros
Poland	Andrzej Kepel
Hungary	Oliver Vaczi
Greece	Dionysios Gioulatos
Macedonia	Werner Haberl
Romania	Zsolt Hegyeli
Czech Republic	Honza Mateju

Based on species description and some apparent limiting aspects of the environment for EGS occurrence, available environmental information layers that illustrate these limitations with ArcGIS were chosen. These layers were:

- Elevation,
- Temperature (Hijmans *et al*. 2005),
- Water management (ESDB v2.0 2004),
- parent material (ESDB v2.0 2004),
- texture of the soil (ESDB v2.0 2004),
- slope (ESDB v2.0 2004),
- limitations to agricultural use (ESDB v2.0 2004),
- CORINE landuse (European Environment Agency).

These GIS layers were downloaded from the internet. Metadata can be found in Appendix I.

5.1.2. Distribution per country

The habitat use of EGSs in the different countries was analysed using different ArcGIS layers. A corine land use polygon layer from 2006 with 44 different categories of land use (see Appendix II for categories and Appendix I for metadata) was overlaid on a point layer with the distribution of the EGS in each country. Greece was not included in the corine land use layer from 2006 but in the one from 2000. Greece land use was clipped out of the layer from 2000 and mosaicked into the layer of 2006, to have all range countries included in one map. The whole analysis process done in ArcGis is illustrated in Figure 2a.

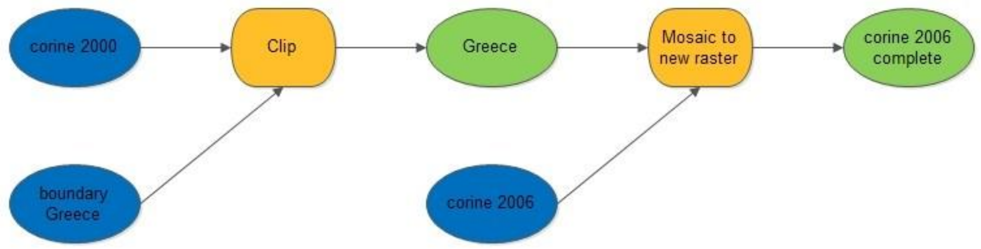

Figure 2a. ArcGIS model to combine the corine landuse layer from 2006 with missing Greece clipped from corine landuse 2000 layer. (Blue: input features, yellow: tools and green: output features or Tables.)

The two layers (corine land use and point layer with distribution points) were overlaid and the land use under the points was selected. A buffer of 25 meters around each point (colony or individual) was made to include surrounding areas on the assumption that EGS disperse up to 50m from their burrows in the stationary non-migrating phases during reproduction (Strijkstra 2012, pers. comm.), and to avoid edge effects and exclude measurement inaccuracies of the GPS points.

The selected land use features were then exported into a new polygon layer. The area size was calculated. The field with the code of the land use type was summarized, resulting in a table with all land use types occupied by EGS in these countries, with corresponding areas size around the points. A model was built to run the whole process for each country for which distribution data was available. In Figure 2b the analysis model is illustrated.

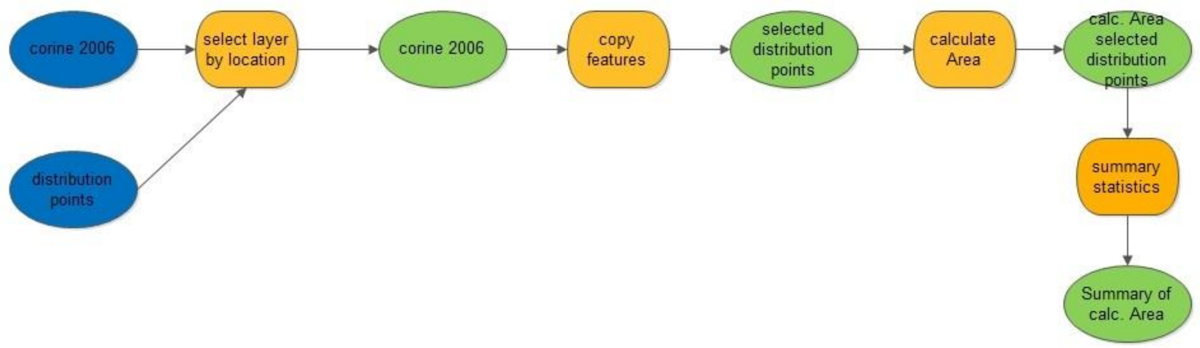

Figure 2b. ArcGIS model to obtain the habitat use of EGS in the different range countries. (Blue oval: input features, yellow rectangle: tools and green ovals: output features or tables.)

5.1.3. Other environmental parameters

To obtain information on the other environmental parameters, also these environmental layers were overlaid with the distribution point layer. The 'extract values to point' tool was used to get the single values of each information layer below each point. These were then summarized in a table. The whole process was done per range country and percentages were calculated for different information categories.

Thus, environmental layers concerning life history issues and obtained distribution data by consulting researchers over the range countries were combined. The co-occurrence of observations and environmental data was analysed in ArcGIS obtaining distribution maps and a habitat preference analysis per range country was performed. In the next sections, the results per country will be shown including a summary of available literature about threats, conservation status, and conservation projects concerning EGS per range country and for the entire distribution range.

5.2. Range countries: current distribution data and analysis

In the following chapters the status, distribution and possible threats of EGS in each range country are discussed by available literature and by the results of the ArcGIS analysis. The order of the countries follows a North to South, West to East sequence.

5.2.1. Austria

Status

In 2005/2006 EGSs were counted for the first time in Lower Austria. In comparison with current data it is obvious that all formerly inhabited areas are still inhabited but that a few areas south of the river Donau, along the river Traisen and along the "Thermenlinie" got lost. In the 4 main areas in which EGS live in lower Austria, colonies are still stable but in the rest of Lower Austria individual numbers in colonies decreased. (Gross et al. 2006)
374 EGS colonies are known in lower Austria today (Enzinger et al. 2012). In 2011 in most of the regions in its distribution range 58% of the EGS colonies were decreasing. Only in 18% of the colonies individual numbers increased. The rest of the populations stayed stable.
In 2012 127 of these colonies were recounted. Development trends of 98 colonies were estimated. 16% of the colonies were estimated as increasing, 36% as decreasing and the rest were classified as stable. 13 colonies seem to be extinct (Enzinger et al. 2012).
The EGS population in lower Austria is significantly decreasing. In 2009 there were 1166 individuals in 84 places. In the same places two years later in 2011 there were only 813. Furthermore 18% less burrows were counted in 2011 than in 2009. It is unknown if this decrease of EGS between 2009 and 2011 is significant or only a cause of natural fluctuations. Reasons can be a cold and humid May 2010 (mating season) bad weather conditions with a lot of rain during 2010 or a too low intensity of moving of grasslands and pastures. Austria is optimistic that the numbers of individuals and colonies will increase again during the next years because the weather will be better, no habitat is significantly destructed and no areas lost their quality. (Enzinger et al. 2012)

Legislation

In Lower Austria EGS are protected under § 17 and §18 of the Nature protection law which claims that wild living animal (…) may not be chased, caught, injured, murdered or taken off their natural habitat which also should be untainted of human impact. Furthermore there have to be taken measures for the protection of the habitat, preservation and reproduction of the species (…) (NÖ Naturschutzgesetz 2000).
2005 the EGS was included in the Lower Austrian "Artenschutzverordnung" (Species protection act) and is fully protected in Lower Austria now.

Distribution and Habitat

The EGS is distributed through the eastern and north-eastern High- and Lowlands of Lower Austria, through Burgenland and Wien. There are 4 main areas which are populated by EGSs. The Kremser Raum as well as north as south of the river Donau, around the big steppe areas in Steinfeld, on fallow ground distributed through Lower Austria and in a big Vineyard in the Arbesthaler hill country. (Gross et al. 2006) The rest of the colonies are dispersed through the whole distribution range. In the 4 main areas the size of a colony can reach up to 500 individuals with 152 individuals per hectare. Smaller colonies contain 20 to 50 individuals and the smallest only 5 individuals. The total population of EGSs in whole Lower Austria is estimated between 7,550 and 13,000 individuals (Gross et al. 2006).

From Ilse Hoffmann we go data about the distribution of EGS around Vienna; it is shown in Figure 3.

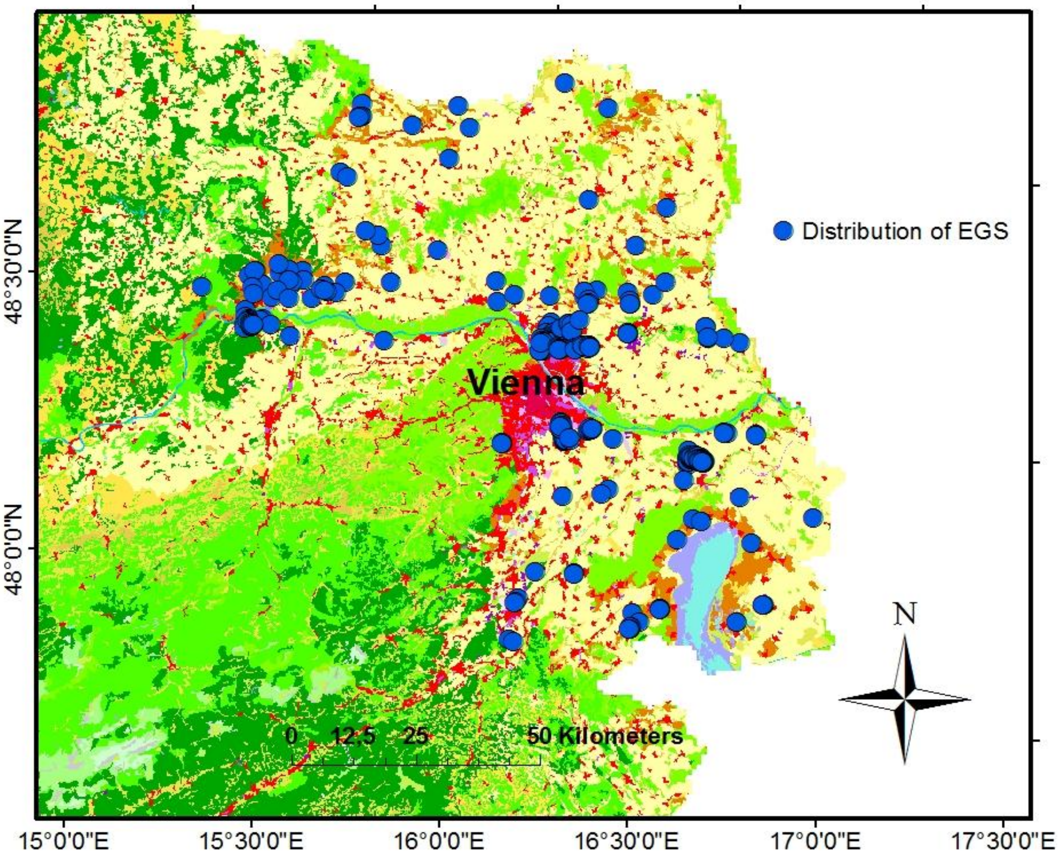

Figure 3. Distribution of EGS around Vienna in lower Austria.

EGSs are widely distributed around Vienna and very common also in urban areas. All populations we got data from are distributed through 15 different habitats (A legend with the habitat types and colour codes can be found in Appendix II). The most populated habitat is non-irrigated arable land. 25% of all recorded populations around Vienna live in those areas. Also favourite areas are agricultural areas like vineyards (16%) and complex cultivation patterns (16%).Natural pastures get less and less through urbanization, infrastructure or similar human invasion and so EGSs have to switch to Artificial surfaces (like Airports (2%), Sport and leisure facilities (4%) and agricultural areas like pastures (2%) and agricultural land with natural vegetation patches (7%). The rest is distributed through semi-natural areas (like natural grasslands (4%), at the boarders of broad leaved forest (1%), coniferous forest (1%) and mixed forest (1%).) In the following Table 9 you can find an overview over the number of areas EGS populate in different habitat types.

Table 9. Type of habitats inhabited by EGS in Austria

Habitat type	Number of areas
Non-irrigated arable land	24
Vineyards	15
Complex cultivation patterns	15
Discontinuous urban fabric	11
Agricultural land with natural vegetation	7
Industrial or commercial units	5
Sport and leisure facilities	4
Natural grassland	4
Pastures	2
Airports	2
Construction sites	1
Mineral extraction sites	1
Mixed forest	1
Broad-leaved forest	1
Coniferous forest	1

EGS do not only depend on the type of habitat a certain area contains but they also depend on the following factors which can be seen in table 10. All soil parameters are listed which were found in the habitats of EGS. An annual temperature range in those areas is given and an elevation range. The legends with the explanation of the attributes can be found in appendix III.

Table 10. Environmental variables in habitats of EGS in Austria

Environmental variables	
limitation to agricultural use:	No limitation to agricultural use (85%), Gravelly (10%), Concretionary (4%), Saline (1%)
Texture of soil:	Coarse (1%), medium (99%)
Parent material:	Limestone (2.6%), acid to intermediate plutonic rocks (4%), basalt (23%), unconsolidated deposits (1.5%), fluvial sands and gravels (3.8%), loess (65%)
type of an existing water management system:	Ditches (4%), no information (96%)
Slope :	Level (5.4%), Sloping (76.4%), Moderately steep (14%), Steep (4.2%)
Temperature average per year in °C:	7.5-10.1
Elevation in m:	113-592

Threats and chances

In the course of the Natura 2000 network areas are designated for the protection of the EGS. In these areas measures are taken to prevent deterioration of the natural habitats of the species and to prevent disturbance. (Gross et al. 2006)

EGSs which live outside these areas are protected through Nature protections laws of the federal states.

Although the EGS is protected by law it is still under pressure and the survival of this species is not yet secure. Different causes contribute to its decrease. Natural habitats decreased through landscape transformation which led to a displacement of the EGS what resulted in fragmentation and isolation. (Gross et al. 2006) Small colonies do not have a big chance to survive and so many small colonies got already extinct (Spitzenberger 2002). Human conflict also plays a big role when EGS have to switch to non-natural but structural similar habitats like Airport, Sport places and parks (Gross et al. 2006).

In Austria different measurements are taken to protect the EGS. Very important is regularly mowing of pastures, grazing of animals, deforestation of bushy areas, habitat connection and monitoring (Gross et al. 2006).

5.2.2. Bulgaria

Status: unknown, trend decreasing in south-western periphery (Koshev, 2008; IUCN, 2008). Populations in Dobrudja are assumed to be increasing since 1989 (IUCN, 2008), although Koshev found no increasing colonies (Koshev, 2008).
In the mountain region, Sofia field and Thracian valley, 30% out of 90 investigated colonies disappeared, 28% are vulnerable and 42% are stable (Koshev, 2008).
EGS is considered as extinct in the area of Petrich and Kulata (close to the Greek and Macedonian border) (Koshev, 2008).

Legislation
EGS are included in the Appendix to Resolution No 6 (1998) of the Standing Committee of the Bern Convention.
The Bulgarian Biodiversity Act does not include EGS as a protected species.
Main EGS populations of southern Dobrudzha occur outside protected areas; occasionally populations may be present at the Natura 2000 sites of Staldzha or Derventski Vazvisheniya. In the Thracian valley, some populations may be occurring in the Natura2000 area of Sredna Gora and Tzentralen Balkan. Remaining populations in central western Bulgaria and eastern Rhodopes have their range outside protected areas.

Distribution
EGS is distributed with high densities in southern Dobrudzha, central-western Bulgaria, western part of the Thracian valley and eastern Rhodopes (Koshev, 2008). On an international scale, most dense EGS populations are considered to occur in the eastern part of Bulgaria (Koshev, 2005).
In central-western Bulgaria, populations are very sparse, although EGS occurrence was very dense 10-20 years ago (Spassov *et al,* 2002).
Koshev (2009) recorded for the Pazardzhik district (in central western Bulgaria) that populations are distributed at altitudes between 117m and 2500m (average 2200m a.s.l.), although the main part of the populations was found in the lowlands at 100- 300m a.s.l..
As in other parts of Bulgaria, populations are mostly occurring in pastures (87.% in Pazrdzhik district; 72% on national level) (Koshev, 2009; Koshev, 2008). The rest of the populations in Pazardzhik have their range in agriculture fields (7%) and (5%) in urban territories.
In the Thracian valley, EGS occur in inundation areas close to rivers. That is very rare for a species sensitive to raising water levels. The habitats close to the river may be used as a corridor, because remaining land is intensively used by man (vineyards, orchards) and therefore avoided by EGS (Koshev, 2009).
In contrast to other countries of EGS range, populations in Bulgaria do not occur in areas intensively managed by man (Koshev, 2008).
For Bulgaria, exact EGS distribution records were not available, so we created some estimated points, based on literature distribution descriptions (see Figure 4).

Habitats in described areas are mainly pastures, with mosaics of non-irrigated arable land, discontinuous urban fabric and broadleaved forests.

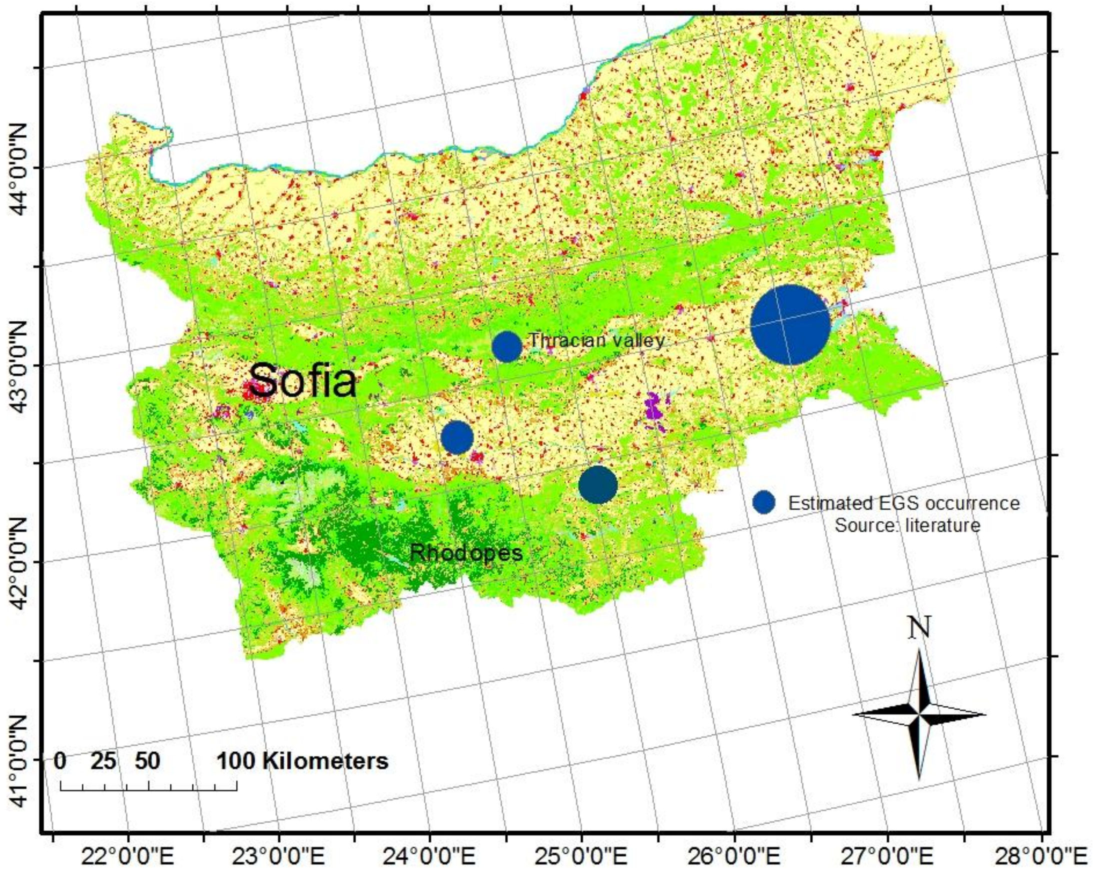

Figure 4. Distribution of EGS in Bulgaria

Table 11. Estimated type of habitats inhabited by EGS in Bulgaria

Habitat type
Pastures
Non-irrigated arable land
Discontinuous urban fabric
Broad-leaved forest

EGS distribution do not only depend on the type of habitat a certain area contains but they also depend on the following factors which can be seen in Table 12. All soil types are listed which were found in the habitats of EGS. An annual temperature range in those areas is given and an elevation range.

Table 12. Environmental variables in estimated habitats of EGS in Bulgaria

Environmental variables	
Climate:	Pannonian-Mediterranean North
Temperature:	2.4-5
Elevation:	72- 256m

Threats
Major threats for EGS populations in Bulgaria are pasture degradation, urban development, intensification of agriculture, interruption of biological corridors and flooding (Koshev, 2008).

Table 13. Major threats, effects and scales to EGS populations in Bulgaria (Koshev, 2008)

Threat	**Effect**	**Scale**
EGS status unknown	Lack on priorities and arguments for conservation	National
EGS not included in Biodiversity act	Lack on legal protection	National
Pasture degradation: Insufficient grazing, overgrazing	Shifting habitat to woodlands	Mountain region
Urban development: roads, industry, golf courses etc.	Habitat destruction, fragmentation, isolation	Black Sea coast, natural steppe habitats, near settlements
Intensification of agriculture: enlargement of agricultural areas, more use of chemicals	Habitat destruction, fragmentation, isolation, contamination	National
Transformation of pastures, natural grasslands, meadows into arable fields, plantations	Habitat destruction, fragmentation, isolation	National
Interruption of biological corridors between EGS populations (forestation, cultivation, urbanization)	Isolation, inbreeding depression	National
Flooding (irregular water control)	Starvation of populations	Thracian valley
Hunting for food	Decreasing populations if status unstable	In areas with Gypsy communities

Conservation projects
Bulgarian Society of Natural Research and BALKANI Wildlife Society are recording EGS populations in the area between the rivers Topolnitsa and Luda Yana. They are also investigating predator- prey relationships (birds of prey- EGS) and have the goal to raise public awareness for the conservation of EGS and birds of prey (Koshev, 2005).
In eastern Bulgaria, in the hillsides of Witoscha national park, EGS occurred in high densities. In the 1990s, EGS populations decreased enormously. Because of that, part of the national park is managed by extensive mowing and the habitat got adjusted for EGS. That way, EGS population are increasing again since 2008 (Zwetkova, 2011).

5.2.3. Czech Republic

Status: endangered

Legislation

Specially protected animal species pursuant to provisions of section 48 of the Czech National Council No 114/1992 Coll. on nature and landscape protection declared by means of Decree No. 395/1992 Coll. against killing, destroying of its habitat and disturbing by human activities (Matějů 2012).

Most EGS populations occur outside protected areas (Mateju *et al*. 2010). Following Natura 2000 areas are declared as sites of community importance (SCIs) where EGS is one of the key species: Praha- Letany (Grassland near airport), Trhovky (recreational used grassland), Bezdecin (grassland near airport), Kolin- Letiste (grassland near airport), Olsová vrata (golf course), Rana- Hradek (deforested area with steppe vegetation, grassland near airport), Milotice – Letiste (Grassland near airport), Letiste Marchanice (grassland near airport) (Mateju *et al*., 2010). Apart from that, EGS may be present at the Natura 2000 areas of Doupovske Hory, Radouc, Udoli Jihlavy, and Hovoransko- Cejkovicko.

Distribution

During 1947- 1952, EGS populations were very dense and considered as an agricultural pest species in Czech Republic (Grulich, 1960). By intensification of agriculture, populations became isolated and decreased (Mateju *et al*, 2010). In 2007, population mapping showed EGS occurrence in 34 isolated sites. Populations are distributed throughout the whole country, with an exception for East Bohemia and North Moravia (Mateju *et al*, 2010). Simultaneous, Czech population sizes were estimated with 3180 individuals (Mateju *et al.*, 2007).

In the Czech Republic, many EGS populations occur in manmade landscapes like areas around airports (74% of total population in 2007), gardens, camping sites, golf courses and even on a military shooting range. Other habitat types of EGS range are vineyards, steppes, meadows and pastures (Mateju *et al*. 2010).

Currently, most of the populations occur in the east part of the Czech Republic. In the west, populations are more isolated and fragmented. No populations have been recorded in central Czech Republic (Figure 5).

Combining species records from Mateju et al (2011) with corine land cover 2006 layer, most of the populations occur in areas of sport and leisure facilities (35%) and non irrigated arable land (23%) (Table 14).

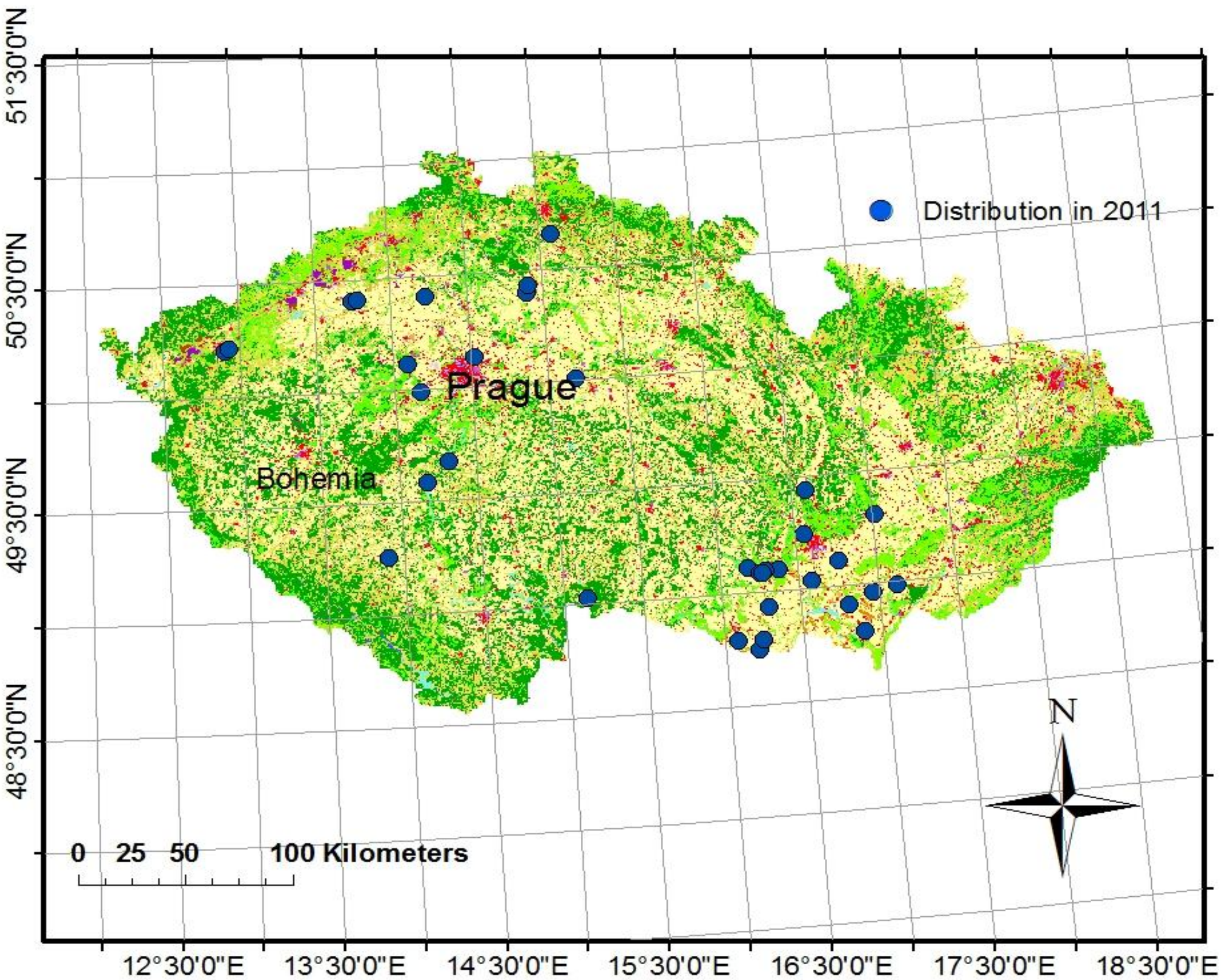

Figure 5. Distribution of EGS in the Czech Republic

Table 14. Type of habitats inhabited by EGS in Czech Republic

Habitat type	**Number of areas**
Airports	1
Sport and leisure facilities	11
Non irrigated arable land	7
Pastures	3
Complex cultivation patterns	4
Land principally occupied by agriculture, with significant areas of natural vegetation	2
Coniferous forest	1
Transitional woodland-shrub	1
Water bodies	1

EGS do not only depend on the type of habitat a certain area contains but they also depend on the following factors which can be seen in Table 15. All soil types are listed which were found in the habitats of EGS. An annual temperature range in those areas is given and an elevation range.

Table 15. Environmental variables in habitats of EGS in Czech Republic

Environmental variables	
Limitation to agricultural use:	No limitation to agricultural use (74.3%) Gravelly (22.9%) Stony (2.9%)
Texture of soil:	Medium (70, 6%), Coarse (20%), Fine (8.6%)
Parent material:	Loess (45,7%, marl, granite, acid regional metamorphic rocks, unconsolidated deposits (alluvium, weathering residuum and slope deposits) (8.6% each)
Type of an existing water management system:	No information (91.4%) Pipe under drainage (8.6%)
Slope :	No information (5.7%) Level (8.6%) Sloping (57.1%) Moderately steep (28.6%)
Temperature average per year in °C:	4.3-10.7
Elevation in m:	98-1046

Threats

Table 16. Major threats, effects and scales to EGS populations in the Czech Republic (Mateju et al., 2010)

Threat	**Effect**	**Scale**
Shifting habitats	Habitat loss and fragmentation, population isolation	National, meta population
Absent grass cover management	Too high vegetation cover: increasing predation risk	Regional (Mladá Boleslav-Debr and Dublovice-Chramosty amongst others)
Weather variations	Flooding, freezing-> death	Regional (Small populations e.g. near golf courses)
Increasing construction	Habitat loss	Local (Around cities: industrial sites, airports)
Genetic isolation	Inbreeding, decreasing populations	Regional (e.g. OlsováVrata)
Most populations outside protected areas	Habitat loss, lack of legal protection	National

Projects

In the area of Ceský Kras, the first EGS ex situ breeding and release site got installed in 1989 (*Jansova, 1992*). Reintroduction did not succeed, due to the small amount of animals released. Other captive breeding and reintroduction experiments took place in the areas of Krivoklátsko- Novina, Sykorice, Castonice, Velká Buková, Bohemia and Vitkuv that also failed due to resulting small, isolated populations in the release sites.

In order to maintain existing EGS populations, the conservation area of Nad rekami, the temporarily protected area close to Jamolice community and the slopes of Raná hill are managed by mowing and grazing (Mateju *et al*, 2010).

5.2.4. Greece

Status: vulnerable (Legakis et al. 2009)

Legislation
No one of the recorded populations have their range within a Nature 2000 area.

Distribution:
EGS populations are fragmented in three areas of western Macedonia, central Macedonia and Thrace. Main habitats are meadows, open clearings, agricultural areas, roadsides, areas dominated by Sclerophillous vegetation, as well as gardens, parks and golf courses (Youlatos, 2009).
Combining obtained species records from Dionysios Gioulatos with the corine land use layer from 2000, most populations occur in non- irrigated arable land (30%) and Land principally occupied by agriculture, with significant areas of natural vegetation (23%). Remaining populations occur in permanently irrigated land, vineyards, complex cultivation patterns, broad-leaved forest, salt marshes and sea and ocean, (7.9% respectively) (Table 17).
Obtained records overlap with the official map of the IUCN Greece (Figure 6 and Figure 7).

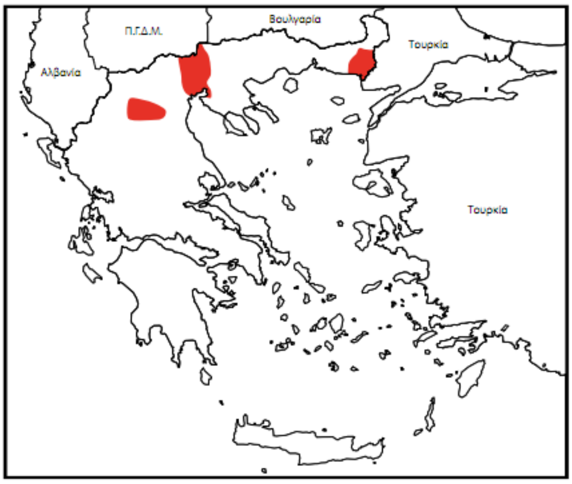

Figure 6. EGS distribution in Greece (Legakis et al. 2009)

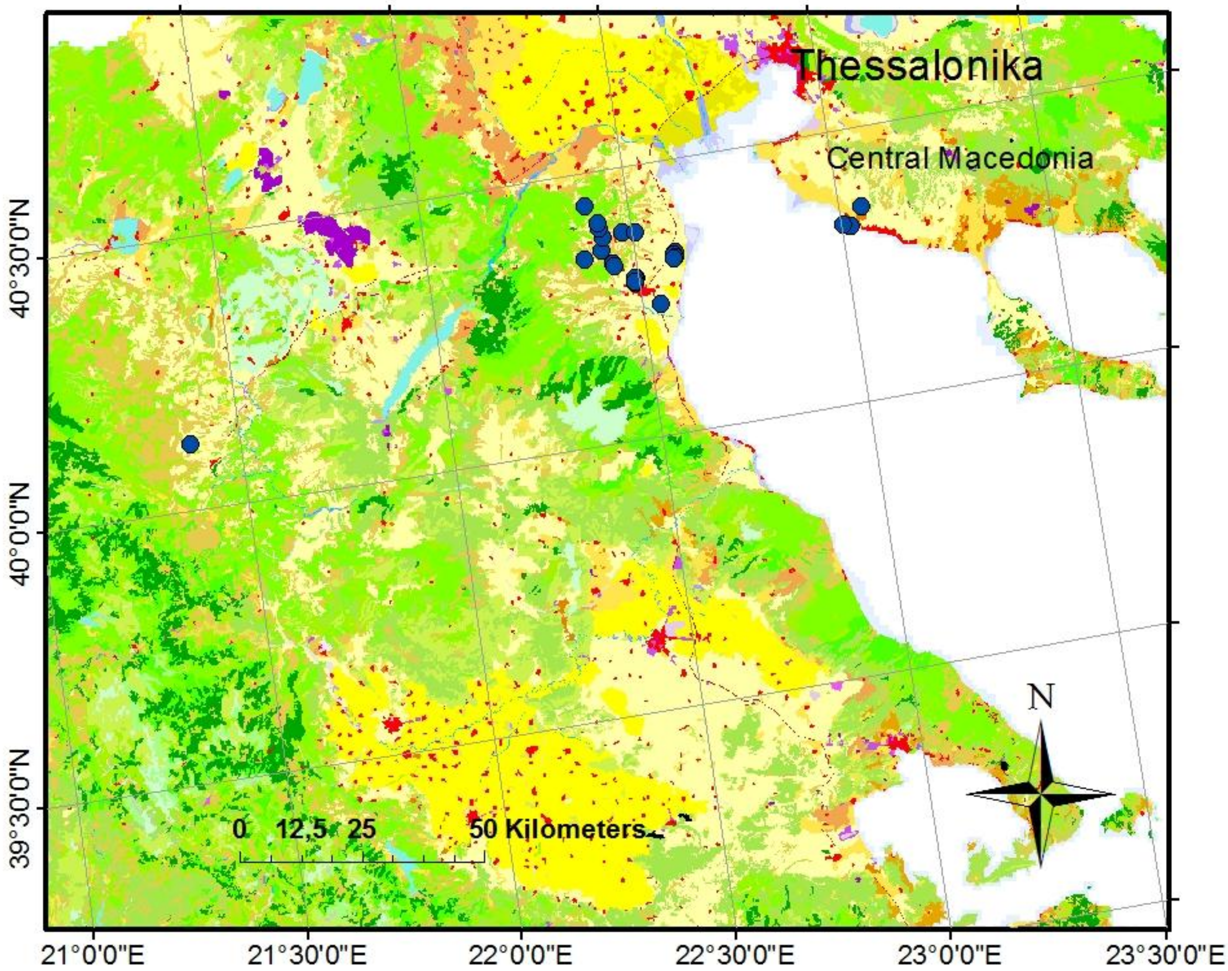

Figure 7. Distribution of EGS in Greece

Table 17. Type of habitats inhabited by EGS in Greece

Habitat type	**Number of areas**
Non-irrigated arable land	4
Permanently irrigated land	1
Vineyards	1
Complex cultivation patterns	1
Land principally occupied by agriculture, with significant areas of natural vegetation	3
Broad-leaved forest	1
Salt marshes	1
Sea and ocean	1

EGS do not only depend on the type of habitat a certain area contains but they also depend on the following factors which can be seen in Table 18. All soil types are listed which were found in the habitats of EGS. An annual temperature range in those areas is given and an elevation range.

Table 18. Environmental variables in habitats of EGS in Greece

Environmental variables	
Limitation to agricultural use:	No limitation to agricultural use (57.1%) Gravelly (23.8%) Saline (19%)
Texture of soil:	Medium (95.2%), Very fine (4.8%)
Parent material:	Fluvial clays, silts and Loams (71.4%), Flysch (23.8%), Terrace clay and silt (4.7%)
Type of an existing water management system:	No information (57.2%) Overhead sprinkler (42.8%)
Slope :	No information (42.9%) Moderately steep (33.3%) Steep (22.8%)
Temperature average per year in °C:	1.7-5.5°C
Elevation in m:	0-657m

Threats

Table 19. Major threats, effects and scales to EGS populations in Greece (Youlatos, 2009)

Threat	**Effect**	**Scale**
Shifting habitats (changing agricultural practices, infrastructure development)	Isolation, inbreeding, decreasing populations	National
Parasitism	Decreasing populations	National?
Increasing urbanization: Predation by dogs and cats, road kills	Decreasing populations	National
Climate change: droughts, high temperatures	Death, decreasing populations	National
Lack of legal protection (e.g. Natura 2000 areas)	Lack of legal conservation importance	National

5.2.5. Hungary

Status

Since the middle of the 20th century the Hungarian EGS population has dramatically decreased as a consequence of loss of suitable habitats (Váczi et al. 2008).

Legislation

In Hungary the EGS is protected under the Act No. 13/2001 of Ministry of Environmental Protection on the protected and strictly protected Plant and Animal Species, strictly protected caves as well as on the plant and animal species of community importance (European Commission 2009)

Distribution and Habitat

EGS are distributed through almost entire Hungary. They are concentrated around Budapest in artificial areas and in the middle of the country, south of Budapest (see Figure 8).
There are also some populations in the east of Hungary and scattered populations also in the west around the Lake Balaton.

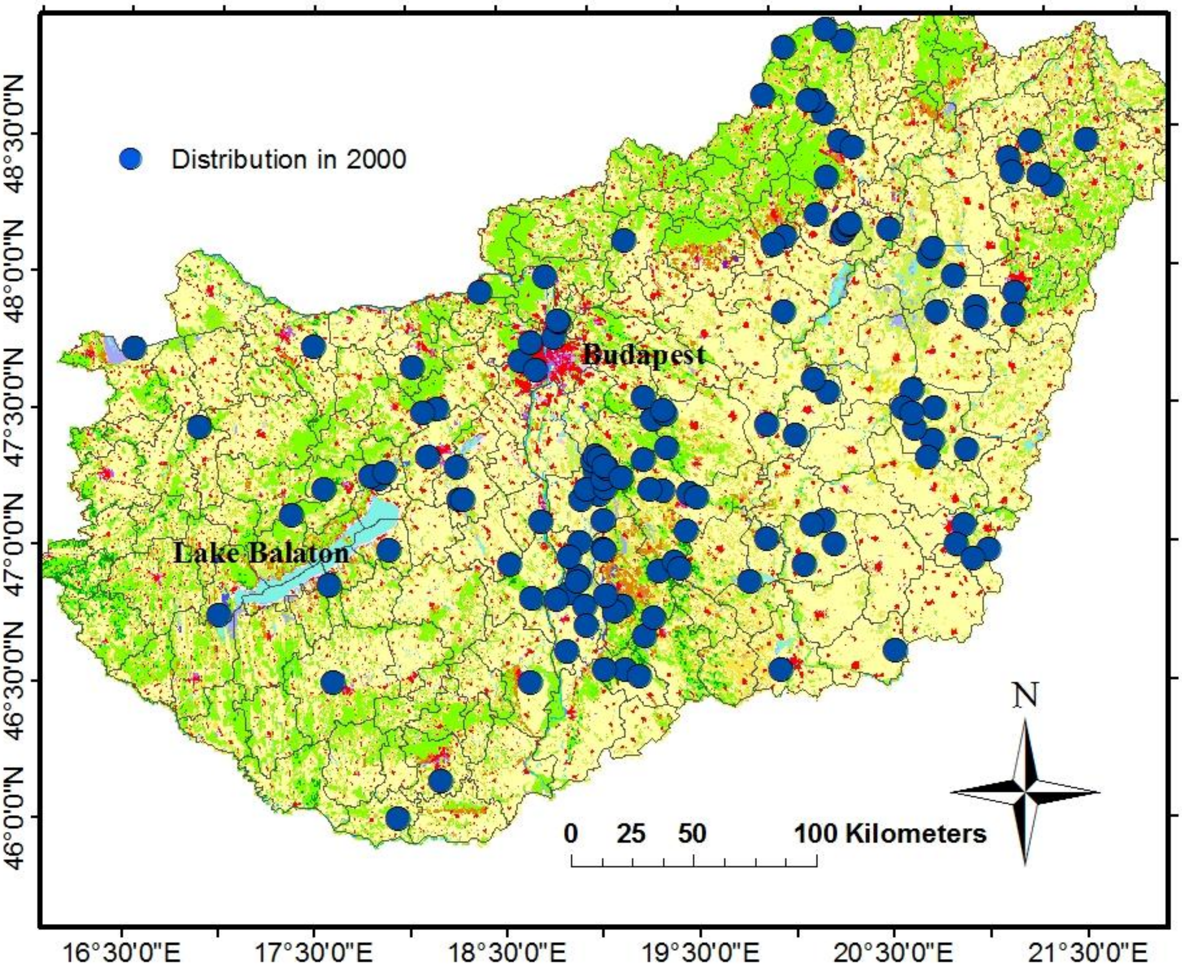

Figure 8. Distribution of EGS in Hungary in the early 2000

We got information about 140 populations in Hungary from Oliver Vazci from the early 2000. The data does not say anything about the size of the populations but represents present absent data. All populations we got data from are distributed through 11 different habitats (A legend with the habitat types and colour codes can be found in Appendix II). Most of the Populations of EGS in Hungary live in agricultural areas like Pastures (32%), in semi-natural areas, like grasslands (18%) and in agricultural areas with non-irrigated arable land (16%). The rest is distributed through artificial surfaces like discontinuous urban fabric (10%), road and rail networks with associated lands (0.9%), airports (4.5%) and sport and leisure facilities (2.7%) or through agricultural areas like vineyards (1.8%). EGS can also be found in semi-natural areas like broad-leaved forest (8.1%). A summary of all habitat types can be found in Table 20.

Table 20. Type of habitats inhabited by EGS in Hungary

Habitat type	**Number of areas**
Pastures	35
Natural grassland	20
Non-irrigated arable land	18
Discontinuous urban fabric	11
Broad-leaved forest	9
Airports	5
Complex cultivation patterns	5
Sport and leisure facilities	3
Vineyards	2
Road and rail networks and associated land	1
Agricultural land with natural vegetation	1

EGS do not only depend on the type of habitat a certain area contains but they also depend on the following factors which can be seen in Table 21. All soil parameters are listed which were found in the habitats of EGS. An annual temperature range in those areas is given and an elevation range.

Table 21. Environmental variables in habitats of EGS in Hungary

Environmental variables	
limitation to agricultural use:	No limitation to agricultural use (87%), Lithic (4.3%), Saline (7%)
Texture of soil:	Coarse (8.6%), Medium (14.3%), Medium fine (47.1%), Fine (20.7%), Very fine (6.4%), Peat soils (1.4%)
Parent material:	Dominant sorts are : unconsolidated deposits (21%), river terrace sand (16%) and loess (25.7)
Type of an existing water management system:	No information (99%), ditches (1%)
Slope :	No information (71%), Level (13%), Sloping (11%), steep (0.5%)
Temperature average per year in °C:	8.8-11.3
Elevation in m:	77-320

Threats and chances

In the year 2000 as part of the Hungarian Biodiversity monitoring system (HBMS) a monitoring program was developed with the aim of early detecting changes in population quality and quantity. As an additional method, Internet-based survey was tested on the Red Squirrel *(Sciurus vulgaris)*, for further localization of unknown EGS populations. (Váczi et al. 2008) Every year surveys of EGSs are organized in the week of Earth Day which is conducted by volunteers. For the relative estimation a rigorous estimation protocol is used. Relative size of a colony is estimated by burrow entrance counting.

The up to date data shows, that there has been no drastic change in the last few years in the Hungarian populations but EGSs have disappeared from certain localities. What needs to be included in the program is to explore unknown populations and to expand the program to all EGS range countries. (Váczi et al. 2008)

Hulová Š et al. investigated in 2008 population genetic structure of bottleneck EGS populations in the Czech Republic and compared it with populations from Slovakia, Hungary and Romania. They analysed neutral and adaptive variation at 12 microsatellite loci and two immune genes (DRB, DQB) of the major histocompatibility complex (MHC) for a total of 470 samples of the EGS. In the Czech Republic, the expected Heterozygosity of the two MHC loci was very low (He=0.156) compared to the Hungarian populations (He=0.428). Also the mean microsatellite Heterozygosity was lower (He=0.23) in the Czech Republic than in Hungary (He=0.41). The variability in Hungarian population is still higher than in populations of the Czech Republic and populations seem not to be isolated and genetically differentiated. (Hulová Š et al. 2008)

5.2.6. Macedonia

Status: unknown

Legislation
EGS is not included in Macedonian national Legislation. Assessed populations do not occur within protected areas, except for one population that has its range within the Natura 2000 area of Limini Doirani.

Distribution
In Macedonia exist two isolated EGS subpopulations: *Spermophilus citellus gradojevici* that occur in the lowlands of the River Vardar and the Dojran region and *Spermophilus citellus karamani* that has its range in Sckara in the central Macedonian mountain pastures (Jakupica and Karadzica) (Krystofek, 1993) (figure 9). Both populations are genetically divergent from remaining European EGS populations. Populations in south-eastern Macedonia are fragmented and irregular distributed and do not reach the other subpopulation by the geographical border of the mountain range (figure 10). Populations in the Djoran region may be invaded from Greece via Gevgelija, Dojran, Nikolic (Haberl, 2010).

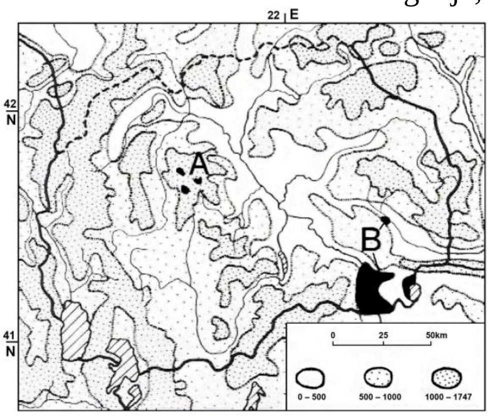

Fig. 1: Present distribution (black) of mountain (A) and lowland (B) populations of the European souslik *Spermophilus citellus* in Macedonia (modified after BK93 with permission).

Figure 9. EGS distribution in Macedonia (Haberl, 2010 from Krystufek, 1993)

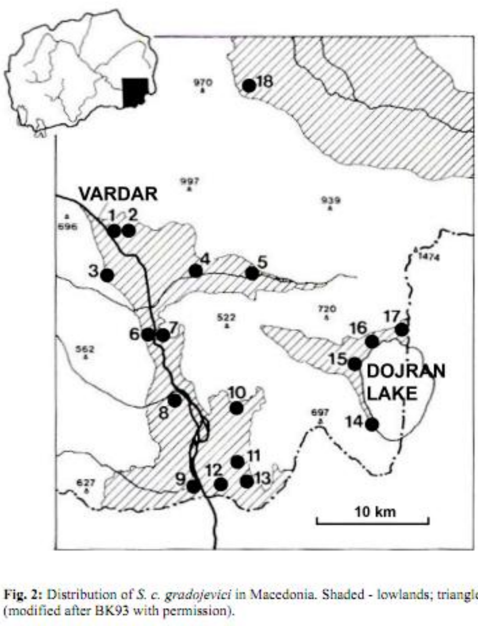

Fig. 2: Distribution of *S. c. gradojevici* in Macedonia. Shaded - lowlands; triangles - mountain peaks (modified after BK93 with permission).

Figure 10. EGS distribution Djoran region in Macedonia (Haberl, 2010 from Krystufek, 1993)

Djoran populations of *S.c. gradojevici* occur in fallow land, meadows and wheat fields (Haberl, 2010). Combining species records from Werner Haberl with our corine land cover 2006 layer, main populations are present in complex cultivation patterns (24%), vineyards (15%), pastures (12%) and agricultural areas with natural vegetation (12%) that is mainly comparable with obtained results from Haberl for range habitats (Figure 11).

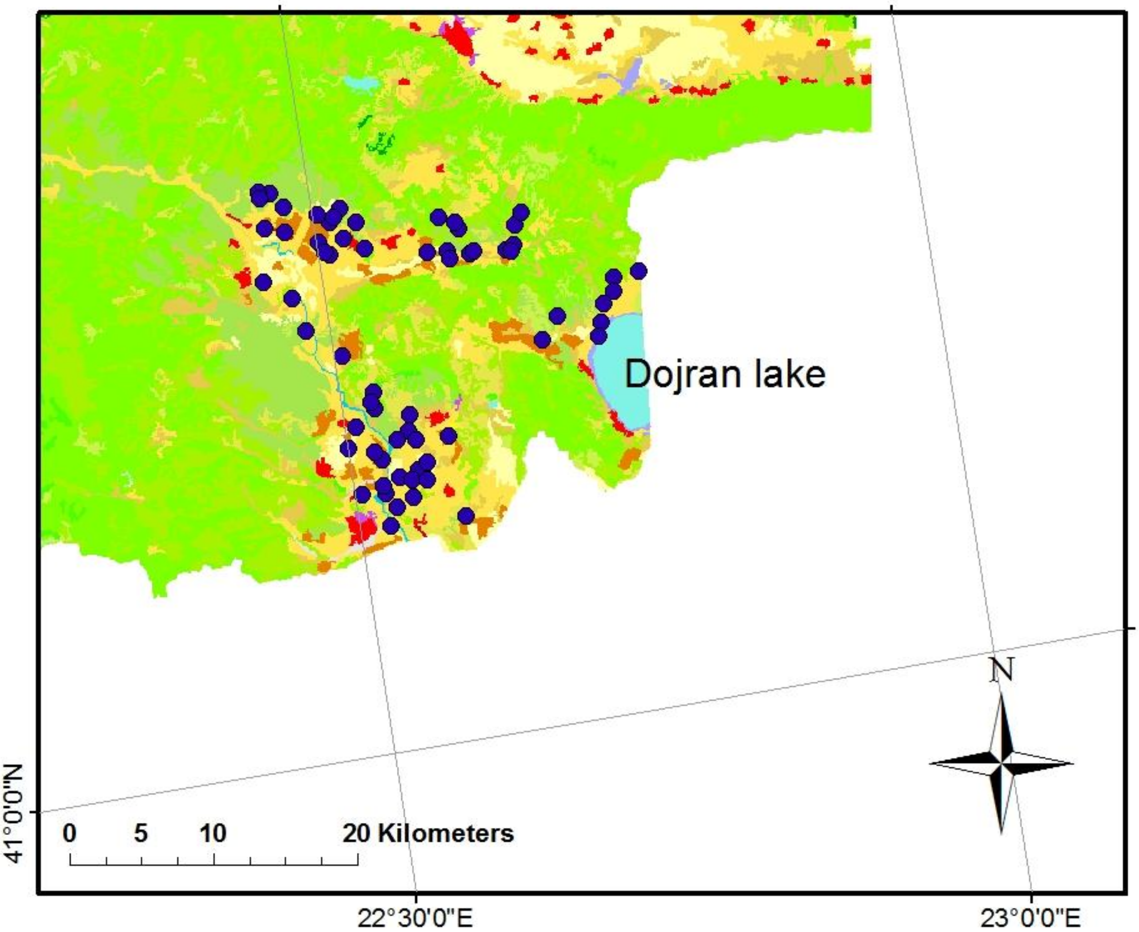

Figure 11. Distribution of EGS in Macedonia

Table 22. Type of habitats inhabited by EGS in Macedonia

Habitat type	**Number of areas**
Discontinuous urban fabric	1
Non-irrigated arable land	3
Vineyards	6
Pastures	5
Complex cultivation patterns	10
Agricultural land with natural vegetation	5
Broad-leaved forest	2
Sclerophillous vegetation	4
Transitional woodland scrub	4
Inland marshes	1

EGS do not only depend on the type of habitat a certain area contains but they also depend on the following factors which can be seen in Table 23. All soil types are listed which were found in the habitats of EGS. An annual temperature range in those areas is given and an elevation range.

Table 23. Environmental variables in habitats of EGS in Macedonia

Environmental variables	
Limitation to agricultural use:	No information (1.5%) No limitation to agricultural use (98.5%)
Texture of soil:	No information (1.5%) Coarse (98.5%)
Parent material:	No information (6.1%), sandstone (29.3%), fluvial clays, silts and loams (64.6%)
Type of an existing water management system:	No information (100%)
Slope :	No information (95.4%) Moderately steep (4.6%)
Temperature average per year in °C:	12.5-14.7°C
Elevation in m:	30- 483m

Threats

Table 24. Major threats, effects and scales to EGS populations in Macedonia

Threats	Effects	Scale
Not included in national Legislation	Status not evaluated, no legal protection	National
Considered as a pest species	Lack of conservation importance and monitoring	national
Small, fragmented and isolated populations	Inbreeding, decreasing populations	National (distribution range)
Infrastructure development	Habitat loss and fragmentation, decreasing populations	National
Intensification of agriculture, shifting habitats	Habitat loss and fragmentation, decreasing populations	National

5.2.7. Moldova

Status: unknown

Literature not found

The EGS is still present in 353 UTM squares with relatively large populations in Dobroudja and some parts of Moldavia (Azabolai 2011).

5.2.8. Romania

Status

The EGS is listed as vulnerable on the Romanian red list of threatened species (Animal info 2004).

Legislation

In Romania the status of the EGS is deteriorate although not much is known and data regarding current distribution, isolation and threats are lacking. Between 2006 and 2009 a survey of the Pannonian population took place in the western plains of Romania for the proposal of new Natura 2000 sites for the EGS and the Saker falcon (*Falco cherrug*). Colonies and available habitat which were detected in 78 UTM squares are generally isolated. A picture of the Natura 2000 proposal areas can be seen in Figure 12 below. Habitats in this area are mainly agricultural areas with non-irrigated arable land and pastures. Between 2009 and 2010 a survey of the Balkan population took place with the main aim of proposing new Natura 2000 sites. During the survey most of the historical localities of the species known from the literature, as well as a large number of potential sites were checked for the presence of EGSs (Azabolai 2011).

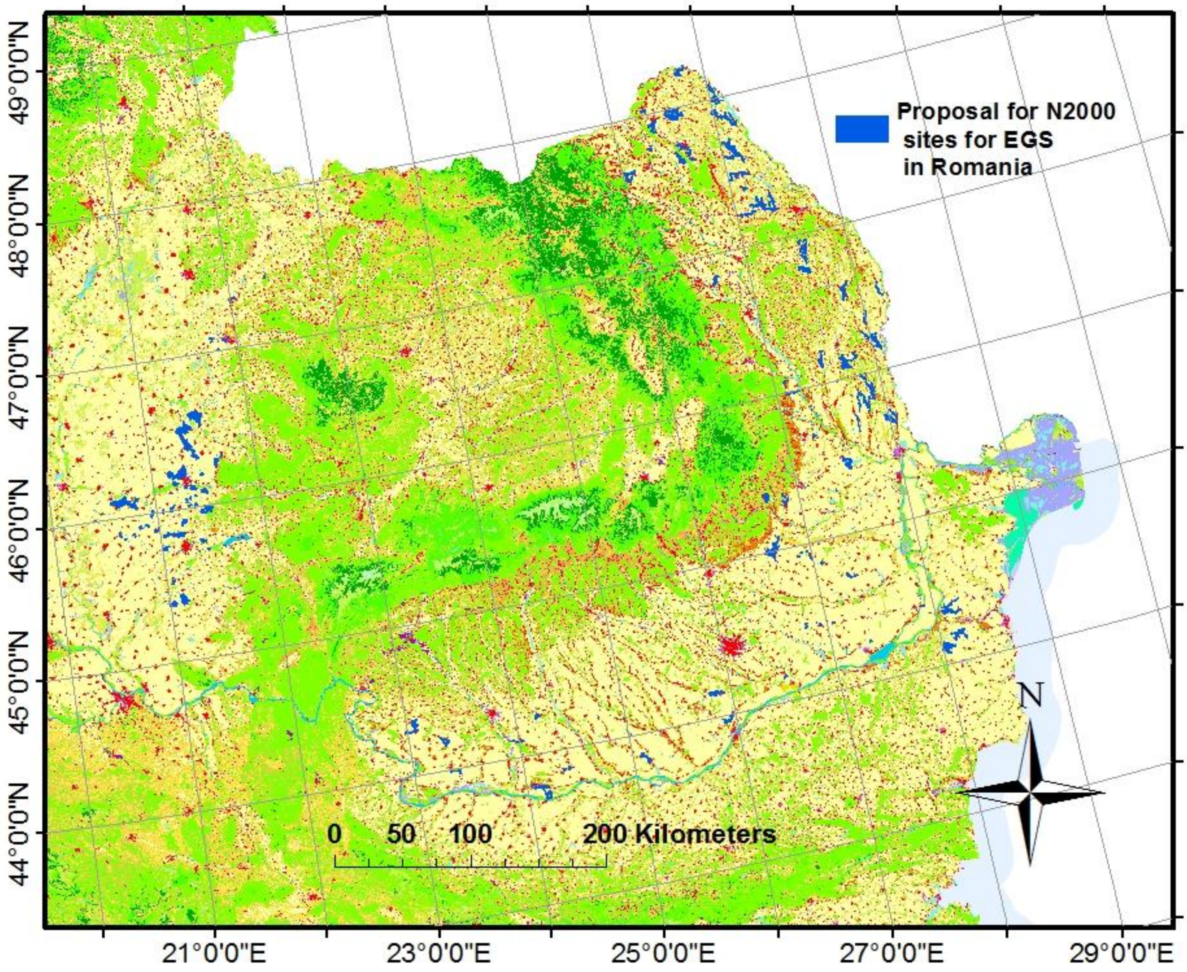

Figure 12. Proposal for new Natura 2000 areas in Romania concerning EGS for the conservation of the saker falcon (Data by Natura 2000, 2012)

Distribution

Scattered data of field biologists from various parts of the country have continuously been collected. The EGS is still present in 353 UTM squares with relatively large populations in Dobroudja and some parts of Moldavia. In the southern part of the country populations are small and isolated and are facing extinction. (Azabolai 2011)

There are stable populations of *S. citellus* in Grindu, Garvan, Smârdanu Nou, Luncaviþa, Cocoº, Dãeni, Casimcea and Beidaud all localities with open and uncultivated outskirts (Murariu 2006).

In 1956 S. citellus was cited by R. Cãlinescu from Cefa Nature Park but a research of Benedek et al. between 2005 and 2008 revealed that it is probably extinct in this area today (Benedek et al. 2009).

Threats and chances

A main threat and reason for the decrease in EGSs in Romania between localities Topolog, Ciucurova and Cataloi is the traffic. But EGSs are also more and more subjected to pressure by the decreasing of the common surfaces and the more intense grazing of the others (Murariu 2006).

Hulová et al. Investigated in 2008 population genetic structure of bottleneck EGS populations in the Czech Republic and compared it with populations from Slovakia, Hungary and Romania. They analysed neutral and adaptive variation at 12 microsatellite loci and two immune genes (DRB, DQB) of the major histocompatibility complex (MHC) for a total of 470 samples of the EGS. In the Czech Republic, the expected Heterozygosity of the two MHC loci was very low (He=0.156) compared to the Romanian populations (He=0.524). Also the mean microsatellite Heterozygosity was lower (He=0.23) in the Czech Republic than in Romania (He=0.61). The variability in Romanian population is still higher than in populations of the Czech Republic and populations seem not to be isolated and genetically differentiated. (Hulová et al. 2008)

The EGS is also part of an action plan for the conservation of the *Falco Cherrug* in north east Bulgaria, Hungary, Romania and Slovakia. The EGS is an important prey for the falcon and for that reason its specific habitat demands need to be achieved. It needs short grazed Grassland. So one action will be the Elaboration of habitat management guideline for grasslands and proposal for appropriate subsidies to stimulate proper farming on the protected *S. citellus* habitats (Nagy et al. 2005)

5.2.9. Serbia

Status

During the period of 2004-2008 Population monitoring of the EGS in Serbia was carried out at the localities: Neradin, Krušedol and Banatska Palanka. During the five-year period the abundance and density of populations were determined by census method on experimental 50x50 m sample plots. In Neradin 42 individuals per ha were counted, in Krušedol 39 individuals per ha and in Banatska Palanka 43 individuals. These populations may be described as viable but their survival depends of the conservation of their natural habitat (Ćirović et al. 2008).

Some populations of EGS also exist in Slano Kopovo (Ramsar 2004) and Fruska Gora National Park (NPFG 2012).

Legislation

Unknown- nothing to find about in literature.

Distribution and Habitat

Slano Kopovo is one of the last preserved salt marshes in Serbia (Ramsar site no.1392). It is one of Serbia's most important bird habitats and regularly supports more than 20,000 water birds, breeding and migrating and supports a significant number of vulnerable, threatened and critically endangered species such as *Spermophilus citellus*. But this area is threatened by decrease in water level, ploughing of pastures, use of chemicals and artificial fertilizers for agriculture. Human activities include regulated hunting, livestock husbandry, agriculture, and the use of mud for curing ailments (Ramsar 2004).

Fruska Gora National Park has an extent of 25,525 ha. It is characterized by mild slopes, centennial forests and famous vineyards. In the bordering steppe habitats are numerous colonies of EGS, which make significant source of food for birds of prey (NPFG 2012).The following Figure 13 displays the locations in which EGSs exist.

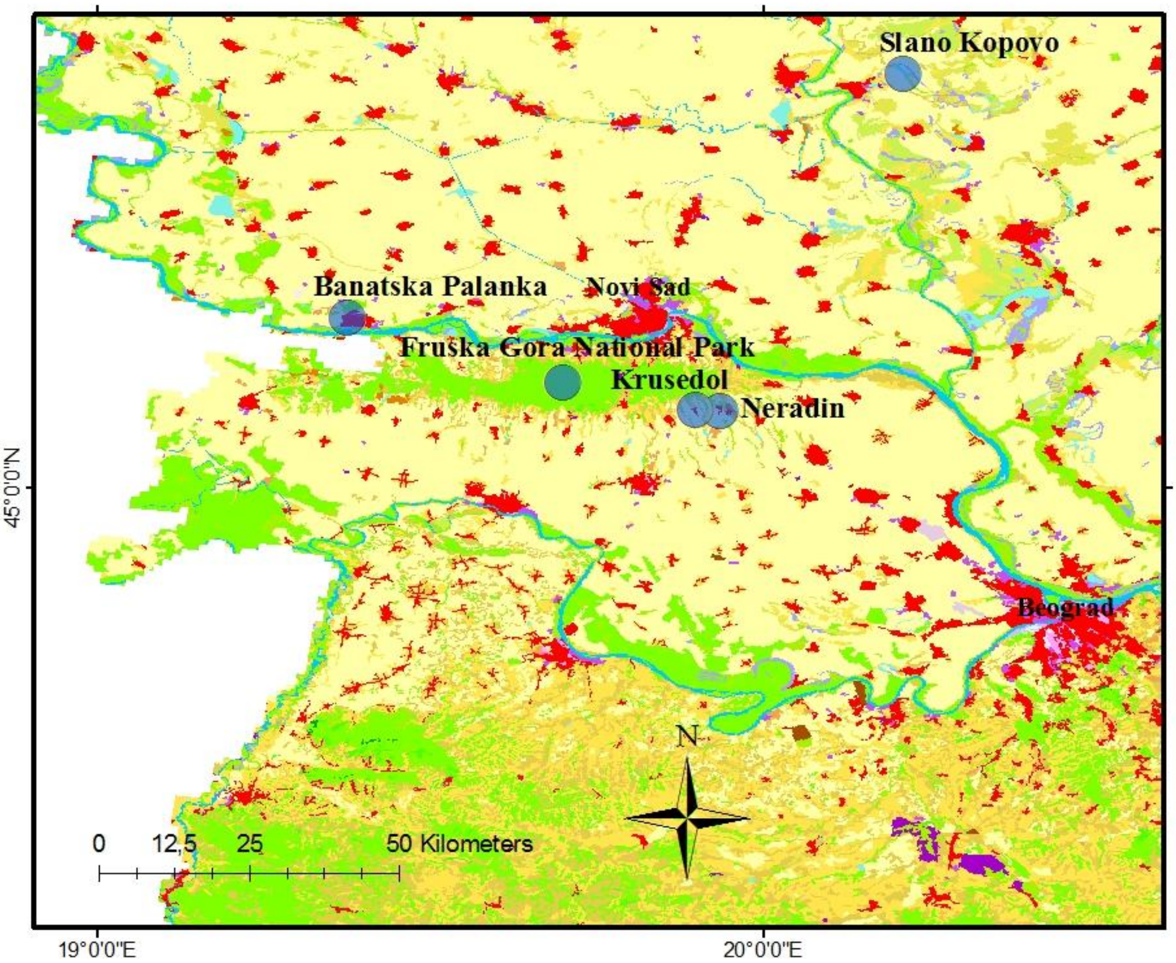

Figure 13. Locations of EGS occurrence in Serbia

The main habitats which are inhabited by EGS in these areas are agricultural areas with non-irrigated arable land, complex cultivation patterns, and agricultural land with natural vegetation, transitional woodland-shrub, broad leaved forest, pastures and natural grasslands.

Threats and chances

In Serbia disappearance and fragmentation of the EGSs habitat are the main threat factors (Ćirović et al. 2008) which can lead to decline of population numbers and a reduced range of this species in Serbia. Therefore the current status of the species needs to be analysed and risk factors to be defined. In their study Ćosić et al have used microsatellite loci to investigate the genetic population structure, degree of fragmentation and level of inbreeding in Serbian populations. They took in total 145 samples from 7 populations, from the northern part of Serbia (Vojvodina). The researchers found a quite high genetic variability based on Heterozygosity (mean value He= 0.518) and allelic richness (mean value of R=4.078). Inbreeding coefficient (FIS) was also quite low (ranged from -0.150 to 0.253). Mean value of FST = 0.16 indicates a strong genetic differentiation among populations. Serbian populations of EGS seem still very viable (Ćosić et al. 2008).

5.2.10. Montenegro

Status: unknown

Literature not found

5.2.11. Slovakia

Status

The EGS is listed as endangered on the Slovakian red list of threatened species. EGS has seriously declined from many parts of its range. In Slovakia the most rapid decline was recorded in 1970s and 1980s especially as a result of extermination of rats, extensive chemization and use of pesticides in agriculture (Adamec et al. 2006).

Legislation

It is a protected species of European importance pursuant to Act No. 345/2002 and Decree No. 24/2003 (Ministry of Environment of the Slovak Republic 2003)

Distribution

2008 Ambros et al. mapped the present and past state of the EGS in Slovakia. They reconstructed the occurrence and distribution of the EGS in Slovakia till 1970, from 1971 to 1995 and from 1995 on. In Figure 14 and 15 you can see the distribution of EGS in Slovakia in 1970 and 1995.

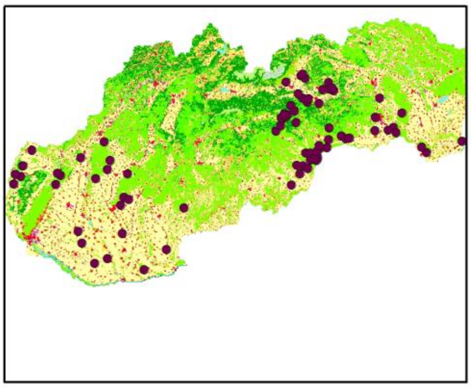

Figure 14. Distribution of EGS in Slovakia in 1970

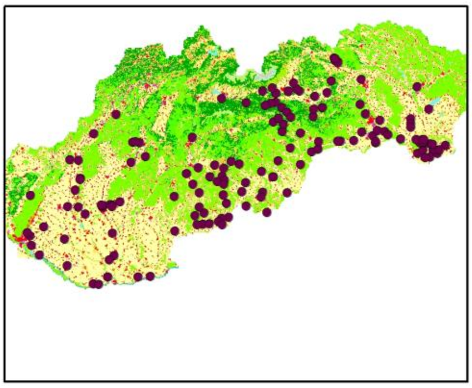

Figure 15. Distribution of EGS in Slovakia in 1995

Since 1996 EGS are being mapped in Slovakia. They also reviewed literature and tried to verify locations of EGS as well as unpublished information and other scientific researches. Between 1996 and 2008 they detected EGSs in 115 localities of Slovakia. In 87% of the localities were EGS occurred in the past concerning literature, there do not occur any EGS today anymore. Many localities were altered in for example habitat use so that they were no longer suitable for EGS to live in. In other areas there still exist populations of EGS but the areas were found in various succession stages as a consequence of farming technology changes. Ambros et al. expect EGS to disappear from these areas in the next 3 or 4 years. Comparing the past distribution with present distribution of EGS the species distribution in

Slovakia lost its continuous pattern from 1950 and broke into several more or less separated segments. Many EGS populations show progressing isolation of existing colonies (Ambros et al. 2008).

In Figure 16 the present distribution of EGSs is shown. The up to date data that exist is from 2006 collected by Michal Ambros et al. (2008). Populations are distributed through almost whole Slovakia, especially in the lowlands around Bratislava and Nitra, in the southwest of the Donau lowland and in the regions of south Rimavská Sobota, Lučenec and south Košice-Okolie along the border to Hungary. Colonies are also distributed in the grass and steppe-like areas around Levoča and Košice.

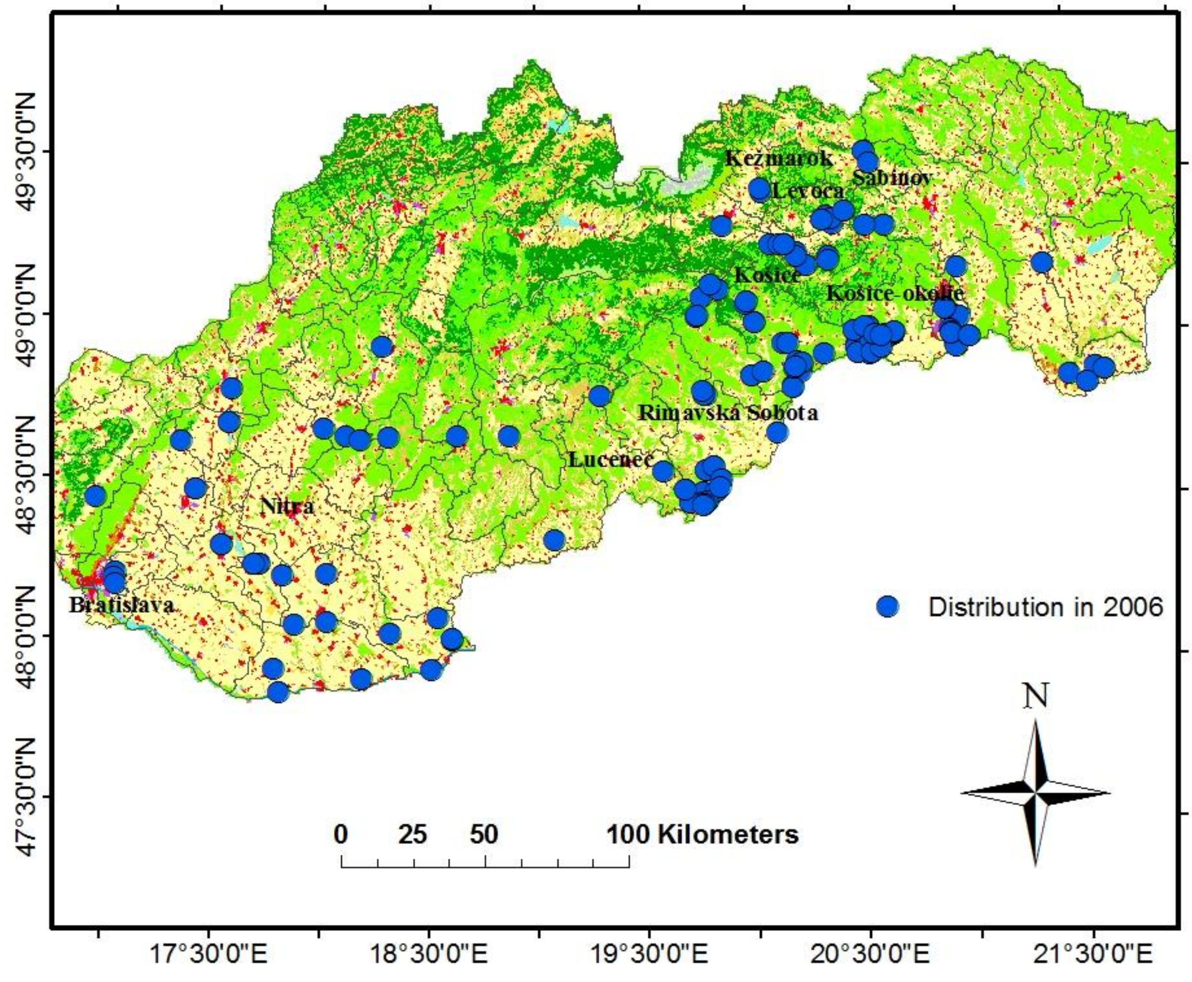

Figure 16. Distribution of EGSs in Slovakia in 2006

In total we got data of 171 species records of EGS in Slovakia, from Michal Ambros et al. These populations inhabit different habitats. 66% of the 171 populations inhabit non-irrigated arable land (21%), Pastures (23%) and agricultural areas with natural vegetation (22%). These three habitats compose 14% or rather 698733m^2 of the total area (4995944m^2) of Slovakia. The rest of the populations are gathered in artificial surfaces like airports (3%) and discontinuous urban fabric (4%), in agricultural areas like vineyards (2%) and other complex cultivation patterns (4%). Populations of EGS are also found in forest and semi-natural areas like Broad-leaved forest (8%), Coniferous forest (3%), Mixed forest (2%), Natural grassland (2%) and transitional woodland-shrub (4%). An overview over the number of areas EGS inhabit in the different types of habitats can be found in table 25.

Table 25. Type of habitats inhabited by EGS in Slovakia

Habitat type	Number of areas
Pastures	23
Agricultural land with natural vegetation	22
Non-irrigated arable land	21
Broad-leaved forest	8
Discontinuous urban fabric	4
Complex cultivation patterns	4
Transitional woodland-shrub	4
Airports	3
Coniferous forest	3
Vineyards	2
Natural grassland	2
Mixed forest	2

EGS do not only depend on the type of habitat a certain area contains but they also depend on the following factors which can be seen in Table 26. All soil parameters are listed which were found in the habitats of EGS. An annual temperature range in those areas is given and an elevation range.

Table 26. Environmental variables in habitats of EGS in Slovakia

Environmental variables	
limitation to agricultural use:	No limitations (76%), Stony (23%), Lithic (1%)
Texture of soil:	Coarse (1.2%), Medium (89%), Medium fine (9.5%)
Parent material:	Limestone (23%), fluvial sands and gravels (21%), river terrace sand (15%), molasses (14%), the rest is others
type of an existing water management system:	No information (87%), Pipe under drainage (13%)
Slope :	No information (22.8%), Level (1.8%), Sloping (58%), Moderately steep (16%), Steep (1%)
Temperature average per year in °C:	4.3-10.7
Elevation in m:	98-1046

From 2001 to 2008 Ďurica conducted a monitoring of EGSs in the Cerová vrchovina Protected Landscape Area by counting EGS by visual observations in different habitats. Altogether 15 localities were monitored in Cerová vrchovina in 2001 – 2008. The total EGS population in the region was estimated at about 1,500 individuals. In 2008 Ďurica noticed a growth of EGS populations at 3 localities, stagnation at 7 localities and a decline at 5 localities. The monitoring has proven the decline of numbers in small colonies which are greatly isolated by "ecobarriers" from other colonies and habitats suitable for settlement (Ďurica 2008).

Threats and Chances

Hulová Š et al. investigated in 2008 population genetic structure of bottleneck EGS populations in the Czech Republic and compared it with populations from Slovakia, Hungary and Romania. They analysed neutral and adaptive variation at 12 microsatellite loci and two immune genes (DRB, DQB) of the major histocompatibility complex (MHC) for a total of 470 samples of the EGS. In the Czech Republic, the expected Heterozygosity of the two MHC loci was very low (He=0.156) compared to the Slovakian populations (He=0.503). Also the mean microsatellite Heterozygosity was lower (He=0.23) in the Czech Republic than in the Slovak Republic (He=0.39). The variability in Slovakian population is still higher than in populations of the Czech Republic and populations seem not to be that isolated and genetically differentiated.(Hulová Š et al. 2008)

Low abundance of EGS is directly associated with *Aquila heliaca* and *Falco cherrug* population stability (Adamec et al. 2006). That is why the EGS is part of an action plan for the conservation of the Saker falcon (*Falco cherrug*) (Nagy et al. 2005) and the Imperial eagle (*Aquila heliaca*) (Latková et al. 2007) because it is an important prey species of these birds of prey. Actions concerning the maintenance of EGS populations include creating favourable conditions for the presence and breeding of sousliks and exclusively manage areas by mowing or grazing with farm animals (Nagy et al. 2005).

Conservation projects

In Slovakia, five conservation projects have been organised since 1992 (one of them is still in process). They were usually not primarily focused on *S. citellus* conservation, but as support for the foraging base of the Saker falcon (*Falco cherrug*) and the imperial eagle (*Aquila heliaca*; "LIFE" projects) (Matějů et al. 2011). In Figure 17 all location of current and past reintroduction program can be seen.

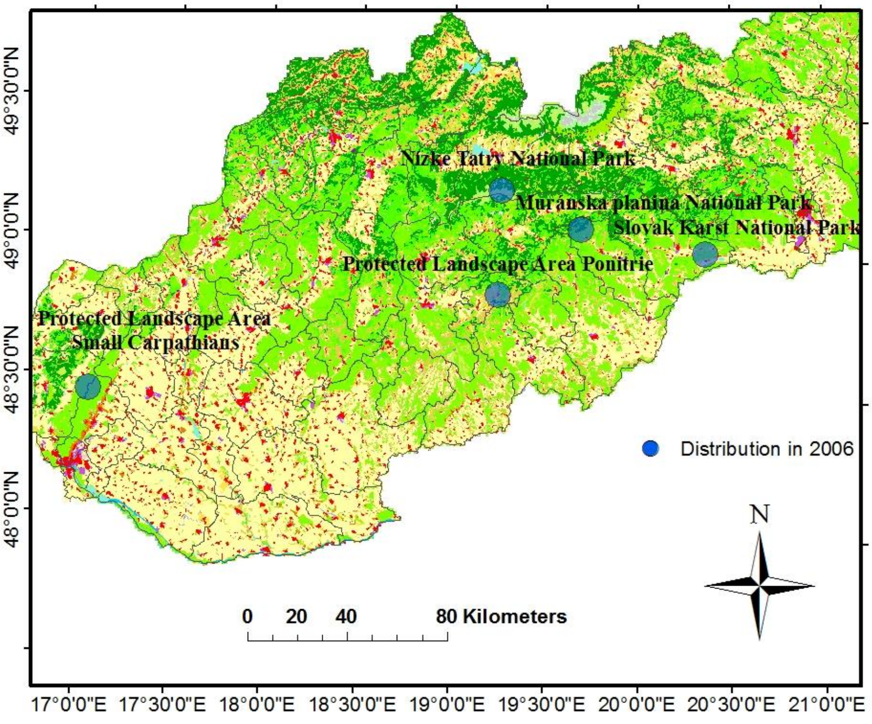

Figure 17 Areas of EGS conservation projects in Slovakia

The first transfer of EGSs in Slovakia was carried out in 1992–1993. Target localities in the Košice basin (Buzica, Milhosť and Perín-Chým in the Košice-okolie district) include several hundreds of hectares of pastures covered with thermophile vegetation. EGSs previously occurred at all of the target localities. EGSs were transferred from the colony inhabiting a pasture (9 ha in size) in the site called Grajciar (Košice-okolie district). It was a rescue transfer, since the Grajciar colony was threatened by planned ploughing of the locality. The repatriation seems not to be as successful as expected and the transferred populations became gradually extinct or/and the established populations were affected by inadequate management of the target localities (Matějů et al. 2011).

One of the Slovak projects (Repatriation of S. citellus in the Košice region) was evaluated as three separate reintroductions because it comprised releases of animals at three distinct sites in the Košice region (Matějů et al. 2011). The chosen areas for returning souslik are: the Slovak Karst National Park (sites Silická ľadnica and Nylaše), Protected Landscape Area Small Carpathians (site Kuchyňa) and Protected Landscape Area Ponitrie (site Cibajky). During the project period, EGSs have been trapped primarily in the airfields of airports in Bratislava and Košice, where populations are naturally stable. In this time 892 individuals were released on new pastures. Positive results of this activity have promoted the decision to continue with reintroduction in the future (Latková et al. 2007). But nevertheless the following restitution projects failed.

The restitution project at Protected Landscape Area Ponitrie failed due to the fact that a too a small amount of individuals was transferred and it seems that the site was not suitable for release, probably also due to predation pressure by birds of prey, weasels and cats (Matějů et al. 2011).

The restitution project at Slovak Karst National Park was more difficult because a population of EGSs already inhabited this area. Aggressive behaviour was shown by the previously resided EGSs, as a part of the transferred animals had settled on the localities. According to reports of the Slovak Karst National Park administration, the transfer did not enhance the abundance of the colonies. It seems that the abundance of the populations rather randomly oscillates in time (Matějů et al. 2011).

The restitution project at Protected Landscape Area Small Carpathians also failed due to a too high number of individuals transferred (16 transfers with 950 individuals) to the area which was not suitable to hold so many EGSs. The population exhibits natural reproduction but the abundance is only 10% of the transferred amount (Matějů et al. 2011).

Restitution project have also taken place in Nízke Tatry National Park. EGSs were transported from the Košice International Airport. In three transfers 125 individuals were released in the area. In the next spring no EGSs were observed on the locality. Regarding the insufficient documentation, it is difficult to analyse its results. One possible reason of the repatriation failure could be an unbalanced sex ratio of the released individuals (only 35% of females). Moreover, unsuitable management of the target locality cannot be excluded. (Matějů et al. 2011).
A last locality in which restitution took place is the Muránska planina National Park. From 2000 till 2009, altogether 23 transfers were organized and 1057 individuals were released. Up to now, results of EGS repatriation on the Biele vody locality seems to be positive. In 2007, the estimated abundance of the colony was around 400 individuals and the annual population increment seemed to compensate for the loss caused by predation by birds of prey, foxes and

badgers. However, the colony is still reinforced by the transfers and it is not clear how the situation develops when the transfers will be stopped. (Matějů et al. 2011).

Until now, restitution of EGS populations has been successful at two localities (Kuchyňa and Biele Vody) (BALÁŽ et al. 2008).

For future transfers or reintroductions of EGSs the following prerequisites are important. Release of a high number of individuals (about 500) during several consecutive years (on average 5 years) in an adequate habitat and continuous monitoring and protection of the EGS population. In 2007 a captive breeding program started at Bojnice zoo to have a backup population for future reintroductions (BALÁŽ et al. 2008).

5.2.12. Turkey

Status
- Unknown -

Legislation
- Unknown -

Distribution and Habitat

Three species of EGSs occur in Turkey. EGS is native only to the European part of Turkey, west of the Bosporus. This species was recorded from 2 different localities in Turkish Thrace; Edirne and PÝnarhisar-KÝrklareli (Özkurt et al. 2005). In the following Figure 18 the localities are displayed.

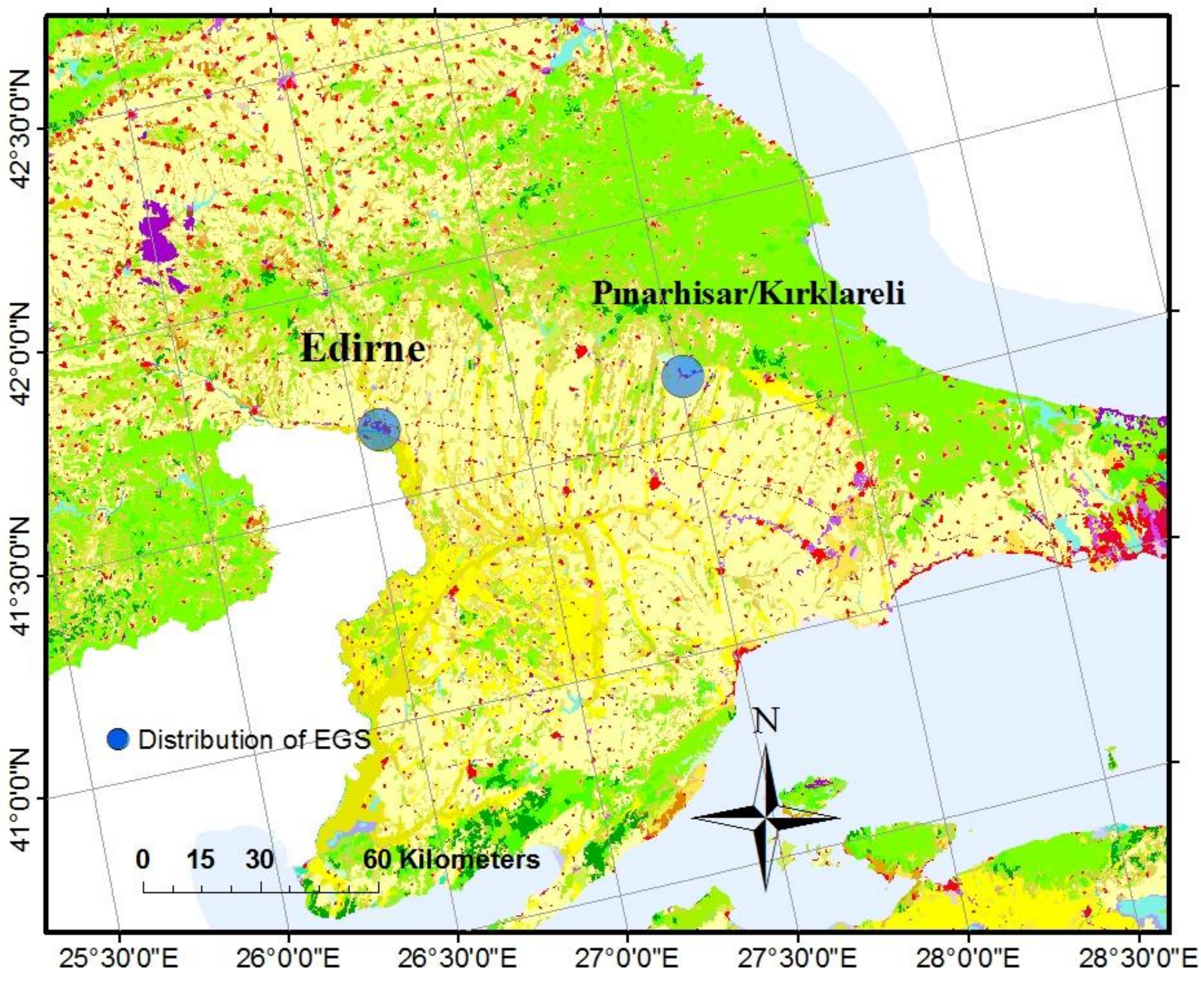

Figure 18. Recorded locations of EGS in Turkey

The habitat types in these areas are mainly agricultural areas with non-irrigated arable land, permanently irrigated land (Artificial water supply with drainage network, channels and spray sprinklers), agricultural land with natural vegetation and rice fields.

To other parts of Turkey Taurus EGSs (*Spermophilus taurensis*) are native which inhabit areas in the Anatolian part of Turkey, in the eastern part of the western Taurus mountains and are parapatric with Anatolian EGSs (*Spermophilus xanthoprymnus*) at the northernmost limit of their distribution. Anatolian EGSs inhabit central lowland and eastern Highland of Anatolia and small areas in adjacent Armenia and northwest Iran. They are also known from a few localities in southern Anatolia (Gür et al. 2010).
In their research Yigit et al investigated genetics of three populations of *Spermophilus citellus* in western Turkey, from Turkish Thrace, southwest Anatolia and central Anatolia. Populations with two different karyotypic forms were analysed biometrically (NTSYS) and genetically from their 16S rRNA sequence data. The populations from Turkish Thrace and southwest Anatolia where considered different species in the past but their study revealed, that both belong to the same species S. citellus because they share the same chromosomal number. In contrast, the population from central Anatolia has a different chromosomal number and is for that reason identified as *S. xanthoprymnus*. UPGMA cluster analysis with genetic sequence data of 16S rRNA showed similar results. The close biometric and genetic associations indicate a rather recent immigration of *S. citellus* into western Anatolia via the land bridge between the Balkans and Anatolia, probably at least no earlier than the end of the Pleistocene, and *S. xanthoprymnus* originating from *S. citellus* apparently later invading the central Anatolia steppe towards eastern Turkey (Yigit et al. 2005).

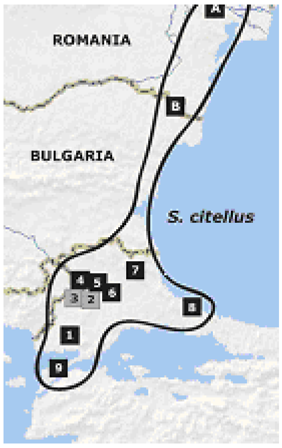

Figure 19. Distribution of EGS in Turkey west of the Bosphorus; Gündüz et al 2007

By examining additional genes, and by introducing more sophisticated morphometric techniques, Gündüz et al. found out in their research about multigenic and morphometric differentiation of EGSs in Turkey, that the EGSs from southwest Anatolia are divergent from *S. citellus* and *S. xanthoprymnus* and they defined *S. taurensis* as a third species of EGS in Turkey (Gündüz et al 2007). Distribution of EGS west of the Bosporus after Gündüz et al can be seen in Figure 19.

Threats and chances
- Unknown -

5.2.13. Poland

Status

In Poland as well as Germany, Moldavia, Serbia and northern Greece EGS exist only in some small isolated populations. Populations in Germany and Poland became extinct (1968 Germany, 1983 Poland) (Matějů et al. $2010_{(1)}$) during the last few decades (Kryštufek 1996).

Legislation

In Poland EGS is a strictly protected species (Act of 16. April 2004, Coll. 2004, Item no 92/880; Decree of 24th September 2004, Coll. 2004 Item no. 220/2237) (Matějů et al. 2010) In the red list of Poland it is still mentioned as extinct although successful reintroduction have taken place, the red list has not been updated until 2001.

Distribution and Habitat

In the following Figure 20 the reintroduction areas are displayed.

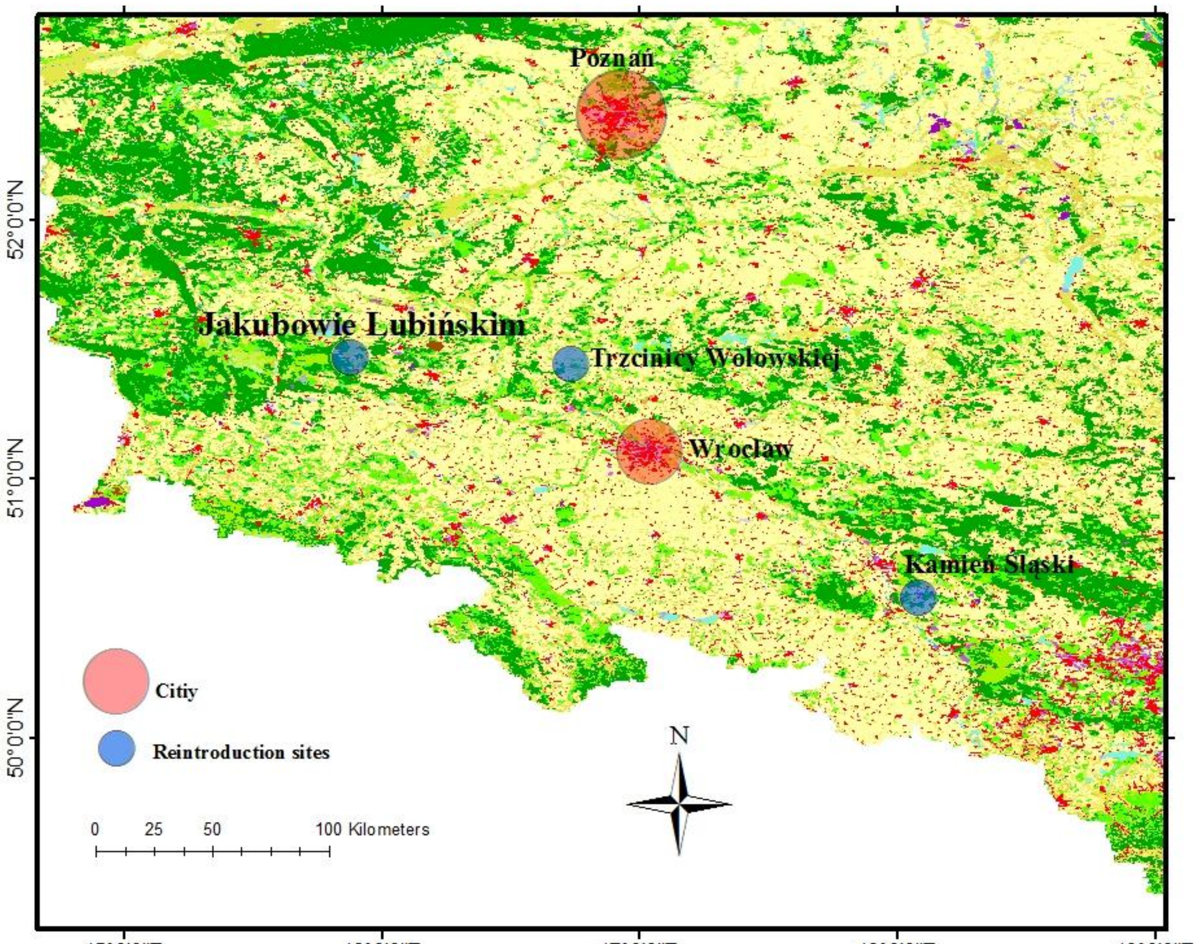

Figure 20. Reintroduction sites of EGS in Poland

Threats and chances
EGSs are extinct in Poland but conservation project give new hope for EGSs in Poland.

Conservation projects
In 2000 the process of reintroduction of EGSs in Poland started. The organisation "Salamandra", the polish society of Nature protection tried to introduce EGSs in areas from which they disappeared during the 80ths. The first step was to analyse why EGS got extinct from a certain area and to find out if these threats still predominate (Kepel, 2008). After getting all licenses and breeding EGSs in Zoos (Bern and Budapest) EGS were introduced near Kamień Śląski in the province Opolskie in a 30 ha big area of meadows where an abundant EGS colony was reported in 1973 (Matějů et al. $2010_{(1)}$) At the time of reintroduction, the meadows were used for hay production and mowed twice a year. Moreover, management of adjacent areas enabled future expansion of the colony (Matějů et al. $2010_{(1)}$).The start was at July 24th 2004 at 7.30pm. 10 individuals were released. For the purpose of the project, almost 180 EGS from Hungary (from two localities: Budakeszi grassy airport and Budapest International Airport) and Slovakia (Bratislava International Airport) were imported to the Poznań Zoo. In addition, nine individuals came from the breeding colony in the Bern Zoo (Switzerland). EGS were bred in three separate open enclosures, each of them 100 square meters in size. Both adults and their offspring were released at the target site the following offspring (Kepel, 2004, Matějů et al. 2010). Each to be released individual was labelled by a subcutaneous microchip (Matějů et al. $2010_{(1)}$). EGS released in the area around Kamień Śląski were already reproducing in 2005 and the first wild offspring since 30 years was born (Kepel $2005_{(1)}$). In July 2005, 79 EGSs were released in Kamién Śląski after an acclimatization of a few weeks in large cages. Most of them were born in Poznan Zoo. EGSs were monitored by naturalists and volunteers for weeks. In the end all Squirrels found a place to dig and prepared for hibernation. The winter of 2006 was long and cold but EGSs survived and reproduced effective (Kepel 2007). Monitoring of the locality in late July 2008 revealed 230 inhabited burrows and the abundance of the population was estimated at 150–200 (Matějů et al. $2010_{(1)}$).
In 2008 60 EGSs were released at a second place the meadows of Trzcinicy Wołowskiej with a sandy sub-soil and thermophilous vegetation. The meadow is owned by a non-governmental organization, the Polish Society of Friends of Nature "ProNatura". This organization also provides regular management of the locality (Matějů et al. $2010_{(1)}$). After successfully hibernating and reproducing, the populations comprised already 75 individuals in 2009. Another 20 individuals were added in summer 2009 to this population (Kepel 2009). In 2010, 23 Individuals were added to the population in Trzcinicy Wołowskiej again (Kepel et al. $2010_{(1)}$). A new population in a third area was established summer 2010 as well. On a meadow in Jakubowie Lubińskim 42 EGSs were released (Kepel et al. $2010_{(2)}$). Another 66 EGSs were released on this meadow in 2011 (Kończak $2011_{(1)}$) Salamandra already received some funding for a fourth area. With the support of the European Union through the European Regional Development Fund under the Operational Programme Infrastructure and the National Fund for Environmental Protection and Water Management for the next three years. Salamandra will be able to implement measures to maintain the achieved results and further reconstruct the population of EGSs spotted in Poland (*Kończak* $2011_{(2)}$). Dr. Andrzej Kepel the president of Salamandra wants to establish at least 15 reintroduction sides for the EGS (Kepel, 2008)

5.2.14. Croatia

Status: extinct (IUCN, 2008)

No literature found

5.2.15. Germany

Status: extinct

Legislation
In Germany, EGS is protected by the Bundesnaturschutzgesetz (BnatSchG 25 März 2002).

Distribution
Former distribution in Germany was on a very small scale. As a result of deforestation, shifting habitats facilitated EGS dispersal in Germany about 500-300 years ago (Grulich, 1990). By passing the Krusne Hory Mountains, EGS invaded from Czech Republic (Barta, 1965). EGS historic occurrence was recorded in Silesia and Saxony as well as in Lusatia and Vogtland County, but established populations stayed isolated (Stubbe & Schipke, 1992). The last EGS sighting close to Oelsengrund (Saxony) was recorded in the end of the 60s and in the beginning of the 80s, the last individual was seen in Geising (Saxony, border region to Czech Republic) (Feiler, 1988). Nowadays, the species is considered as extinct (Coroiu *et al*, 2008). The former distribution area is characterized by mosaics dominated by non-irrigated arable land, complex cultivation patterns and land principally occupied by agriculture. Also areas of natural vegetation, mixed forest, discontinuous urban fabric, construction sites, mineral extraction sites, coniferous forests, transitional woodland-shrub are present.

Projects
In the historical distribution area of the eastern Erzgebirge (border area to the Czech Republic), an EGS release project got installed. Since 2009, individuals become reintroduced and volunteers are involved to manage the landscape for EGS maintenance and to monitor released populations (Riether, W., *pers.comm*. 2012). Landscape of the release site is characterized by complex cultivation patterns (Figure 21).

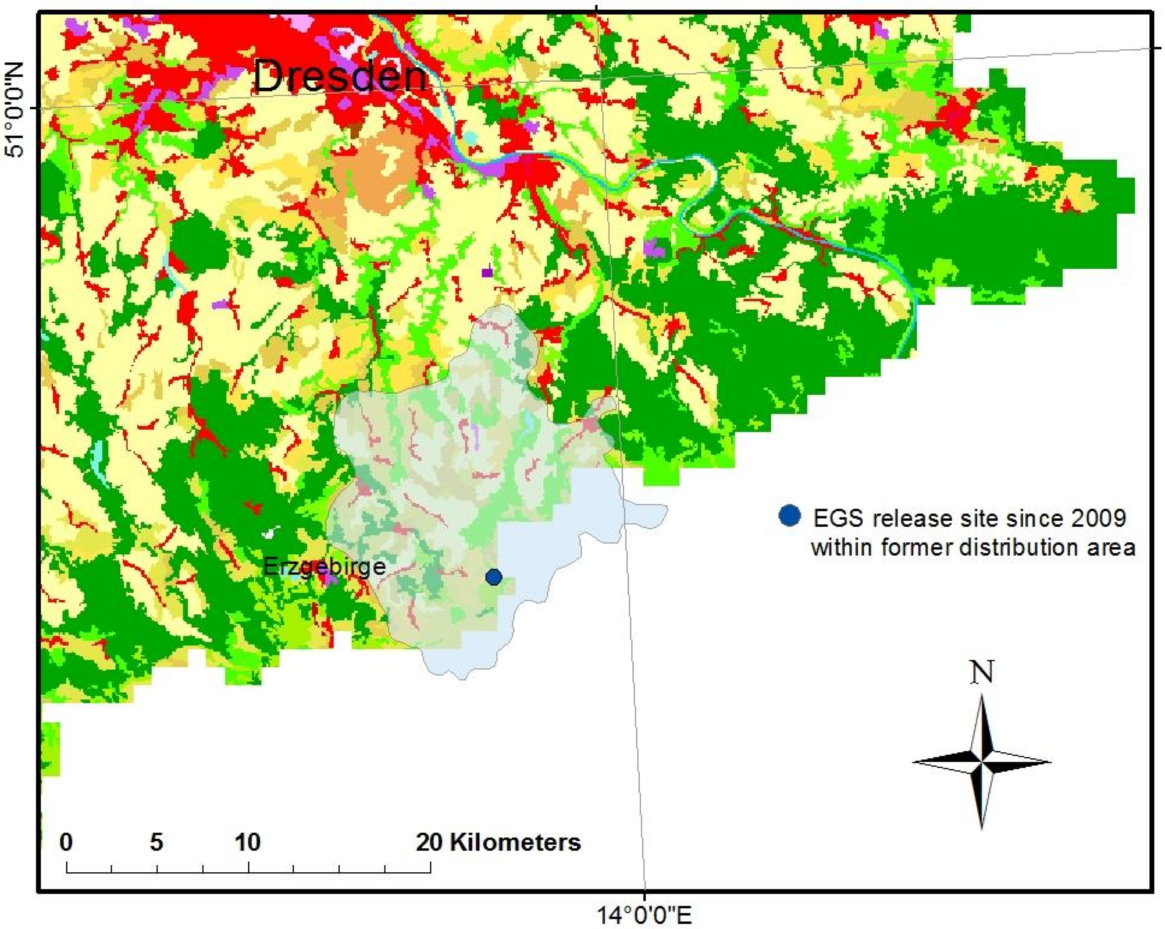

Figure 21. Reintroduction site of EGS in Germany

Table 27. Type of historic habitats inhabited by EGS in Germany

Habitat type
Non-irrigated arable land
Complex cultivation patterns
Land principally occupied by agriculture
Areas of natural vegetation
Mixed forest
Discontinuous urban fabric
Construction sites
Mineral extraction sites
Coniferous forests
Transitional woodland-shrub

EGS do not only depend on the type of habitat a certain area contains but they also depend on the following factors which can be seen in Table 28. All soil types are listed which were found in the habitats of EGS. An annual temperature range in those areas is given and an elevation range.

Table 28. Environmental variables in habitats of EGS in Germany

Environmental variables	
Soil type:	
Climate:	continental
Temperature:	4.1°C
Elevation:	480- 841m (release site: 742m)

Threats

Table 29. Major threats, effects and scales to EGS populations in Germany

Threats	**Effects**	**Scale**
Small population size	Inbreeding, decreasing population	Erzgebirge
Lack of legal protection	Lack of official conservation importance	National

5.3. Integration: range countries

5.3.1. Land cover analysis of range countries

In the following Table 30 you see a summary of the percentages of the types of habitats inhabited by EGS in the different range countries. This analyse was of course only possible in countries from which we obtained distribution data. In the other range countries only estimations by description of distribution areas were possible. In the Table only the highest percentages of each country are summarized.

	Habitat type	**Land cover in %**					
		Austria	**Czech Republic**	**Greece**	**Hungary**	**Macedonia**	**Slovakia**
Artificial surfaces	Discontinuous urban fabric	11			10	1	4
	Industrial or commercial units	5					
	Airports	2			5		3
	Sport and leisure facilities	4	11				
Agricultural areas	Non-irrigated arable land	24	7	30	16	3	21
	Permanently irrigated land			8			
	Vineyards	15		8		6	
	Pastures	2	3		32	5	23
	Complex cultivation patterns	15	4	8		10	
	Land principally occupied by agriculture, with significant areas of natural vegetation	7	2	23		5	22
Forest and semi natural areas	Broad-leaved forest	1		8	8	2	8
	Natural grasslands	4			18		
	Transitional woodland scrubs		1			4	
	Sclerophillous vegetation		13			4	

Table 30. Summary of the percentages of land cover types inhabited by EGS in the range countries concerning obtained distribution data. (The highest percentages per country are summarized in the Table.)

The most frequent occurrence of EGS concerning this data seems to be on artificial surfaces and in agricultural areas and not in semi-natural areas. In almost every country EGS were found on non-irrigated arable land and on land principally occupied by agriculture but with significant patches of natural vegetation. In Hungary and Slovakia there seem to be more pastures which get regularly mowed or grazed and which are a suitable habitat for EGS then. These results could indicate the shifting of their natural habitats to agricultural areas or artificial surfaces. EGS have to switch more and more from more or less natural habitats like grasslands to artificial areas like urban fabric or airports and to agricultural areas like pastures, Vineyards or complex cultivation patterns.
We validated the analysis by comparing results with recent (2012) air photos from bingmaps.com. In Hungary, where EGS is widely distributed, main landuse is constituted of agricultural areas; forest areas are ~20% only of total countries´ territory. Slovakia inhabits ~40% forest areas and EGS do occur in territories of forest clearings that are used as agricultural areas.

Suitable land cover for EGS constitute a very small part of the total area throughout the range countries, since pastures have the highest percentages with 6.9%, in contrast to forest areas (mixed, broadleaved and coniferous forest) that occupy 31.3% of the total range (Table 31).

Table 31. main land use of EGS, total area size and percentage compared with areas occupied by forest in range countries

Land use	**Total area count of land use** in km^2	**Percentage**
Discontinuous urban fabric	47948	3.5%
Non-irrigated arable land	41666	3%
Pastures	94787	6.9%
Annual crops associated with permanent crops	24	0.008%
Land principally occupied by agriculture, with significant areas of natural vegetation	92400	6.8%
Forest areas	**427749**	**31.3%**

5.3.2. Environmental parameters analysis of range countries

With this analysis it is similar as with the habitat analysis per country. It could only be conducted with distribution data of EGS. Much of the information summarized in Table 33 overlap between range countries. For example by analysing limitations to agricultural use, it is obvious, that in all the countries there was not really much information about limitations in agricultural use. Concerning the texture of the soil EGS seem to be able to cope with a range of fine in Hungary to coarse in Macedonia. But the most frequent texture in most of the countries is medium meaning 18% < clay < 35% and >= 15% sand, or 18% <clay and 15% < sand < 65%. The dominating parent materials are loess in Austria, Czech Republic and Hungary, Fluvial clays, silts and Loams in Greece and Macedonia and Limestone (23%), fluvial sands and gravels in Slovakia. Through the fact, that EGS switch more and more to agricultural areas and artificial surfaces because of habitat fragmentation and destruction, the species has to cope with the local water management systems of farmers. About water management systems there is still not much information available in EGS range countries. In Austria EGS have to cope with ditches, in the Czech Republic and Slovakia with pipes under drainage and in Greece with overhead sprinklers. EGS do not only inhabit plain areas but they tolerate moderate slopes. The range which resulted from our analysis is level to moderately steep. Expressed in numbers this means a slope from 0 up to 25%. EGS are hibernating during winter, so the temperature in the winter may not fall too much so that the EHS do not freeze. The analysis resulted in an average annual temperature range from 1.7 °C and 11.3 °C. EGS are not restricted to a certain height above sea level. Our analysis resulted in a range from 0 to 1046 but from literature we know, that they are present up to height of about 2500 meters.

5.3.3. Habitat analysis of range countries

To combine the results from the land use analysis (Table 31) and the analysis of the other environmental parameters (Table 33) we conducted an overlay analysis with all parameters included in the land use and environmental parameter analysis. So in Table 32 the land use characteristics were related with all the other environmental parameters. We have 8 layers with suitable environmental characteristics but only areas in which all characteristics from these 8 layers overlap are thus highly suitable areas for EGS to inhabit. In the Table you see numbers from 1-8 which represent how many of our 8 layers overlap. We also calculated the area size of these overlapping areas which is presented aside. The most suitable habitat with all 8 layers overlapping is 222012 km^2 and accounts for 16.26% of the total area in the range countries. 7 or 6 overlapping layers account for 32.05% and 27.73% of the total area in the range countries. Depending on which layers do not overlap this habitat types can still be very suitable for EGS.

Table 32. Habitat analysis by numbers of overlapping environmental layers in the range countries.

Number of overlapping layers	**Area size in km^2**	**Percentage**
8	222012.01	**16.26%**
7	437669.10	**32.05%**
6	378641.67	**27.73%**
5	204387.15	14.97%
4	84758.08	6.21%
3	36452.46	2.67%
2	1531.86	0.11%
1	10.89	0.00…%
Total Area range countries	1365463.22	

Table 33. Summary of all environmental parameters found in areas inhabited by EGS concerning obtained distribution data

Environmental variables	**Austria**	**Czech Republic**	**Greece**	**Hungary**	**Macedonia**	**Slovakia**
Limitation to agricultural use:	No limitation (88%),	No limitation (74%	No limitation (57%)	No limitation (87%),	No limitation (98%)	No limitations (76%),
Texture of soil:	Medium (99%)	Medium (70%),	Medium (95%),	Medium (14%), Medium fine (47, 1%), Fine (20%),	Coarse (98%)	Medium (89%),
Parent material:	Loess (68%)	Loess (45%,)	Fluvial clays, silts and Loams (71%),	Unconsolidated deposits (21%), loess (25 %)	Sandstone (29%), fluvial clays, silts and loams (64%)	Limestone (23%), fluvial sands and gravels (21%),
Type of an existing water management system:	Ditches (2%), no information (97%)	No information (91%), Pipe under drainage (8%)	No information (57%) Overhead sprinkler (42%)	No information (99%),	No information (100%)	No information (87%), Pipe under drainage (13%)
Slope :	Sloping (72%),	Sloping (57%) Moderately steep (28%)	Moderately steep (33%)	No information (71%), Level (13%),	No information (95%) Moderately steep (4%)	No information (22%), Sloping (58%),
Temperature average per year in ° C:	7.5-10.1	4.3-10.7	1.7-5.5°C	8.8-11.3	1.8-3.1°C	4.3-10.7
Elevation in m:	112-506m	98-1046m	0-657m	77-320m	30- 483m	98-1046m

6.1. Maxent potential distribution modeling

Analysing data with Maxent species distribution modelling we reached step 6 of our conceptual model (Appendix IIV). The point shapefiles of ArcGIS have to be converted into .csv files and the environmental parameters layers to ASCII files. This process is described in chapter 6.1.1 and 6.1.2. The resulting output is validated see chapter 6.1.3 and 6.2. where also the potential species distribution map is discussed. The map is loaded into ArcGis and a part of the map is than overlaid with Natura 2000 areas and discussed again.

6.1.1. Occurrence data

Only data collected in the period 2000-2011 were selected for this study. We chose not to discard any data from the selection, because predictions based on many records generally perform better (Pearce and Ferrier 2000a; Kadmon et al. 2003; Hernandez et al. 2006). The final database contained 1116 species' records. These records were converted in ArcGIS 10 to Meters and plotted into the WGS 1984 UTM zone 33N coordinate system. After that the file was exported to excel and saved as a csv file.

6.1.2. Environmental parameters

Based on literature study (chapter 1) and expert judgement (pers. comm. Arjen Strijkstra 2012), we identified eight types of relevant environmental variables to include in the model: corine land use (cofina), water management (wm), parent material (par), texture of the soil (txs), elevation (ele), slope (slop) limitations to agricultural land use (agl) and mean annual temperature (temp) were downloaded from the internet. (Metadata see Appendix I and III). Mean annual temperature was downloaded at WorldClim (http://www.worldclim.org/) with a resolution of 1x1 km (30 arc seconds) (Hijmans *et al* 2005). Corine land cover datasets 2000 and 2006 with a resolution of 2000-100m were obtained at the website of the European Environment Agency (http://www.eea.europa.eu/). Soil and elevation databases were derived by the European Soil Committee (ESDB v2.0 2004). The soil database was downloaded from the following website: http://eusoils.jrc.ec.europa.eu.
All variables were set to equal cell sizes of 100x100 and coordinate system (WGS 1984 UTM zone 33N). The linear unit was set to meters. The corine landuse layer already was set to the 100x100 extent. Minimizing cell sizes would result a data loss and because of that the resolution of 100x100 was used to ensure most accurate model performance. The extents of remaining layers were adjusted by extracting all the layer files with a mask file with the desired extent.

6.1.3. Distribution modeling

Maximum entropy modelling (Maxent) of species' geographic distributions was used to predict EGS distribution by combining species occurrence points (.csv files) with the environmental datasets (.ascii files) (Phillips et al. 2006, Maxent version 3.3.3e). In total, 862 presence records were used for training, 61 for testing in Maxent. 10851 points were used to determine the Maxent distribution (background points and presence points). Maximum entropy got achieved by the constraint that the expected value of each variable must equal the mean value at the presence points (the empirical average) (Phillips *et al*. 2006). The model output displays the relative occurrence probability of a species within the grid cells of the study area. Maxent was used with default settings and 15 replicates were run to achieve average predictions.

6.1.4. Model validation

The model is tested by the all receiver operating characteristics (ROC) curve plots that plot the true-positive rate against the false-positive rate. The average area under the curve (AUC) was used to determine the adjustment of the model.

Because data input only contains species occurrence data, the AUC is calculated using pseudo-absences chosen at random from the study area (Phillips *et al*. 2006). The AUC can be defined as an index of habitat suitability (0.00 highly unsuitable; 0.7-0.75 potentially useful; 1.00 very suitable) that reflect the probability that a random chosen presence site are be ranked above a random chosen absence site (Pearce & Ferrier 2000; Phillips *et al.* 2006).

6.2. Maxent: potential distribution Europe

The average performance value of the 15 models was an AUC of 0.934 with a standard deviation of 0.015 (Appendix V) The model is considered as potentially use full and the AUC value represents a very suitable habitat suitability.
Response curves were created to demonstrate how each environmental variable affects the Maxent prediction. Curves show how the logistic prediction changes as each environmental variable is varied, keeping all other environmental variables at their average sample value. According to the output, EGS occur in areas with an average annual temperature between 5 ºC and 18 ºC. Most dominant parent materials of the predicted distribution range were areas with basalt (≈0.77), river terrace sand (≈0.68) and loess (≈0.7). Land use with the highest influence are Vineyards (≈0.8), artificial surfaces (≈0.6) and agricultural areas like non-irrigated or permanently irrigated land (0.4). Low probability of EGS occurrence is considered in forest areas and wetlands (0.1). Response curves predicted a distribution of the species at elevations between 0 and 500m (Table 33).
A description of each response curve can be found in Appendix V.
To determine relative contributions of the environmental variables to the model, the increase in regularized gain was added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda was negative. Resulting contributions are shown in Table 34. The average of all 15 runs shows a relatively high contribution of 20% of the temperature layer and a very low contribution of 1% of the wm (water management) layer.

Table 34. Relative contributions of the environmental variables to the Maxent model and output of response curves as environmental requirements

Variable	Percent contribution	Output of response curves as environmental requirements
temp	**20.4**	*5-18* ºC
par	18.2	Basalt(≈0.77) river terrace sand (≈0.68) loess (≈0.7)
cofina	15.3	Vineyards (≈0.8) artificial surfaces (≈0.6) (≈0.48) non-irrigated or permanently irrigated land
ele	15	*0-500m*
txs	12.7	coarse to medium fine soil 18% < clay > 65% sand < 35%
slop	8.9	8%
agl	8.3	coherent and hard rock fragments within 50 cm (≈0.68), Petrocalcic areas, cemented or indurated calcic horizon within 100 cm (≈0.51)
wm	**1.2**	overhead sprinklers (0.45) Trickle irrigation (0.5). no water management (0.25)

According to the jack-knife test, the environmental variable with highest gain when used in isolation is par (parent material), which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is temp (temperature), which therefore appears to have the most information that is not present in the other variables. (Appendix V).

6.2.1. Whole Europe

The representation of the Maxent model (Figure 22) shows EGS potential distribution throughout Europe (areas of suitable environmental conditions). A high probability (0.77) of EGS presence is found in the areas of eastern Austria around Vienna, south eastern and northern Czech Republic and southern Slovakia around Nitra as well as along the border to Hungary. Also in northern Slovakia close to Medzilaborce and south eastern Poland the probability of occurrence of EGS is high. Small populations are considered to occur in south western and eastern Hungary via the Romanian border till Satu Mare and in central Romania in the area near Sibiu. In Slovenia, EGS presence is predicted with 0.77 in the eastern part (east of Maribor and around Krsko) on the border to Croatia and in Croatia in the area of Cakovec at the border triangle to Slovenia and Hungary. High probability of presence is also predicted for Greece in the area around Thessaloniki and Xanthi, as well as close to Naousa and Larisa. In remaining areas throughout the whole above mentioned distribution area as well as in Germany, EGS presence is predicted with mediate probability (0.31- 0.54), except for central Hungary and the Alpes area in Austria where the species in considered to be absent. Low probability of presence is also predicted for southern Romania, Bulgaria, main part of Macedonia, Kosovo, Albania, Montenegro and southern Bosnia- Herzegovina.

Areas outside EGS current distribution range with high probability of presence are in Germany close to Würzburg, central Belgium, very fragmented in France close to the Belgian and German borders, as well as in central and south eastern France, in Spain south of Zaragoza and close to Madrid, on the northern coastline of Portugal till Mira, throughout Ireland and in Southern United Kingdom. Although there seem to be suitable environmental conditions in these areas EGS apparently have not been able to colonize them due to geographic barriers. There can be various reasons why EGS do not occur there and why their distribution range is restricted to central and south-eastern Europe (see Figure 22 red line). One reason are large rivers (like the Danube, the Rhine or the Elbe, see Appendix VI). Although EGS are able to swim it is not likely that they cross large rivers in great numbers to develop stable populations. Other obstacles are mountains. The range of EGS is already divided into two by the Carpathian Mountains. In Europe there are also the Alps or the Pyrenees which make it difficult for EGS to cross to areas beyond. Also continuous forest areas make it difficult for EGS to subdue to new areas (Appendix VI).

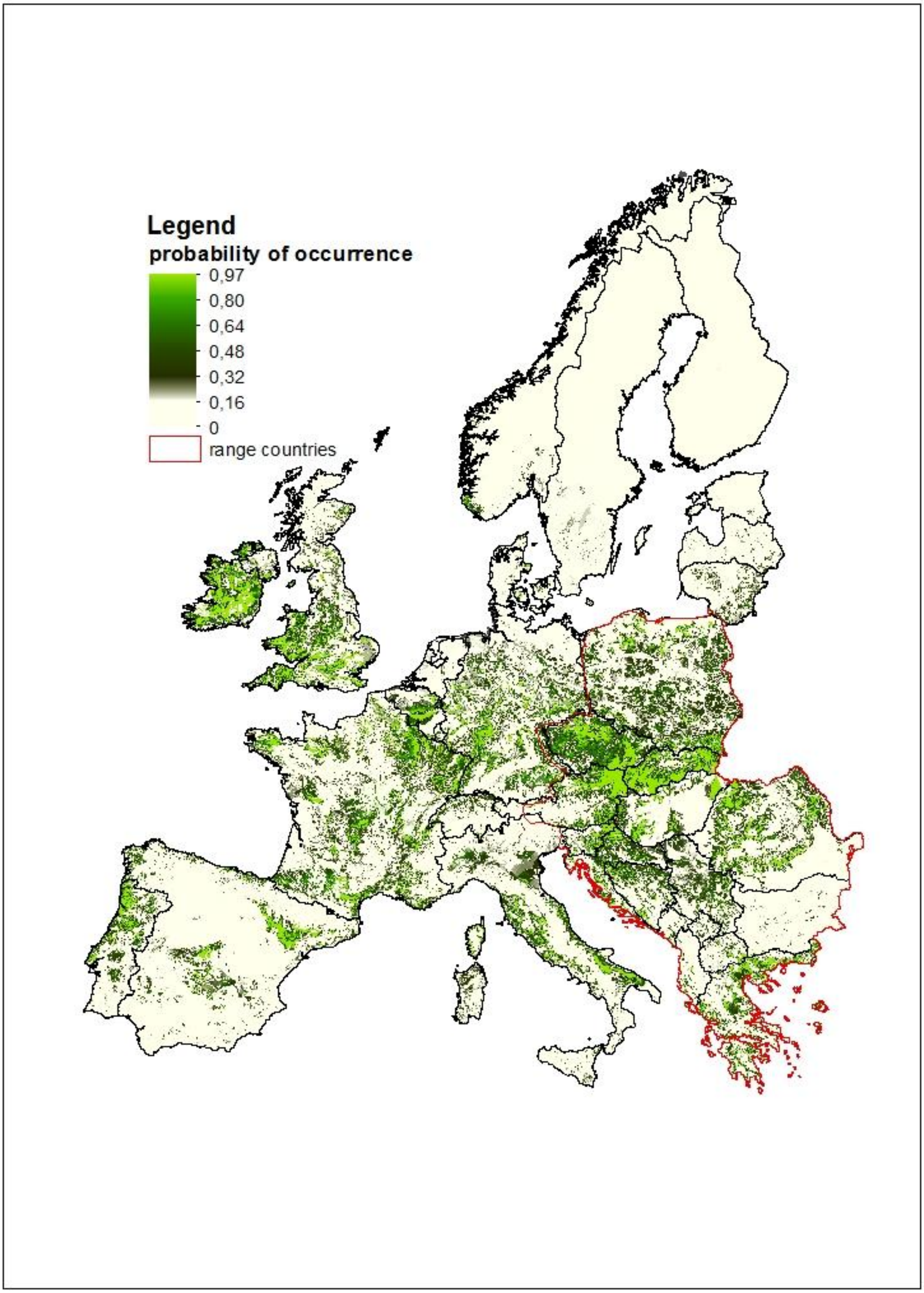

Figure 22. Potential distribution of EGS concerning Maxent in whole Europe (Maxent 3.3.3e)

6.2.2. Maxent potential distribution combined with Natura 2000 areas

Core area

An area within the current distribution range with a very high suitability of environmental conditions and a high probability of occurrence, a so called "core area" of EGS distribution is situated within the four countries Hungary, Slovakia, the Czech Republic and Austria.
In Figure 23 the area is zoomed in and the distribution core area (light green) can clearly be seen. This is the largest connected area in whole Europe with very suitable environmental conditions and a very high probability of EGS occurrence. To evaluate the conservation status of this important area of EGS distribution, already existing protected areas, Natura 2000 areas, where included in the map of probable occurrence. In Slovakia, Czech Republic and Hungary a lot of areas are already protected by Natura 2000 areas (Figure 23). In contrast there is no ArcGIS information on Natura 2000 areas available for Austria in that map layer of Natura 2000 areas. From another source information about Natura 2000 areas around Vienna was found (Appendix I for Metadata) and included in the Figure below but that is why we included an extra map of Austria with all Natura 2000 areas (Figure 24).

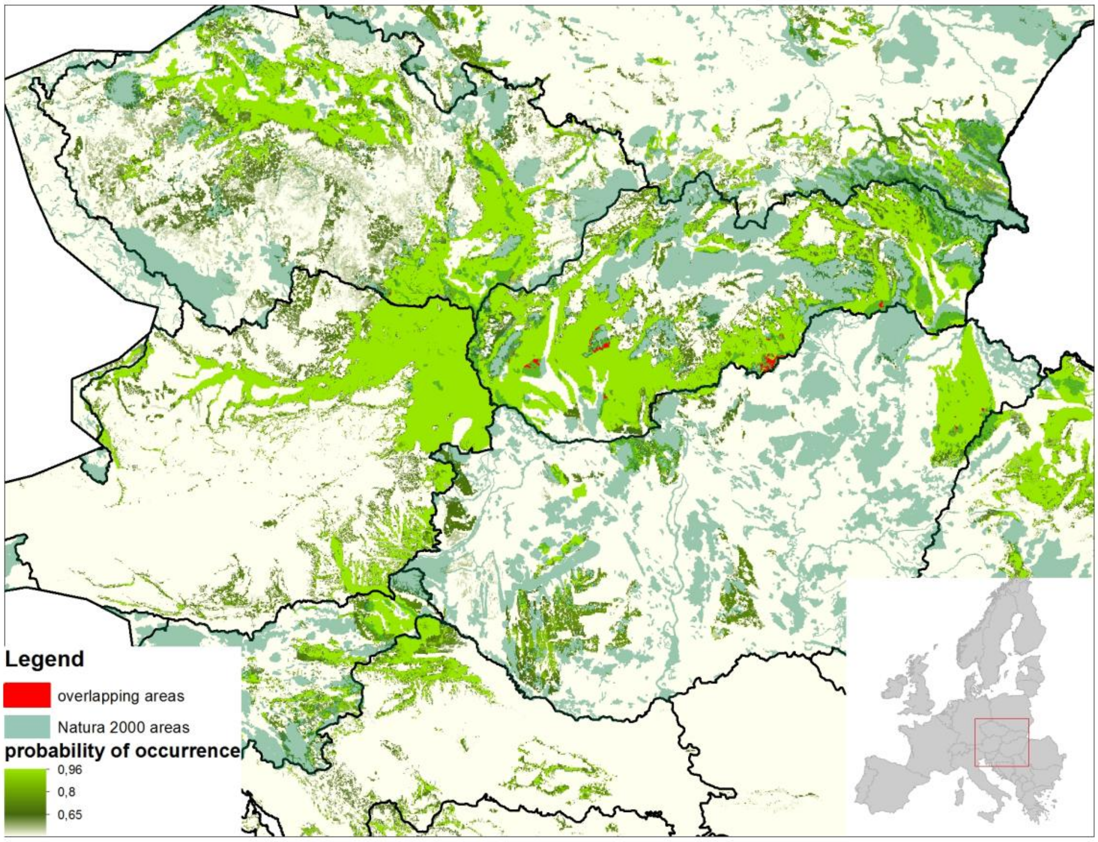

Figure 23. "Core area" of current and potential EGS distribution (Austria, Hungary, Slovakia and Czech Republic) overlayed by Natura 2000 areas.

Slovakia

The area of Slovakia got predicted to be one of the countries of EGS core habitat. Throughout the whole country, EGS may possibly occur, with highest probabilities (0.75) in the areas around Senica close to the Austrian border, south of Nitra along the Hungarian border and south of the Slovak Ore Mountains with exception for the Slovak Karst national park, as well as east of the Slovak Ore Mountains close to Kosice northwards with exception for areas with high elevations (north of Levoca and Sabinov).
In the Danube lowlands (south-western Slovakia) as well as in the area of the Tatra Mountains and in the Slovak Ore Mountains, species presence is predicted with only 0.31-0.54.
The average probability of occurrence of whole Slovakia is 0.25. Slovakias country´s territory is 49198 square kilometres. The Nature 2000 areas compose 37 % of this size with an area of 18019 square kilometres. The probability of occurrence of EGS in the Natura 2000 areas range from 0 to 0.75 with an average probability of 0.2. Natura 2000 areas in Slovakia are located in the Tatra Mountains, the Slovak Ore Mountains and the Danube lowlands and thus outside areas of high probability of occurrence of EGS.

Austria

In Austria the probability of occurrence of EGS ranges from 0 to 0.72 with an average probability of 0.14. A huge percentage of the core area with very suitable environmental conditions for EGS and a probability of occurrence of around 0.65 lays within the eastern High and Lowland of Lower Austria in Burgenland and Wien (Vienna) (Figure 23). Another area with a high probability of occurrence of EGS is in the north of Upper Austria along the border to Germany (average of 0.5). In the north eastern part of Lower Austria the probability of occurrence of EGS is lower (average of 0.25). A low probability is also found in south Carinthia (Kärnten) around Klagenfurt and near the border to Slovenia. There is almost no probability of occurrence in the rest of the federal states. This agrees with the actual distribution of EGS in Austria. Natura 2000 areas in Austria are concentrated in the Highlands of the central part and in the federal states Wien and Burgenland. Comparing Figure 24 with Figure 23, you can see that also in Austria there is almost no overlap between the protected areas and the potential distribution area of EGS. It seems, thst EGS inhabit areas which lay exactly around the protected areas. The reason is that protected areas in Austria are mainly forested areas (see Appendix VI), a habitat, that is not suitable for EGS.

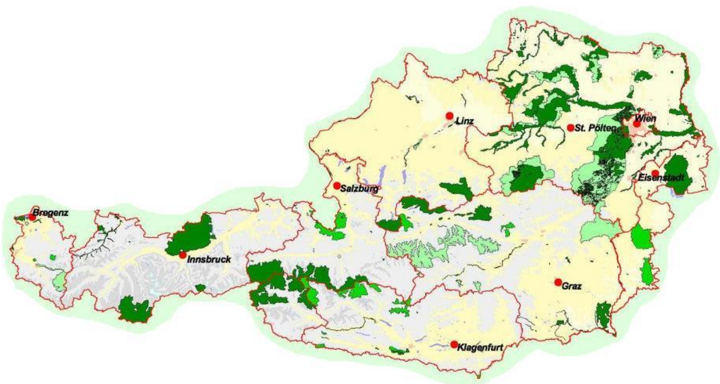

Figure 24. Natura 2000 areas in Austria, dark green: areas concerning habitat directive and bird directive; middle green: habitat directive; light green: bird directive, source: WKO 2012)

Hungary

In Hungary, the probability of occurrence of EGS ranges from 0 to 0.74 with an average probability of 0.06. The biggest part of the core area in Hungary with a probability of occurrence of 0.65 on average, lies in the north east of the country in the county of Szabolcs-Szatmár-Bereg. In north Pest and north Komárom-Esztergom along the Slovakian border there is an area with a probability of 0.4 on average. Throughout the rest of the country the probability of EGS occurrence is very low. Appreciable is the county Somogy in the south west with an average probability of 0.3 and an area in Bács-Kiskun with an average probability of 0.23. Country´s territory of Hungary is 93128 square kilometres. The Nature 2000 areas compose 28 % of this size with an area of 26627 square kilometres. The probability of occurrence of EGS in Natura 2000 areas range from 0 to 0.72 with an average probability of 0.08. There are hardly any Natura 2000 areas in Hungary which overlap with the actual and potential distribution of EGS. An exception is found in the north east in the county of Szabolcs-Szatmár-Bereg where several Natura 2000 area lay within the potential distribution area of EGS. Also in north Pest some part of Natura 2000 areas overlap with distribution areas.

Czech Republic

In Czech Republic, the probability of occurrence of EGS ranges from 0 to 0.71 with an average probability of 0.16.
Areas with a high probability of an average of 0.65 can be found in the south, south east and south west of Jihomoravský close to the boarder of Austria and in central and north-eastern part of Stredoceský close to Prague and within Prague. In a circle around this area, the probability of occurrence get smaller and smaller. In the rest of the country the probability of occurrence of EGS is smaller than 0.2 down to 0.
The Czech Republics surface is 77871 square kilometres. The Nature 2000 areas compose 18% of this size with an area of 14475 square kilometres.
Cell values, thus the probability of occurrence of EGS in the Natura 2000 areas range from 0 to 0.71 with an average probability of 0.17. From this result you can see, that also in the Czech Republic not many Natura 2000 areas overlap with the high probability of occurrence areas for EGS. There are only some Natura 2000 areas which lay in an area of high probability in Jihomoravský close to the border to Austria.
From Figure 23 it is obvious that most of the best sites of the current and potential occurrence of EGS are outside protected areas. Only 0.14% of the protected areas in the range countries and 0.65% of the protected areas in the core area overlap with an area of high probability of EGS occurrence. The EGS range countries cover an area of 1,375,732.3 km^2 but only 0.77% contain suitable habitat with high probabilities of occurrence (>0.65) for EGS. A little bit better situated is the core area with 3.43% suitable sites.
Table 35 summarizes the important numbers concerning the range countries and the core area.

Table 35. Summary of important numbers concerning area sizes in range countries and core area.

	Range countries	**Core area**
Area size	1,375,732.3 km^2	294,336.88 km^2
protected areas size	304,967.2 km^2	70,257.43 km^2
Areas of high suitability (>0.65) for EGS	10561.82 km^2 **0,77%** of the total	10117.39 km^2 **3,43%** of the total
protected areas overlapping EGS high probability areas	450.73 km^2, **0.14%** of total area	450.73 km^2, **0.65%** of total area

Remaining countries

In Figure 25 the potential distribution of EGS in central and south-eastern Europe, its current distribution range, is displayed. We already discussed the core area. In this part we zoom in into the other countries which are also inhabited by EGS and in which there is also a certain probability of occurrence of EGS.

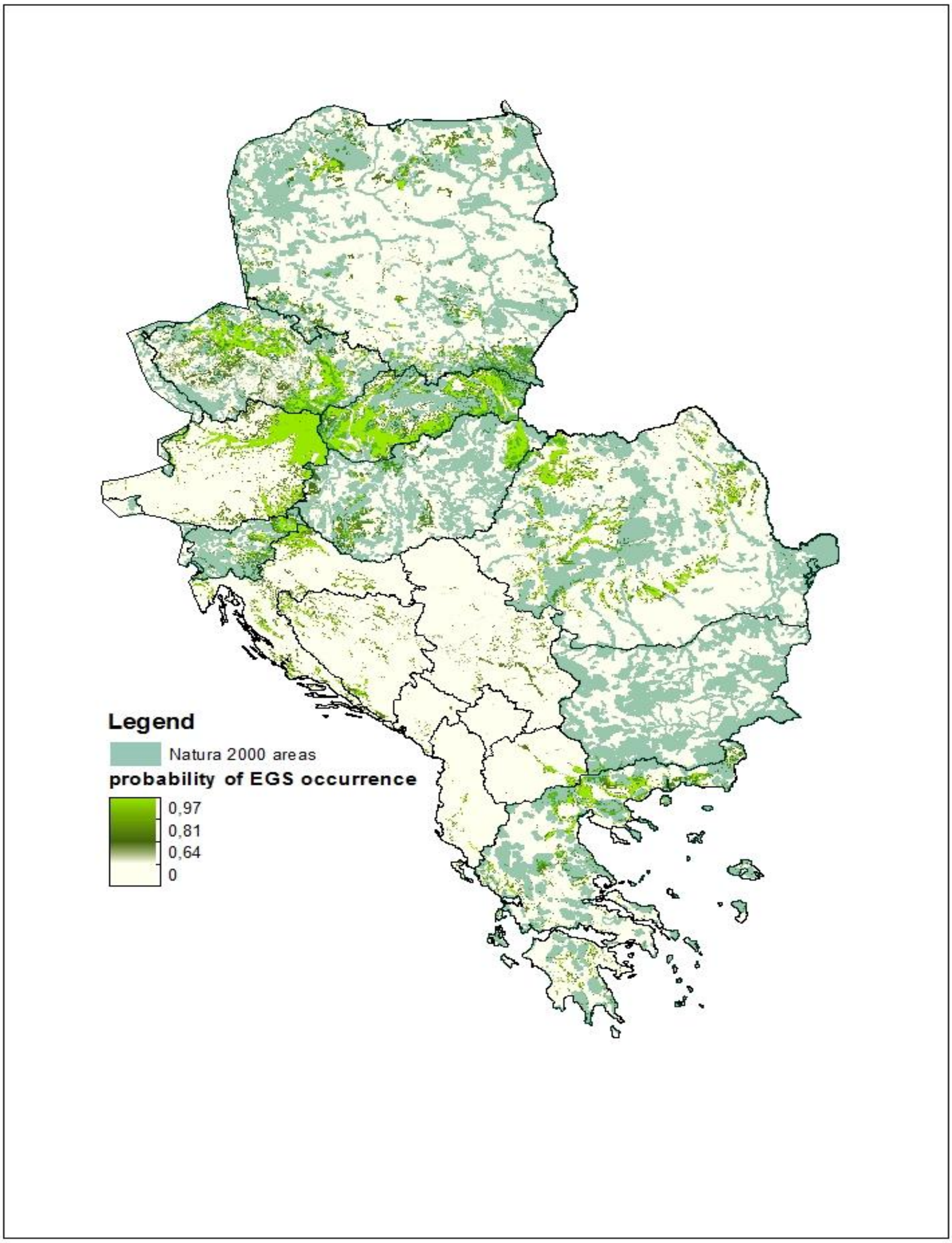

Figure 25. Potential distribution of EGS concerning Maxent in the range countries

Romania

Romania is not part of the “core area” but there are also highly suitable areas found, especially in the north of the country close to the border of Hungary, in Satu Mare and Salaj. In Satu Mare there are also two Natura 2000 areas overlapping with the probable distribution area of EGS: the Raul Tur Nature reserve and Campia Careiului. Areas of moderate probability around 0.45 are found in central Arges, central Dambovita, central Prahova and Western Buzau. Scattered areas of moderate probability of occurrence can also be found north east of the country, in north east, east and south east Bacau, in northwest Vaslui and in south west Iasi, as well as in the western and central part of Romania.
Many Natura 2000 areas in Romania are restricted to mountainous areas of the Carpathians Mountains.

Greece

Areas with high probability of EGS occurrence can be found in the northern part of the country, in central Macedonia. Scattered area with a moderate probability of occurrence (0.45) are in East Macedonia and Thrace. In the rest of the country there are also very small and scattered areas of low (0.25) to moderate probability of EGS occurrence. In Greece there are some Natura 2000 areas which overlap with probable occurrence areas of EGS, for example in central Macedonia Oros Paiko, Limni Kerkini-Krousia-Koryfes orous Beles, Angistro-Charopo and Limnes Volvikai Lagkada- Evryteri Periochi. In central Greece there is some overlap with Natura 2000, for example in Antichasia Ori-Meteora.

In remaining countries of the current EGS range there are some scattered areas as well with highly suitable habitat with a more or less high probability of occurrence like in north east Slovenia, north Croatia and south east Macedonia. But in countries like Bosnia Herzegovina, Serbia, Montenegro, Kosovo, Albania or Bulgaria the probability of occurrence is rather low and areas with suitable habitat are really small and very scattered.

6.2.3. EGS network

By overlaying the Maxent layer of high potential distribution areas with Natura 2000 areas, road network and river network (for Metadata see Appendix I) we executed a gap analysis approach. Nowadays there are tools to measure the degree to which conservation networks are complete and purposeful. We tried to identify gaps through an assessment of representation by overlaying all features which have influence on EGS distribution. As it is diplayed in Figure 26, within the EGS core area there are a lot of potential distribution areas which are not connected to each other because of geographic barriers like roads or rivers. Also for EGS insurmountable habitats like forest areas or cities have to be taken into account. High elevations which are insurmountable for EGS do not occur in the core area because there are hardly any mountains higher than 1000m. Furthermore EGS occur in heights up to 2500m. Creating possibilities for EGS to be able to pass over or through certain areas and creating an international cross border network to connect all highly suitable areas for EGS occurrence would be a necessary to ensure species maintenance on the long term. In the following Figure you can see a possible option for the core area; creating a network of protected areas to connect the areas of high suitability. Cross boarder coordination would be necessary and building of viaducts, overpasses or corridors with suitable habitat through areas with unsuitable habitat.

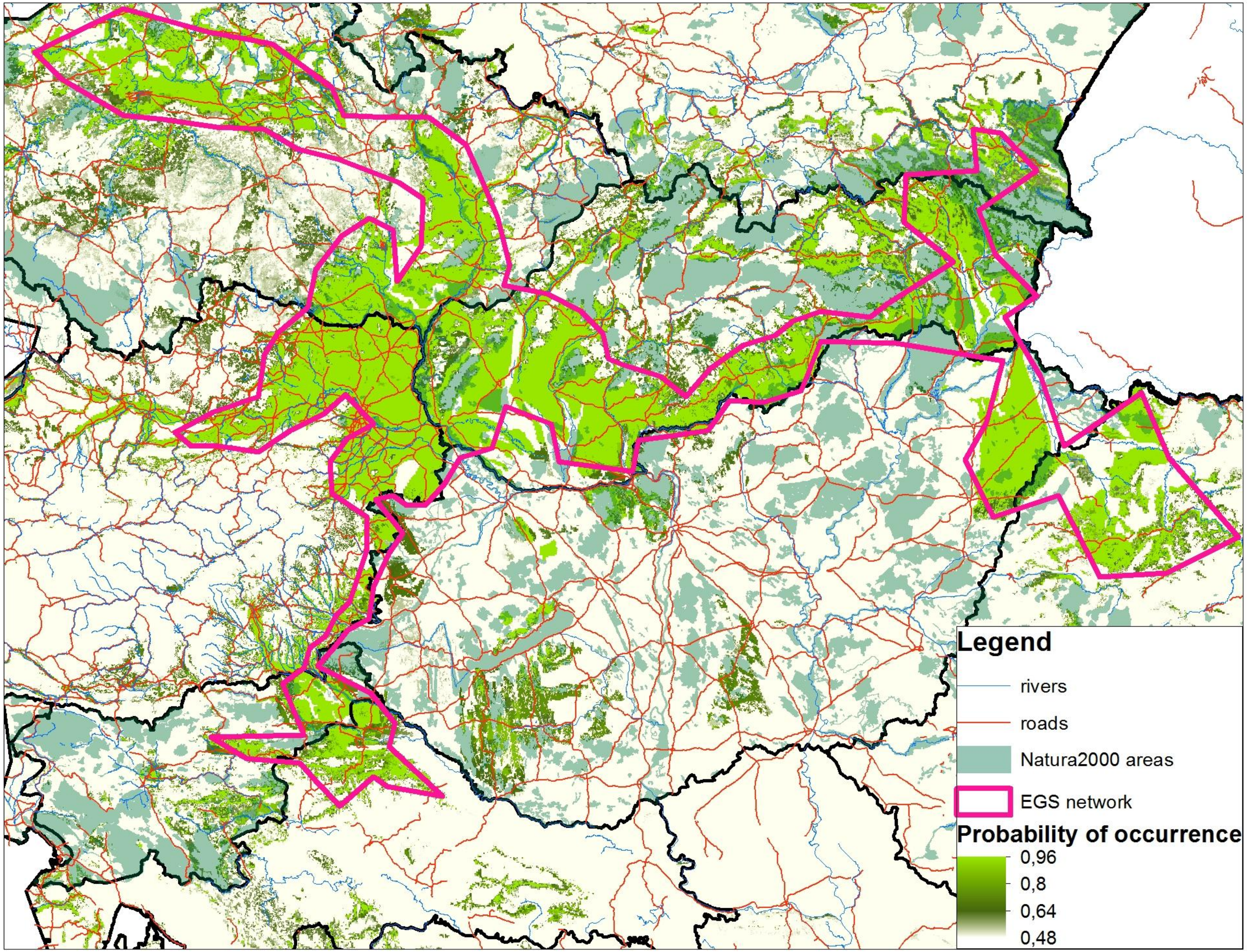

Figure 26. EGS network: Possible solution for EGS protection in core area.

6.2.4. Maxent potential distribution combined with reintroduction areas

In Poland EGS are officially extinct but in Figure 27 is obvious that there are still areas which could be suitable for EGS in the north and in the south close to the boarder to Slovakia and the Czech Republic. Since the year 2000, reintroduction programmes take place in south west Poland. In Figure 27, all reintroduction sites known from literature are shown from Poland as well as from Slovakia and the Czech Republic. Mostly, reintroduction sites are located in areas where EGS historically occurred but where the species got extinct for various reasons. According to the map, places for EGS reintroduction in Poland are chosen beyond highly suitable habitat (Jakubowo Lubinskie: 0.04; Glebowice: 0.05; Kamien Slaski: 0.045). Nevertheless, all reintroduction programmes succeeded because the first and most important step was taken to analyse why the EGS got extinct from a certain area and to find out if these threats still predominate (Kepel, 2008). After that, the area was made suitable for reintroduction.

In Slovakia, most of the reintroduction programs failed. The sites in Nizke Tatry and Muranska planina National park (NP) lay outside of the predicted suitable areas for EGS (probability of 0). Other locations lay within areas with a more or less high probability of occurrence and thus suitable habitat. (Protected Landscape area Ponitrie: 0.24; Small Carpathians: 0.12; Slovak Karst NP: 0.35) Nevertheless, most of this projects failed due to various reasons like inadequate management of the target localities, a too small amount of individuals was transferred, the site was not suitable for release, predation pressure by birds of prey, weasels and cats, a to a too large number of individuals transferred to the area which was not suitable to hold so many EGSs or an unbalanced sex ratio. Reintroductions that succeeded are in the Protected Landscape Area Small Carpathians and in one location in the Muranska planina NP.

Also in the Czech Republic reintroduction took place. In the area of Ceský Kras with a probability of occurrence of EGS is 0.18, in Bohemia with 0.09 and in Velka Bukova with 0.21. In the area of Ceský Kras reintroduction did not succeed, due to the small amount of animals released. The other projects also failed due to small, isolated populations in the release sites.

In Germany EGS are officially extinct but there is one area in the eastern Erzgebirge close to the border of the Czech Republic were a reintroduction project takes place. The place of reintroduction lies in an area of former EGS distribution and in an area of high probability of EGS occurrence.

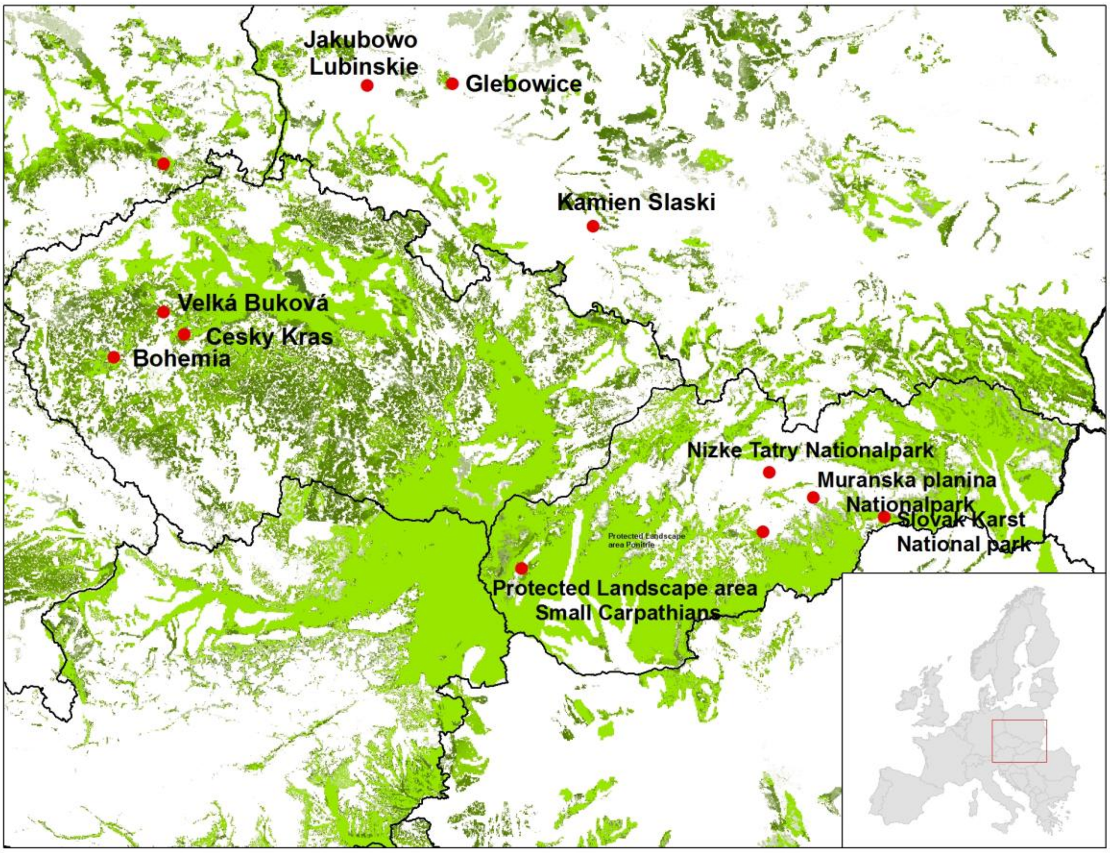

Figure 27. Probabailtiy of occurrence of EGS in reintroductions sites in Germany, Poland, Slovakia and Czech Republic.

7. Conclusions

EGS is a hibernating rodent and is associated in habitats with short vegetation layers. Because of that, most important life history issues are temperature, food availability and habitat (land use). For the facilitation of burrow digging, also soil, slope, elevation and water management are limiting factors to species occurrence.
Main threats to populations are shifting and loss of habitats.
EGS are considered to occur in several east European countries: Austria, Bulgaria, Czech Republic, Slovakia, Hungary, Romania, Serbia, Slovakia, Macedonia, Turkey, Greece, Croatia, and Montenegro. In Poland and Germany, populations became extinct. In some distribution countries as Turkey, Croatia, Serbia and Montenegro, EGS status has not been evaluated.
Maxent predicted high probability of species occurrence in the area of Austria, Czech Republic, Slovakia and Hungary. Scattered populations are also predicted in Romania, Croatia, Greece and Macedonia. High possibility of species presence got also predicted outside current distribution range in countries like Spain and Ireland.
Existing Natura 2000 areas are mainly located outside predicted EGS range, since most Natura 2000 areas got installed to protect forest areas. To protect EGS populations located in the “core area” of distribution, a gap analytic approach was executed. Gaps between high probability areas should become restored to create EGS habitat and the area should get implemented in the Natura2000 network.
Several reintroduction programs took place (and some are still ongoing) in Slovakia, Czech Republic, Germany and Poland. Most sites were chosen due to historical distribution of the species in the area, but lay beyond suitable areas with high probability of species occurrence.

8. Discussion

Maxent model performance and implementation

As Young *et al*. (2011) suggested we used 15 replicates to estimate variability of the model. By using test data additionally, model performance was tested and all data got included to avoid independent data (Young *et al*., 2011).
The average Area Under the Receiver Operating Characteristic (ROC) Curve or AUC was 0.934 with a standard deviation of 0.015 which represents a quality model performance, since 1 indicate better model performance (Swets 1988). Reason for that may be the small rasterization of 100x100m that cause a more accurate selection of locations in comparison with datasets that have larger cell sizes (Seo et al., 2009; Hernandez et al. 2006). Large extent and heterogeneity of environmental variables in the study area achieve high AUC values when species distribution is not that variable which may have been contributed to the achieved AUC (Elith et al. 2006). The selection of variegated environmental layers was originated by the importance of several life history issues (See life history part). Small land cover categories were chosen due to the fact that the corine layer was available in this raster size only. EGS ranges are considered to be small scaled (~20m2) which resulted in inaccuracies by defining EGS habitats, since for instance in Macedonia populations occur in small areas around vineyards, but due to the coarse rasterization of 100x100 our results showed species presence in vineyards and inland marshes.

For Maxent training data, 862 species records were used, although Maxent do not require a large number of species records for running accurate models (Elith, et al., 2006; Hernandez et al., 2006, Phillips et al., 2006). It is recommended to use >30 records, but based on habitat heterogeneity of records, occasionally only 5 locations are considered to be sufficient for accurate model performance (Wisz, et al.,2008, Hernandez et al., 2006, Pearson et al., 2007).

For most accurate model performance, the whole species range should get sampled and included in Maxent (Elith et al., 2011). In our model, we used species records collected by several researchers with different monitoring techniques as well as different scales of study areas (regional and national). Additionally, some range countries did not provide species records which influenced predictions of current and potential distribution areas (Thuiller et al. 2004).
The model was extrapolated for whole Europe which resulted in model outputs with areas of high probability of EGS occurrence that are located outside current species range (i.e. Spain and Great Britain). Due to natural barriers as high elevation and forest areas EGS are not able to get there (Appendix VI). A method to reduce these inaccuracies is to run the model only in countries of used presence points that result a Maxent background file with equal bias as the used species records (Young et al., 2011).
As a result of missing records at some locations of EGS distribution range, the model had problems with transferability from sampled locations to unsampled locations (i.e. in Bulgaria) (Peterson et al., 2007). This issue is considered to be weightier in species as EGS that have varying habitat requirements throughout its range, because also variable contributions may become misjudged (Baldwin, 2009).

In contrast, since Maxent is mapping fundamental niches only, it is liable to overfitting (Person et al., 2007). Result of overfitting are clusters of predicted distribution areas around used species records (Phillips & Dudík 2008). The relaxation component of regularization was used by default, so that an overfitting is not likely to occur but still cannot be excluded for the so called core area ((Phillips & Dudík 2008).

We executed the jackknife test to identify which variables individually contribute most to the model performance, although it is only recommended for models with small amounts of species records (<25) because with larger amounts, it may create overoptimistic representation of predictive power (Pearson et al., 2007).

The model predicted high probabilities of species occurrence in areas with water management by overhead sprinklers and trickle irrigation which can be a result of bias in sampling effort (Hernandez et al., 2006, Phillips et al., 2009). Some study areas of the species records used consist of golf courses and airports that may have influenced the model output. Spatial errors of location data may occur, because some species records were located outside considered suitable EGS habitat (i.e. habitat edges in forest areas or lakes). However, Maxent results are not likely to be highly influenced by these errors if spatial inaccuracies are <5km (Graham et al, 2008).
Relative contributions of variables are according to life history issues, since EGS occurrence is restricted by hibernation (temperature) and habitat (landuse) (life history part).
Response curve of temperature that offered most contribution to the Maxent model show that species occur in temperatures between 5 and 18°C. Representation of decreasing probability between 10 and 15 °C may be due to the lack of species records in these areas.
Model outputs predict a high probability of species occurrence at elevations between 0 and 500 meters above sea level. Probability is decreasing to almost 0 at elevations above 1500m a.s.l., but in Slovakia EGS became observed at elevations above 2500m (W. Arnold, pers.comm. IN: Millesi et al, 1999). This error may be originated in the omitting of including this observation.
The influence of land use to probability of species presence showed an insufficient selection of study areas since highest probabilities are found in Vineyards (≈0.8) and artificial surfaces (≈0.6). With a high probability of 0.48 in agricultural areas and a very low probability of less than 0.1 EGS are predicted in forest areas which is coincidental to the species´ ecology, since EGS occur in open landscapes only (Hulova, 2001).
Remaining environmental variables are consistent with EGS habitat requirements since in parent material, EGS prefer basalt (≈0.77), river terrace sand (≈0.68) and loess (≈0.7) and coarse to medium fine soil textures which facilitate burrow digging.
There is no research available concerning EGS presence and slope, so it has to be investigated if slopes >25% are a limiting factor to EGS distribution.
Furthermore, Maxent model should be rerun, when missing data of whole distribution data may be available.

Natura2000 areas

For evaluation of EGS legal protection, a Natura 2000 layer of the year 2010 was used to combine it with Maxent outputs.
The IUCN recommended countries to assign at least 10% of their land into protected areas (Dudley & Parish, 2006). Countries of the core area of EGS distribution have assigned >20% of country surface as Natura 2000 areas. Although EGS is categorized as a key species in the Habitat directive, there is very little overlap with the used Natura 2000 layer.
There are different elements to implement gap analysis in species conservation. Approaches include the estimation of present biodiversity within protected areas (Specht & Cleland, 1961) by using a Gap Analysis Program, the designation of priority areas for the extension of existing protected areas (Margules & Pressey, 2000) and the appointment of regionally inclusive and comprehensive protected areas (Groves et al., 2002).
Brooks *et al.* (2004) recommended to getto know which amount species recently are protected and at which locations new protected areas should be implemented. We focused on the core area, where probabilities of occurrence are highest in order to optimize the regional legal protection status of priority areas.

EGS network

Our overlay approach to find gaps in EGS legal protection was an assessment of representation by overlaying all features which have influence on EGS distribution and conservation. Looking on the map you are able to see where there are gaps in high suitable areas for EGS and their overlap with Natura 2000 areas but you have no tests which can inform you about the extent. For future work on EGS conservation it may be recommended to execute a tool based gap analysis (e.g. wwf landscape-based gap analysis tool, an extension for ArcGIS).

9. Recommendations

This is the last part of our process of analyzing literature, consulting experts and analyzing distribution data in ArcGIS and Maxent.

<u>International conservation measures</u>

Habitat restoration and network

EGS current distribution has been facilitated by the evolving of agriculture. Conditions similar to steppe habitats became suitable for EGS. Implementation of new technologies in agriculture caused a decreasing in suitable habitat and current EGS populations are isolated. Also shifting habitats (e.g. hazelnut plantations, reforestation etc.) cause decreasing EGS habitats. Because of that EGS shift more to other man made areas as golf courses and airports. Recent Natura 2000 areas are mainly implemented in forest areas and thereby offer no protection to populations. In the core area of EGS distribution, habitat restoration between high probability areas is necessary to create EGS habitat and to conserve the species on meta-population level. Because of that, for EGS conservation and maintenance it is crucial to install a cross- border coordination of a protected areas network that is managed by grazing and/ or mowing on a long term. A gap analysis should get accomplished, taking into account local data.
In agricultural areas, farmers should get subsidies for the implementation of EGS friendly agricultural techniques (as omitting pesticides, fertilizers and flooding, ensuring food availability, mowing/grazing).
Increasing urban development cause threats of habitat loss to EGS throughout its range. Installing of protected areas should take into account this development by e.g. implementation of EGS overpasses in areas where man made barriers (e.g. roads) avoid EGS to disperse.

- Gap analysis including local data
- Habitat restoration in gaps between areas of high probability (core area)
- Creating network of protected areas with suitable habitat management
- Subsidies for farmers for appropriate habitat management
- Overpasses for EGS

Conservation breeding and reintroduction

Several trials took place to reintroduce EGS in different countries of its range. Conservation breeding took place to facilitate species maintenance. Reintroduction sites should be selected after testing habitat suitability (e.g. distribution models, taking into account limiting factors) and protection status to increase prospects of success. Also the connection to other EGS populations should get ensured to prevent small, isolated populations

- Selecting reintroduction sites by using distribution models
- Avoid limiting factors by restoring habitats
- Ensure large genetic pool and connectivity to other populations at release sites

Public awareness

In some countries of EGS range, the species is considered as a pest that will prevent conservation measures to succeed (e.g. Macedonia). Because of that, in every country where EGS conservation measures will be implemented, local people should be informed and if possible, involved to raise awareness for the importance to conserve the species.

- Education and involving of local people

Research requirements

Knowledge on EGS ecology, survival strategies and population genetics (e.g. core populations in comparison with Greece populations) is still lacking.
Efforts should be taken by every range country to increase this knowledge which is crucial for EGS conservation.
Also, future distribution caused by climate change should be investigated and modelled to adapt suitable conservation measures which allow the species to disperse.

National recommendations

Legal protection

Generally, EGS is considered as endangered and its trend is decreasing. It is designated as a Natura 2000 key species. However, in several countries of its distribution, its status is unknown and it is not protected by national law. In order to install a network of protected areas, EGS status should get recorded and countries should include it in their national law. Following countries should include EGS in national Legislation:

- Bulgaria (not in Biodiversity act)
- Serbia
- Turkey
- Greece (not in Natura 2000 areas)
- Macedonia
- Montenegro
- Croatia
- Moldova

Estimating population status

In some areas within EGS distribution range, Maxent predicted high probability of occurrence although the occurrence is not yet verified. Countries should implement monitoring to estimate status of populations if presence is uncertain. Additionally, in several countries, EGS status is uncertain. Population's status should be evaluated in:

- Bulgaria
- Turkey
- Montenegro
- Croatia
- Bosnia Herzegovina

Natura2000 areas

In the areas of high probability of EGS occurrence, Natura2000 areas should get implemented to protect habitat and key species. On a long term, a network should get installed to ensure the maintenance of metapopulations on a long term. Following countries should improve their Natura 2000 network:

- Slovakia
- Austria
- Hungary
- Czech Republic
- Romania
- Greece

EGS network

Creating a network of (protected) areas of high suitability for EGS would be a necessary to ensure species maintenance on the long term. It requires crossborder coordination and an intensive cooperation of each country within the core area. Every country has to take a look at the situation in the gap areas and to decide whether it is feasible to arrange conservation measures. The next step is to decide which measure to take to make the area inhabitable or at least crossable for EGS by using viaducts, overpasses or habitat transformation and/ or management.

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Appendix I: Metadata of the environmental layers

Layer	Eco-geographical parameters	Data format	Resolution	Coordinate system	Period	Source
Mean annual temperature 1950-2000	Annual mean temperature	raster	1x1km	D_WGS_ 84	1950-2000	BioClim (Hijmans *et al*. 2005)
Corine Land cover 2000/2006	Corine land cover	raster	100x100m	D_ETRS_1989	2000 & 2006	European Environment Agency
The European Soil Database distribution version 2.0	Wm2: Code for the type of an existing water management system	raster	1x1km	ETRS89 Lambert Azimuthal Equal Area	2004	(ESDB v2.0 2004)
The European Soil Database distribution version 2.0	Aglim1:Code of the most important limitation to agricultural use of the STU	raster	1x1km	ETRS89 Lambert Azimuthal Equal Area	2004	(ESDB v2.0 2004)
The European Soil Database distribution	Slopese: Secondary slope	raster	1x1km	ETRS89 Lambert Azimuthal Equal	2004	(ESDB v2.0 2004)

version 2.0	class of the STU			Area		
The European Soil Database distribution version 2.0	Parmado: Code for dominant parent material of the STU	raster	1x1km	ETRS89 Lambert Azimuthal Equal Area	2004	(ESDB v2.0 2004)
The European Soil Database distribution version 2.0	text-srf-dom: Dominant surface textural class of the STU	raster	1x1km	ETRS89 Lambert Azimuthal Equal Area	2004	(ESDB v2.0 2004)
Elevation	Elevation	raster	1100x1100m	Projected Coordinate System: WGS_1972_Albers		
Natural Resources	Natura 2000 areas with designated species, habitat types, status	Vector, polygon		Projected Coordinate System: ETRS_1989_LAEA	2010	
Natura 2000 areas in Vienna, Austria	Natura 2000 areas in Vienna, Austria	Vector, polygon		D_WGS_ 84	2010	(Geoland 2012)
Roads	Primary roads	Vector, line		D_WGS_ 84	2012	(mapcruzin 2012)
waterways	Main waterways	Vector, line		D_WGS_ 84	2012	(mapcruzin 2012)

Appendix II: Colour code of the corine Land use layer

ID	Colour	LABEL1	LABEL2	LABEL3
1		Artificial surfaces	Urban fabric	Continuous urban fabric
2		Artificial surfaces	Urban fabric	Discontinuous urban fabric
3		Artificial surfaces	Industrial, commercial and transport units	Industrial or commercial units
4		Artificial surfaces	Industrial, commercial and transport units	Road and rail networks and associated land
5		Artificial surfaces	Industrial, commercial and transport units	Port areas
6		Artificial surfaces	Industrial, commercial and transport units	Airports
7		Artificial surfaces	Mine, dump and construction sites	Mineral extraction sites
8		Artificial surfaces	Mine, dump and construction sites	Dump sites
9		Artificial surfaces	Mine, dump and construction sites	Construction sites
10		Artificial surfaces	Artificial, non-agricultural vegetated areas	Green urban areas
11		Artificial surfaces	Artificial, non-agricultural vegetated areas	Sport and leisure facilities
12		Agricultural areas	Arable land	Non-irrigated arable land
13		Agricultural areas	Arable land	Permanently irrigated land
14		Agricultural areas	Arable land	Rice fields
15		Agricultural areas	Permanent crops	Vineyards
16		Agricultural areas	Permanent crops	Fruit trees and berry plantations
17		Agricultural areas	Permanent crops	Olive groves
18		Agricultural areas	Pastures	Pastures
19		Agricultural areas	Heterogeneous agricultural areas	Annual crops associated with permanent crops
20		Agricultural areas	Heterogeneous agricultural areas	Complex cultivation patterns
21		Agricultural areas	Heterogeneous agricultural areas	Land principally occupied by agriculture, with significant areas of natural vegetation
22		Agricultural areas	Heterogeneous agricultural areas	Agro-forestry areas
23		Forest and semi natural areas	Forests	Broad-leaved forest

24		Forest and semi natural areas	Forests	Coniferous forest
25		Forest and semi natural areas	Forests	Mixed forest
26		Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Natural grasslands
27		Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Moors and heath land
28		Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Sclerophillous vegetation
28		Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Transitional woodland-shrub
30		Forest and semi natural areas	Open spaces with little or no vegetation	Beaches, dunes, sands
31		Forest and semi natural areas	Open spaces with little or no vegetation	Bare rocks
32		Forest and semi natural areas	Open spaces with little or no vegetation	Sparsely vegetated areas
33		Forest and semi natural areas	Open spaces with little or no vegetation	Burnt areas
34		Forest and semi natural areas	Open spaces with little or no vegetation	Glaciers and perpetual snow
35		Wetlands	Inland wetlands	Inland marshes
36		Wetlands	Inland wetlands	Peat bogs
37		Wetlands	Maritime wetlands	Salt marshes
38		Wetlands	Maritime wetlands	Salines
39		Wetlands	Maritime wetlands	Intertidal flats
40		Water bodies	Inland waters	Water courses
41		Water bodies	Inland waters	Water bodies
42		Water bodies	Marine waters	Coastal lagoons
43		Water bodies	Marine waters	Estuaries
44		Water bodies	Marine waters	Sea and ocean

Appendix III: Legend of the soil layers

PAR-MAT-DOM: Code for dominant parent material

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0 No information
1000 consolidated-clastic-sedimentary rocks
1100 psephite or rudite
1110 conglomerate
1111 pudding stone
1120 breccia
1200 psammite or arenite
1210 sandstone
1211 calcareous sandstone
1212 ferruginous sandstone
1213 clayey sandstone
1214 quartzitiic sandstone/orthoquartzite
1215 micaceous sandstone
1220 arkose
1230 graywacke
1231 feldspathic graywacke
1300 pelite, lutite or argilite
1310 claystone/mudstone
1311 kaolinite
1312 bentonite
1320 siltstone
1400 facies bound rock
1410 flysch
1411 sandy flisch
1412 clayey and silty flysch
1413 conglomeratic flysch
1420 molasse
2000 sedimentary rocks (chemically precipitated, evaporated, or organogenic or biogenic in origin)
2100 calcareous rocks
2110 limestone
2111 hard limestone
2112 soft limestone
2113 marly limestone
2114 chalky limestone
2115 detrital limestone
2116 carbonaceous limestone
2117 lacustrine or freshwater limestone
2118 travertine/calcareous sinter
2119 cavernous limestone
2120 dolomite
2121 cavernous dolomite
2122 calcareous dolomite
2130 marlstone
2140 marl
2141 chalk marl
2142 gypsiferous marl
2150 chalk
2200 evaporites
2210 gypsum

2220 anhydrite
2230 halite
2300 siliceous rocks
2310 chert, hornstone, flint
2320 diatomite/radiolarite
3000 igneous rocks
3100 acid to intermediate plutonic rocks
3110 granite
3120 granodiorite
3130 diorite
3131 quartz diorite
3132 gabbro diorite
3140 syenite
3200 basic plutonic rocks
3210 gabbro
3300 ultrabasic plutonic rocks
3310 peridotite
3320 pyroxenite
3400 acid to intermediate volcanic rocks
3410 rhyolite
3411 obsidian
3412 quartz porphyrite
3420 dacite
3430 andesite
3431 porphyrite (interm,)
3440 phonolite
3441 tephritic phonolite
3450 trachyte
3500 basic to ultrabasic volcanic rocks
3510 basalt
3520 diabase
3530 pikrite
3600 dike rocks
3610 aplite
3620 pegmatite
3630 lamprophyre
3700 pyroclastic rocks (tephra)
3710 tuff/tuffstone
3711 agglomeratic tuff
3712 block tuff
3713 lapilli tuff
3720 tuffite
3721 sandy tuffite
3722 silty tuffite
3723 clayey tuffite
3730 volcanic scoria/volcanic breccia
3740 volcanic ash
3750 ignimbrite
3760 pumice
4000 metamorphic rocks
4100 weakly metamorphic rocks
4110 (meta-)shale/argilite
4120 slate
4121 graphitic slate
4200 acid regional metamorphic rocks
4210 (meta-)quartzite

4211 quartzite schist
4220 phyllite
4230 micaschist
4240 gneiss
4250 granulite (sensu stricto)
4260 migmatite
4300 basic regional metamorphic rocks
4310 greenschist
4311 prasinite
4312 chlorite
4313 talc schist
4320 amphibolite
4330 eclogite
4400 ultrabasic regional metamorphic rocks
4410 serpentinite
4411 greenstone
4500 calcareous regional metamorphic rocks
4510 marble
4520 calcschist, skam
4600 rocks formed by contact metamorphism
4610 contact slate
4611 nodular slate
4620 hornfels
4630 calsilicate rocks
4700 tectogenetic metamorphism rocks or cataclasmic metamorphism
4710 tectonic breccia
4720 cataclasite
4730 mylonite
5000 unconsolidated deposits (alluvium, weathering residuum and slope deposits)
5100 marine and estuarine sands
5110 pre-quaternary sand
5111 tertiary sand
5120 quaternary sand
5121 holocene coastal sand with shells
5122 delta sand
5200 marine and estuarine clays and silts
5210 pre-quaternary clay and silt
5211 tertiary clay
5212 tertiary silt
5220 quaternary clay and silt
5221 holocene clay
5222 holocene silt
5300 fluvial sands and gravels
5310 river terrace sand or gravel
5311 river terrace sand
5312 river terrace gravel
5320 floodplain sand or gravel
5321 floodplain sand
5322 floodplain gravel
5400 fluvial clays, silts and loams
5410 river clay and silt
5411 terrace clay and silt
5412 floodplain clay and silt
5420 river loam

5421 terrace loam
5430 overbank deposit
5431 floodplain clay and silt
5432 floodplain loam
5500 lake deposits
5510 lake sand and delta sand
5520 lake marl, bog lime
5530 lake silt
5600 residual and redeposited loams from silicate rocks
5610 residual loam
5611 stony loam
5612 clayey loam
5620 redeposited loam
5621 running-ground
5700 residual and redeposited clays from calcareous rocks
5710 residual clay
5711 clay with flints
5712 ferruginous residual clay
5713 calcareous clay
5714 non-calcareous clay
5715 marly clay
5720 redeposited clay
5721 stony clay
5800 slope deposits
5810 slope-wash alluvium
5820 colluvial deposit
5830 talus scree
5831 stratified slope deposits
6000 unconsolidated glacial deposits/glacial drift
6100 morainic deposits
6110 glacial till
6111 boulder clay
6120 glacial debris
6200 glaciofluvial deposits
6210 outwash sand, glacial sand
6220 outwash gravels glacial gravels
6300 glaciolacustrine deposits
6310 varves
7000 eolian deposits
7100 loess (accumulation of wind-blown silt, typically in the 20–50 micrometre size range, twenty percent or less clay and the balance equal parts sand and silt)
7110 loamy loess
7120 sandy loess
7200 eolian sands
7210 dune sand
7220 cover sand
8000 organic materials
8100 peat (mires)
8110 rainwater fed moor peat (raised bog)
8111 folic peat
8112 fibric peat
8113 terric peat
8120 groundwater fed bog peat
8200 slime and ooze deposits
8210 gyttja, sapropel

8300 carbonaceaous rocks (caustobiolite)
8310 lignite (brown coal)
8320 hard coal
8330 anthracite
9000 anthropogenic deposits
9100 redeposited natural materials
9110 sand and gravel fill
9120 loamy fill
9200 dump deposits
9210 rubble/rubbish
9220 industrial ashes and slag
9230 industrial sludge
9240 industrial waste
9300 anthropogenic organic materials

SLOPE-SEC: Secondary Slope class of the STU

----

0 No information
1 Level (dominant slope ranging from 0 to 8 %)
2 Sloping (dominant slope ranging from 8 to 15 %)
3 Moderately steep (dominant slope ranging from 15 to 25 %)
4 Steep (dominant slope over 25 %)

AGLIM1: Code of the most important limitation to agricultural use

----

0 No information
1 No limitation to agricultural use
2 Gravelly (over 35% gravel diameter < 7.5 cm)
3 Stony (presence of stones diameter > 7.5 cm, impracticable mechanisation)
4 Lithic (coherent and hard rock within 50 cm)
5 Concretionary (over 35% concretions diameter < 7.5 cm near the surface)
6 Petrocalcic (cemented or indurated calcic horizon within 100 cm)
7 Saline (electric conductivity > 4 mS.cm-1 within 100 cm)
8 Sodic (Na/T > 6% within 100 cm)
9 Glaciers and snow-caps
10 Soils disturbed by man (i.e. landfills, paved surfaces, mine spoils)
11 Fragipans
12 Excessively drained
13 Almost always flooded
14 Eroded phase, erosion
15 Phreatic phase (shallow water Table)
16 Duripan (silica and iron cemented subsoil horizon)
17 Petroferric horizon
18 Permafrost

TEXT-SRF-DOM: Dominant surface textural class

\----------------

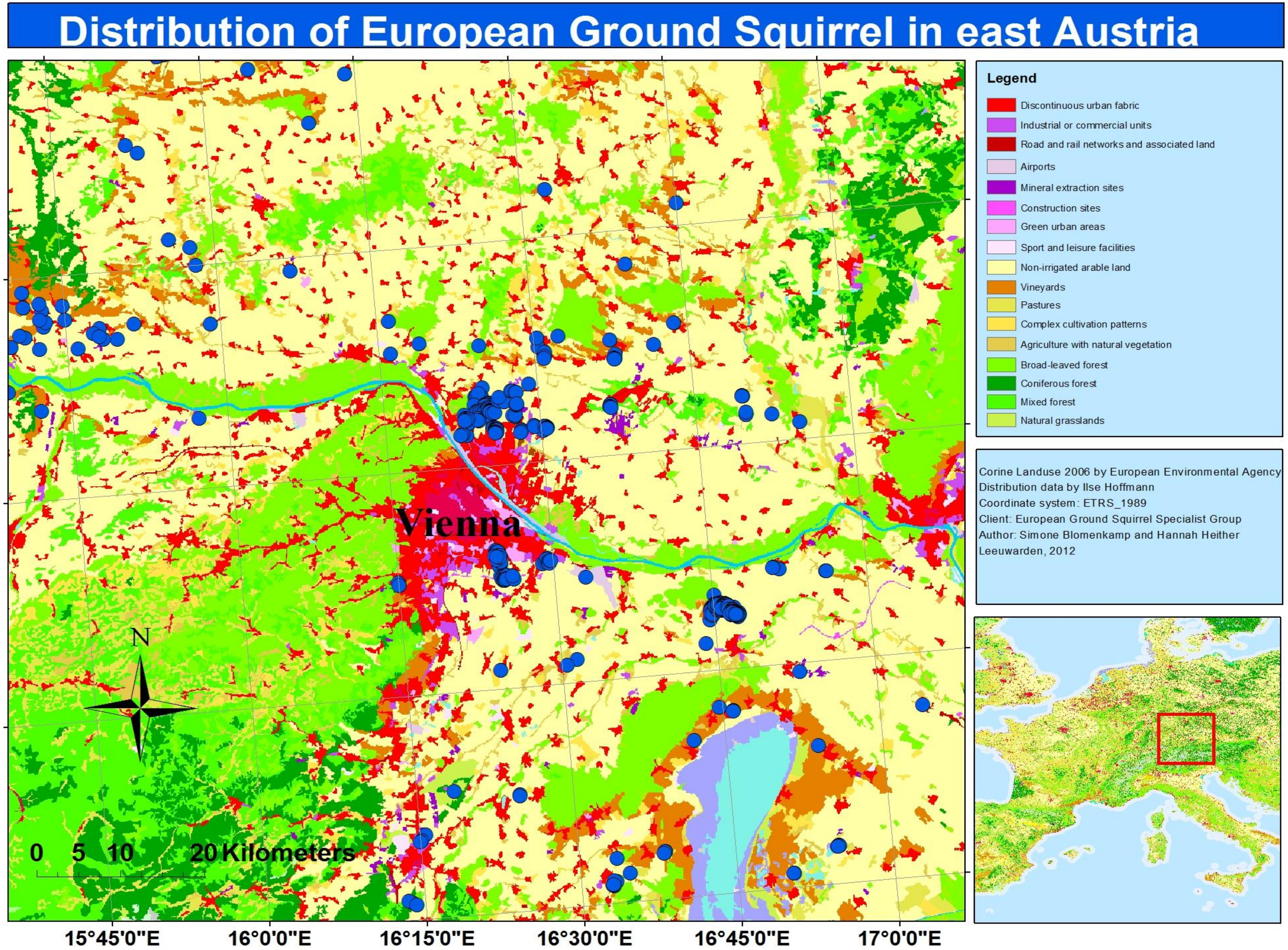
0 No information
9 No mineral texture (Peat soils)
1 Coarse (18% < clay and > 65% sand)
2 Medium (18% < clay < 35% and >= 15% sand, or 18% < clay and 15% < sand < 65%)
3 Medium fine (< 35% clay and < 15% sand)
4 Fine (35% < clay < 60%)
5 Very fine (clay > 60 %)

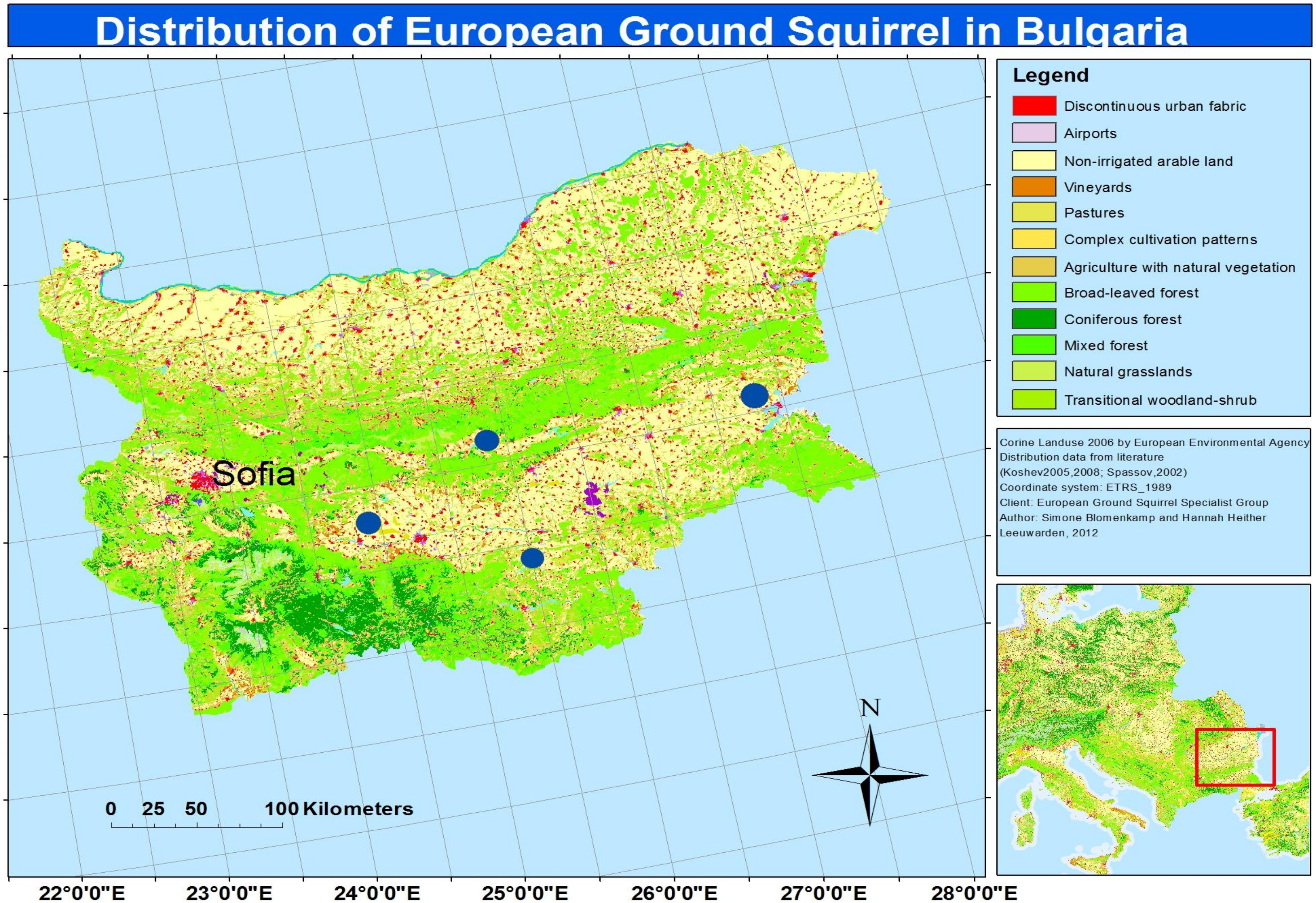
WM2: Code for the type of an existing water management system

\----------------

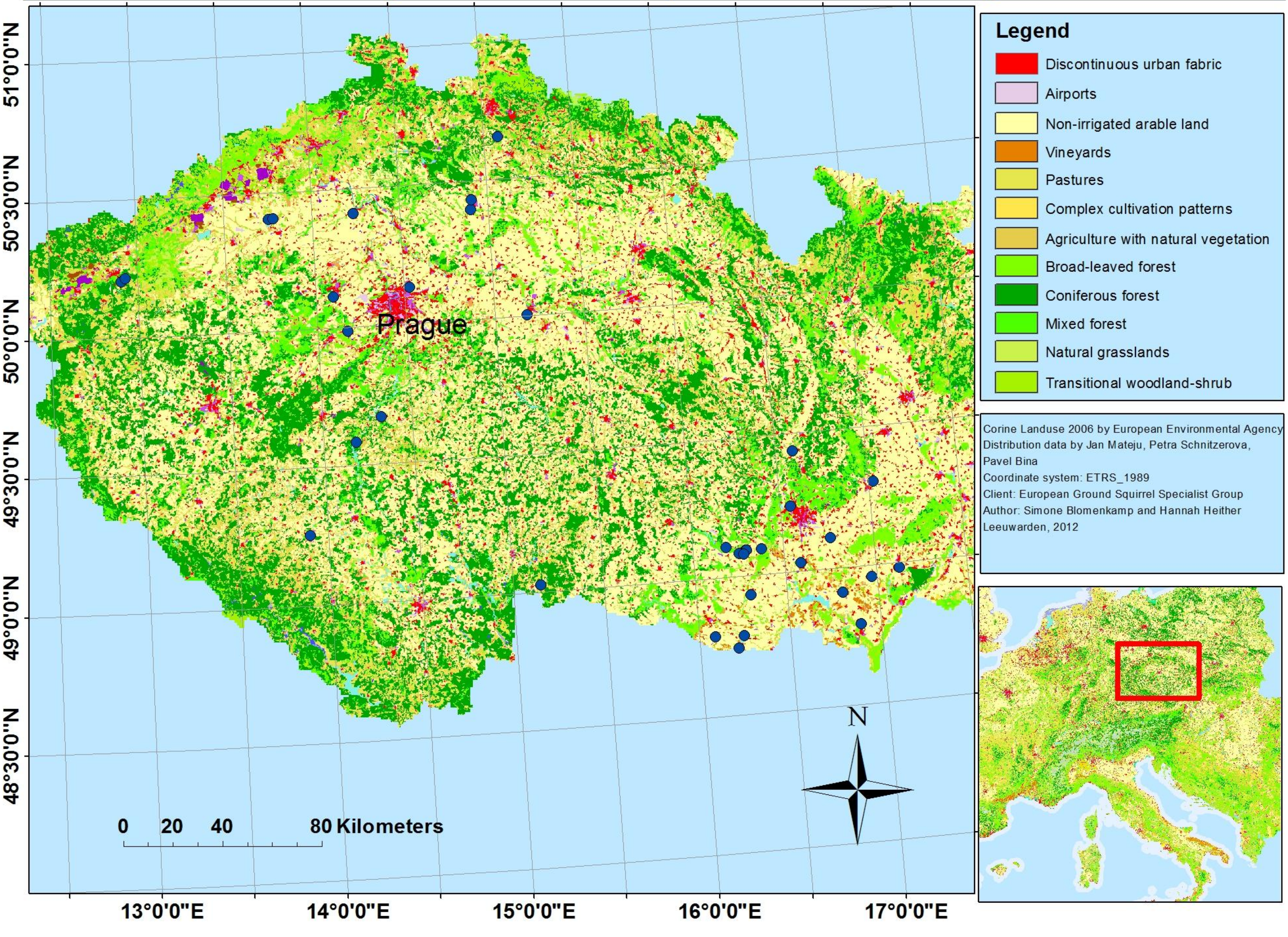
0 No information
1 Not applicable (no agriculture)
2 No water management system
3 Pumping
4 Ditches
5 Pipe under drainage (network of drain pipes)
6 Mole drainage
7 Deep loosening (subsoiling)
8 'Bed' system (ridge-funow or steching)
9 Flood irrigation (system of irrigation by controlled flooding as for rice)
10 Overhead sprinkler (system of irrigation by sprinkling)
11 Trickle irrigation

Appendix IV: Maps of the occurrence data in the different range countries

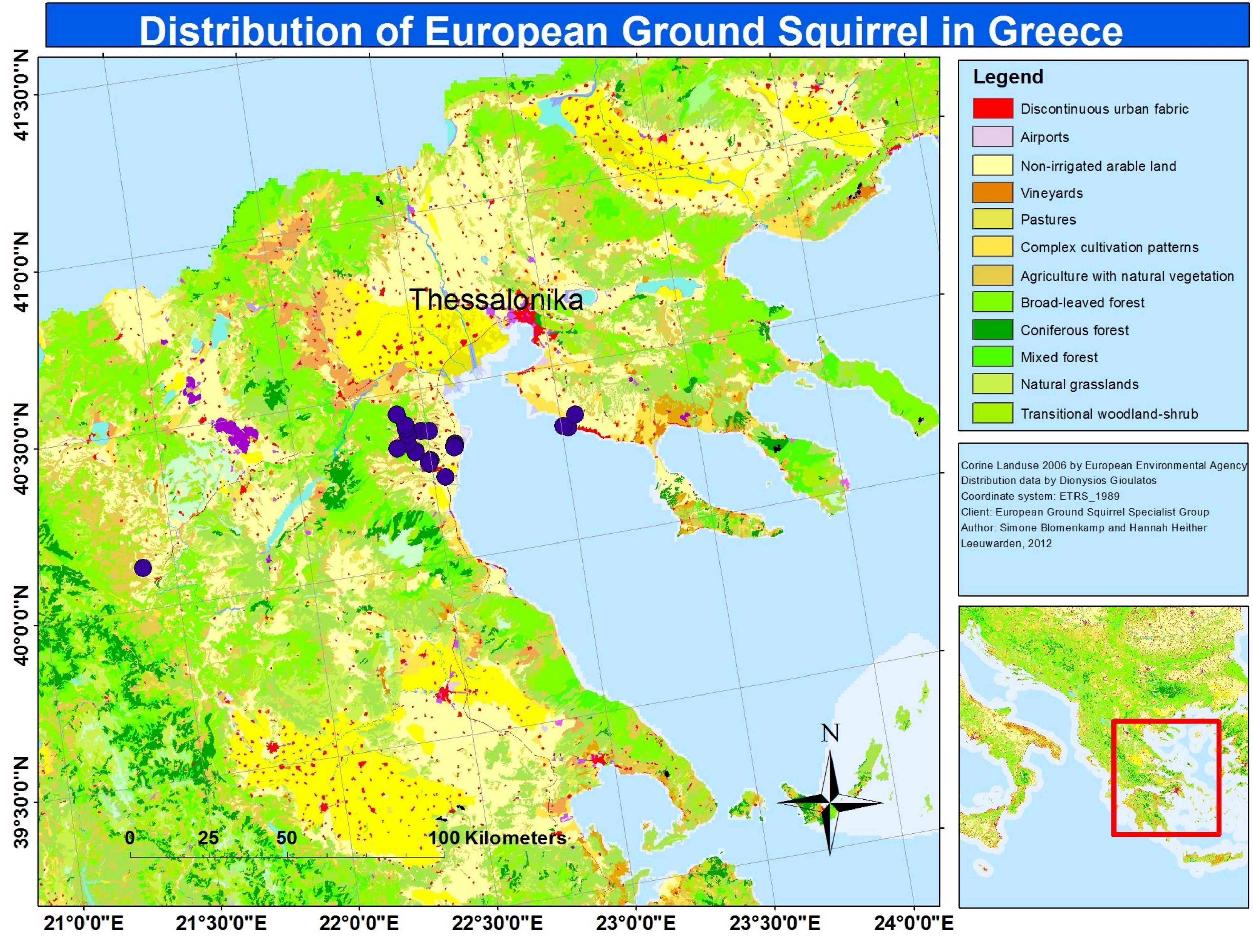



Distribution of European Ground Squirrel in Bulgaria
Legend
Discontinuous urban fabric
Airports
Non-irrigated arable land
Vineyards
Pastures
Complex cultivation patterns
Agriculture with natural vegetation
Broad-leaved forest
Coniferous forest
Mixed forest
Natural grasslands
Transitional woodland-shrub
Corine Landuse 2006 by European Environmental Agency
Distribution data from literature
(Koshev2005,2008; Spassov,2002)
Coordinate system: ETRS_1989
Client: European Ground Squirrel Specialist Group
Author: Simone Blomenkamp and Hannah Heither
Leeuwarden, 2012
Sofia
N
0 25 50 100 Kilometers
44°30'0"N
43°30'0"N
42°30'0"N
41°30'0"N
22°0'0"E
23°0'0"E
24°0'0"E
25°0'0"E
26°0'0"E
27°0'0"E
28°0'0"E

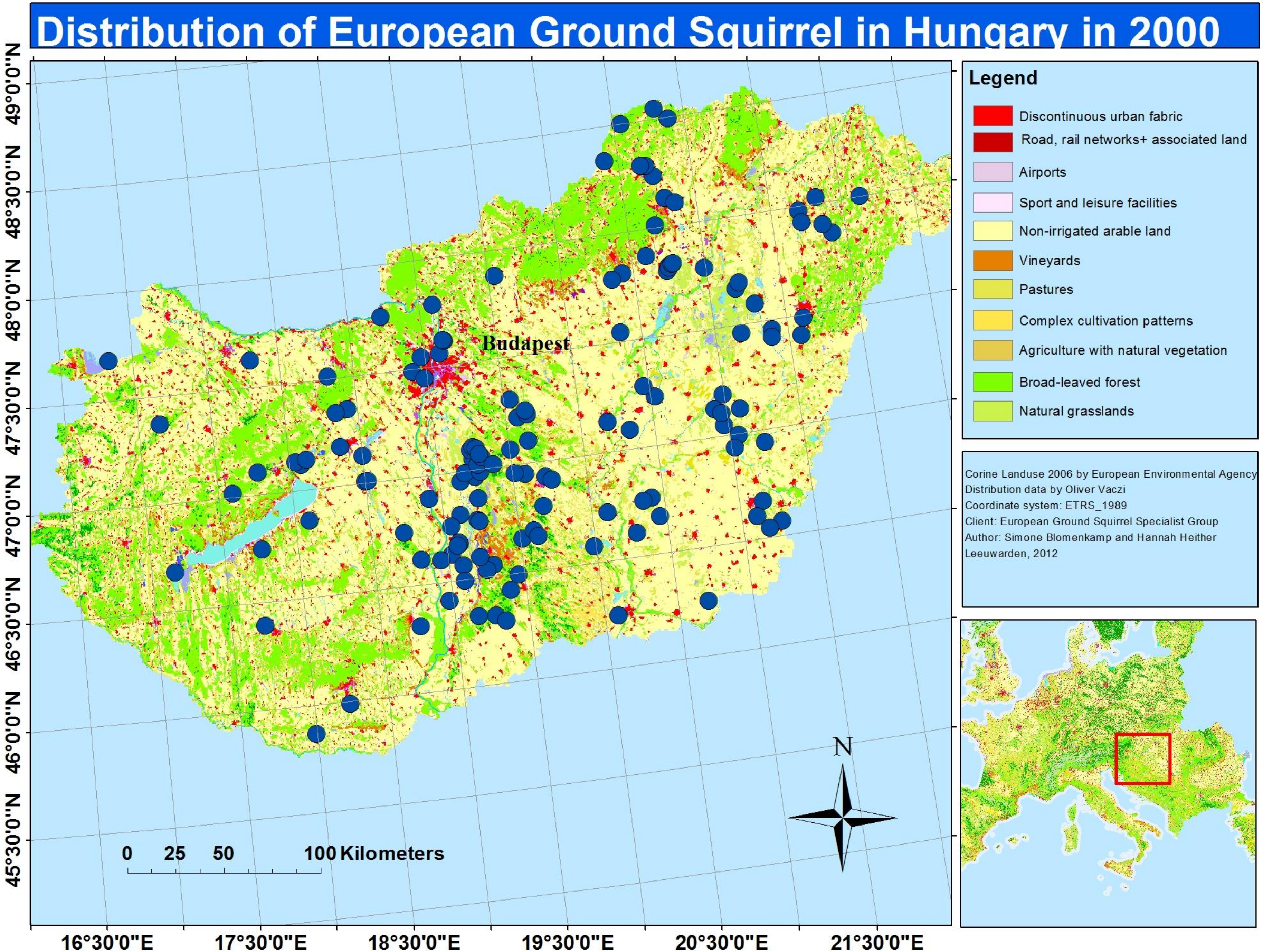
Distribution of European Ground Squirrel in Czech Republic in 2011



Corine Landuse 2006 by European Environmental Agency
Distribution data by Jan Mateju, Petra Schnitzerova, Pavel Bina
Coordinate system: ETRS_1989
Client: European Ground Squirrel Specialist Group
Author: Simone Blomenkamp and Hannah Heither
Leeuwarden, 2012

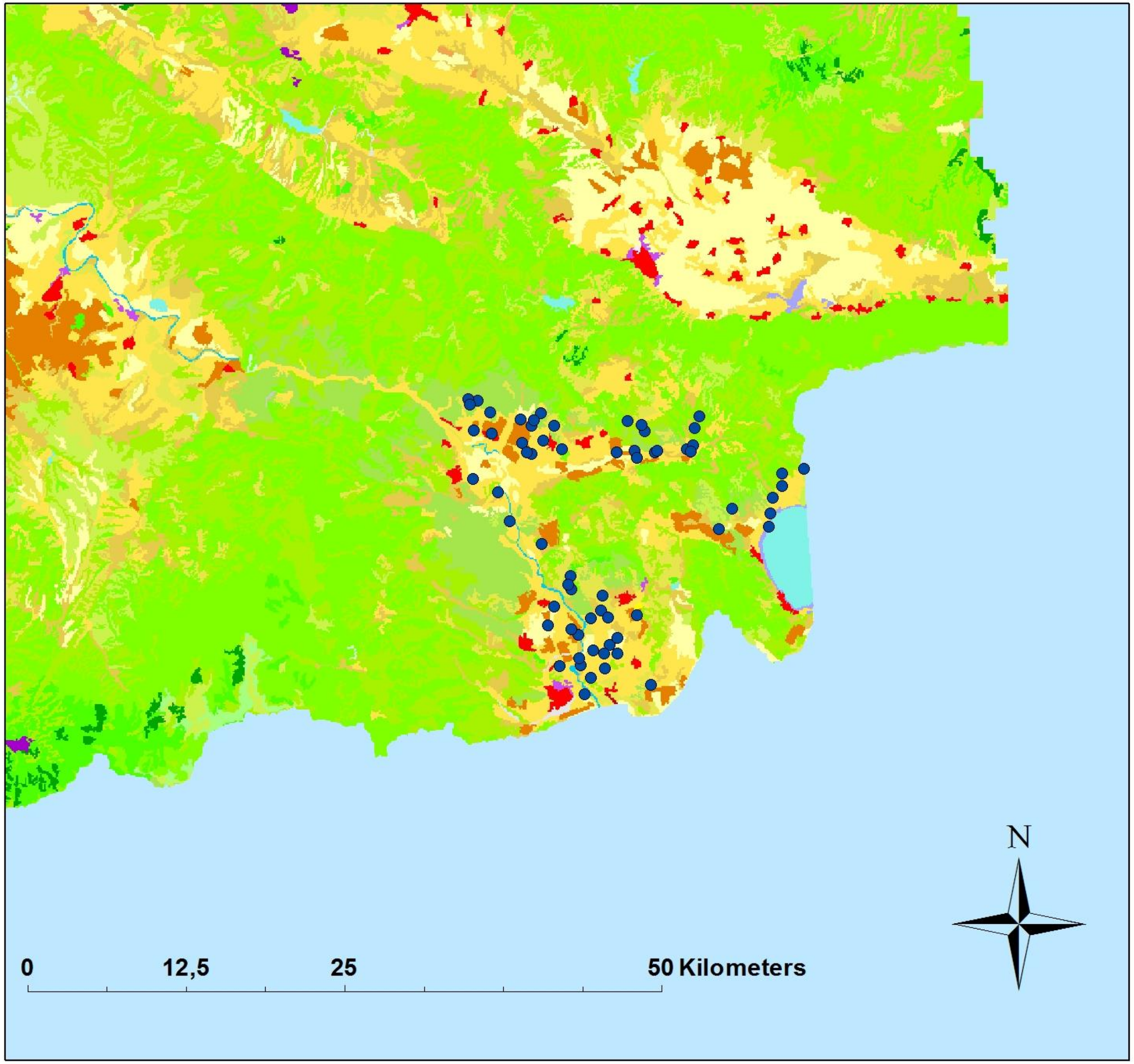


Distribution of European Ground Squirrel in Greece
Thessalonika
Legend
Discontinuous urban fabric
Airports
Non-irrigated arable land
Vineyards
Pastures
Complex cultivation patterns
Agriculture with natural vegetation
Broad-leaved forest
Coniferous forest
Mixed forest
Natural grasslands
Transitional woodland-shrub
Corine Landuse 2006 by European Environmental Agency
Distribution data by Dionysios Gioulatos
Coordinate system: ETRS_1989
Client: European Ground Squirrel Specialist Group
Author: Simone Blomenkamp and Hannah Heither
Leeuwarden, 2012
0 25 50 100 Kilometers
N
41°30'0"N
41°0'0"N
40°30'0"N
40°0'0"N
39°30'0"N
21°0'0"E
21°30'0"E
22°0'0"E
22°30'0"E
23°0'0"E
23°30'0"E
24°0'0"E



Distribution of European Ground Squirrel in Hungary in 2000
Legend
Discontinuous urban fabric
Road, rail networks+ associated land
Airports
Sport and leisure facilities
Non-irrigated arable land
Vineyards
Pastures
Complex cultivation patterns
Agriculture with natural vegetation
Broad-leaved forest
Natural grasslands
Corine Landuse 2006 by European Environmental Agency
Distribution data by Oliver Vaczi
Coordinate system: ETRS_1989
Client: European Ground Squirrel Specialist Group
Author: Simone Blomenkamp and Hannah Heither
Leeuwarden, 2012
Budapest
N
0 25 50 100 Kilometers
49°0'0"N
48°30'0"N
48°0'0"N
47°30'0"N
47°0'0"N
46°30'0"N
46°0'0"N
45°30'0"N
16°30'0"E
17°30'0"E
18°30'0"E
19°30'0"E
20°30'0"E
21°30'0"E

Distribution of European Ground Squirrel in Macedonia in 2010

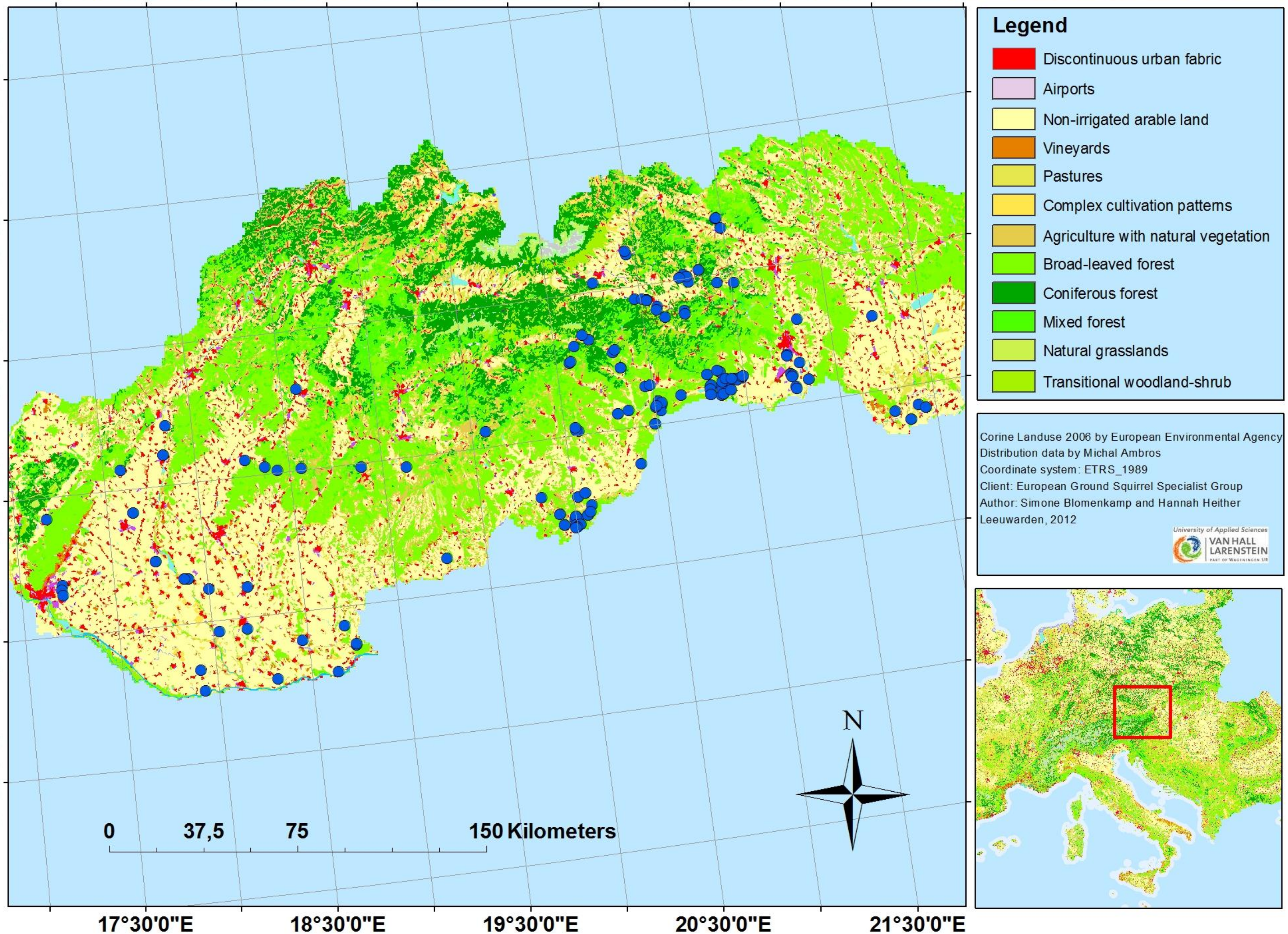


Legend

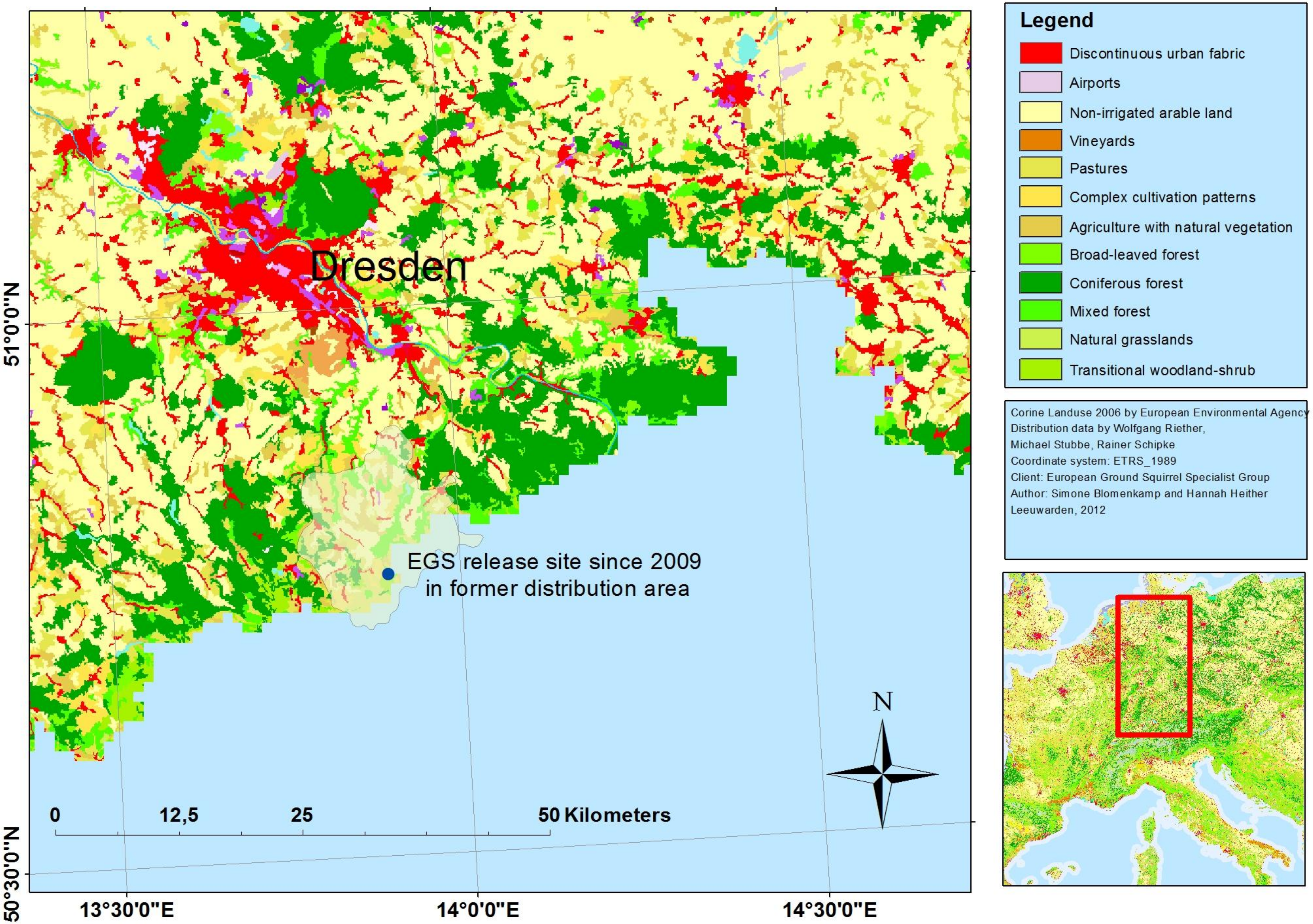
- Discontinuous urban fabric
- Airports
- Non-irrigated arable land
- Vineyards
- Pastures
- Complex cultivation patterns
- Agriculture with natural vegetation
- Broad-leaved forest
- Coniferous forest
- Mixed forest
- Natural grasslands
- Transitional woodland-shrub

Corine Landuse 2006 by European Environmental Agency
Distribution data by Werner Haberl
Coordinate system: ETRS_1989
Client: European Ground Squirrel Specialist Group
Author: Simone Blomenkamp and Hannah Heither
Leeuwarden, 2012

Distribution of European Ground Squirrel in Slovakia in 2006

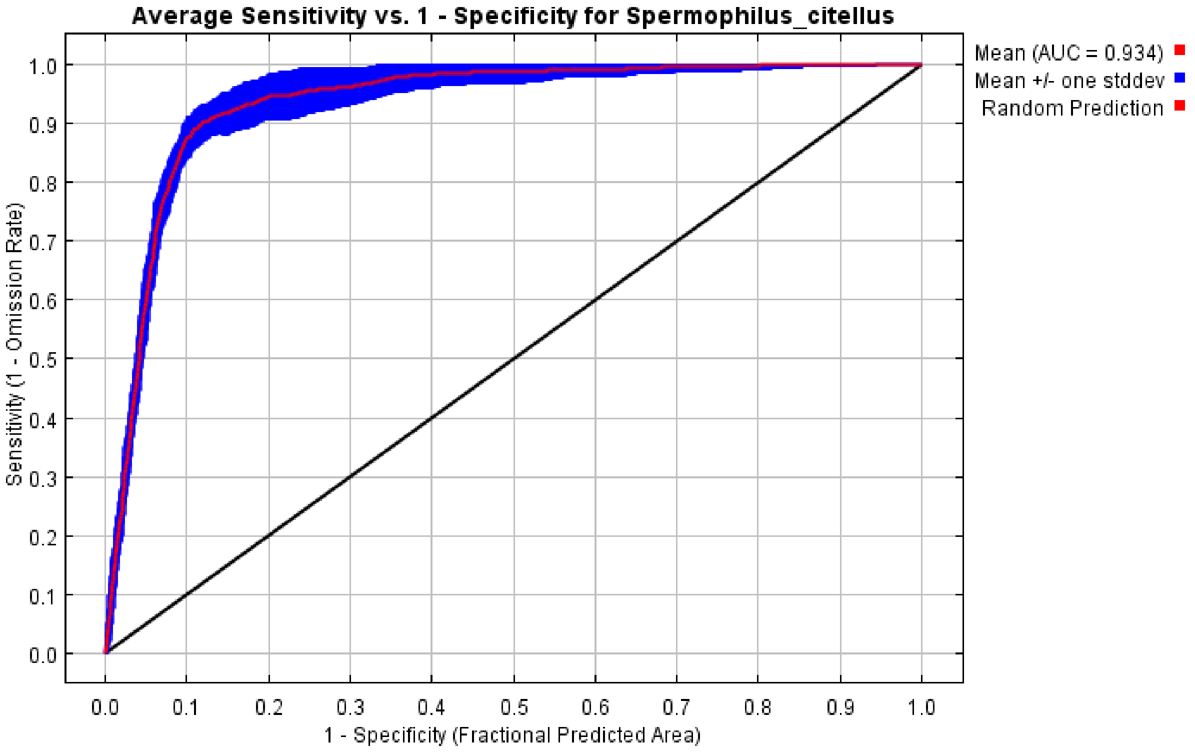


Distribution of European Ground Squirrel in Germany

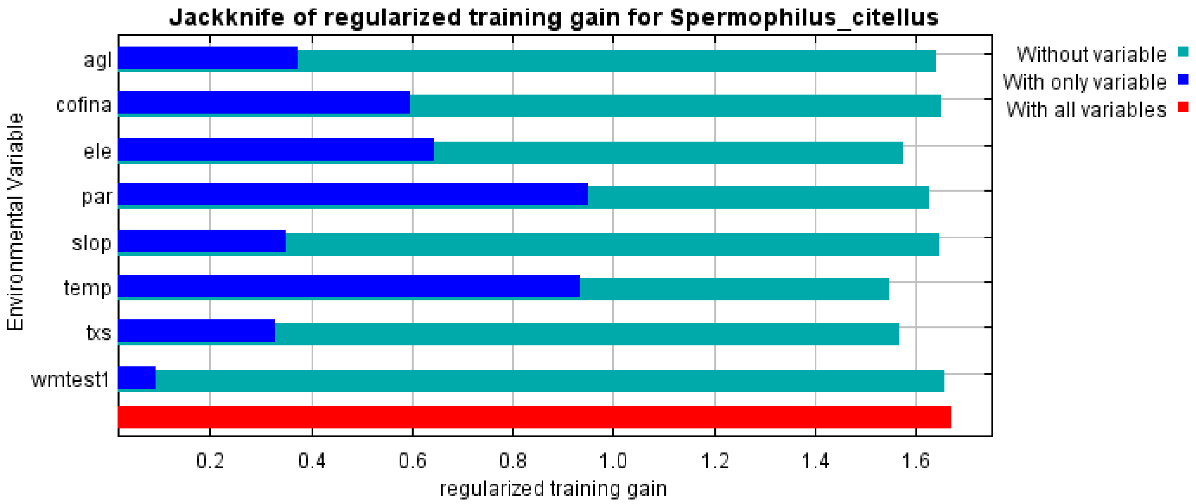


Appendix V: Maxent results

Receiver operating characteristic (ROC) curve

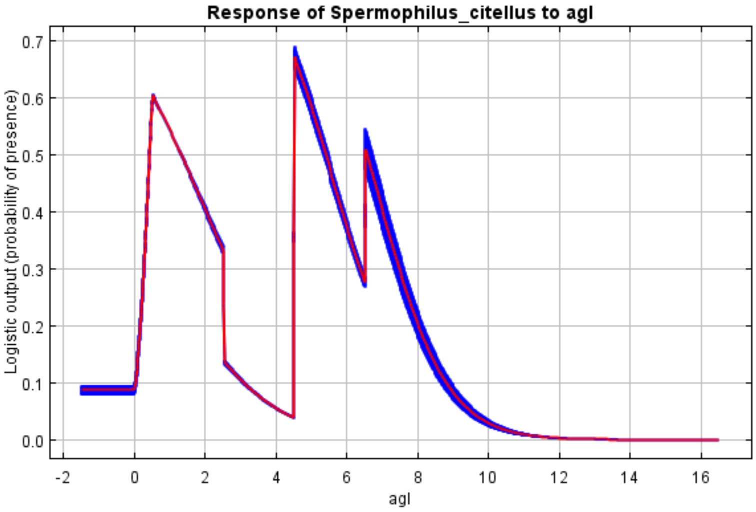


Jack-knife test of variable importance

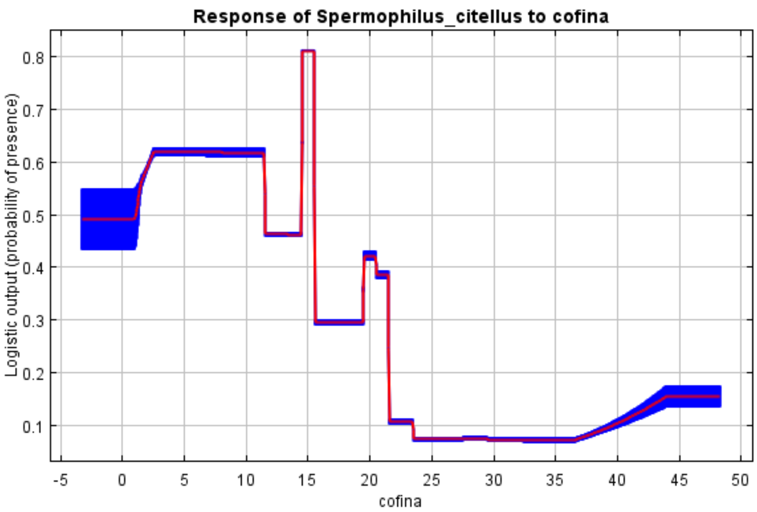


Maxent: Response curves

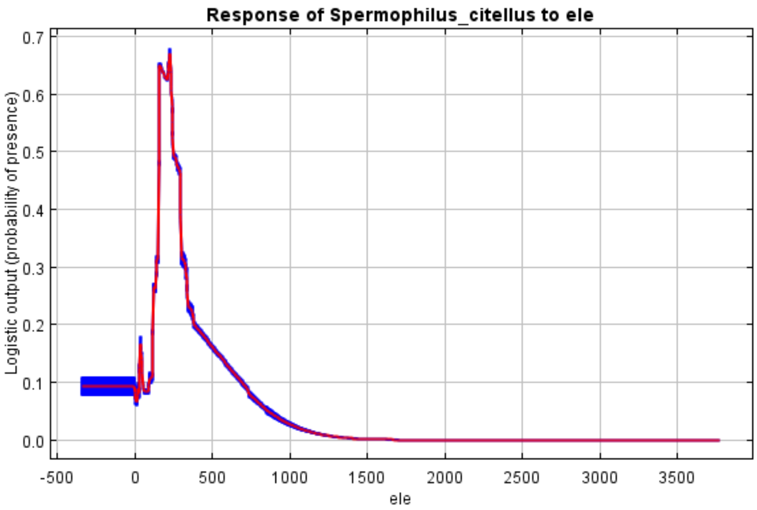
Curves show how the logistic prediction changes as each environmental variable is varied, keeping all other environmental variables at their average sample value.



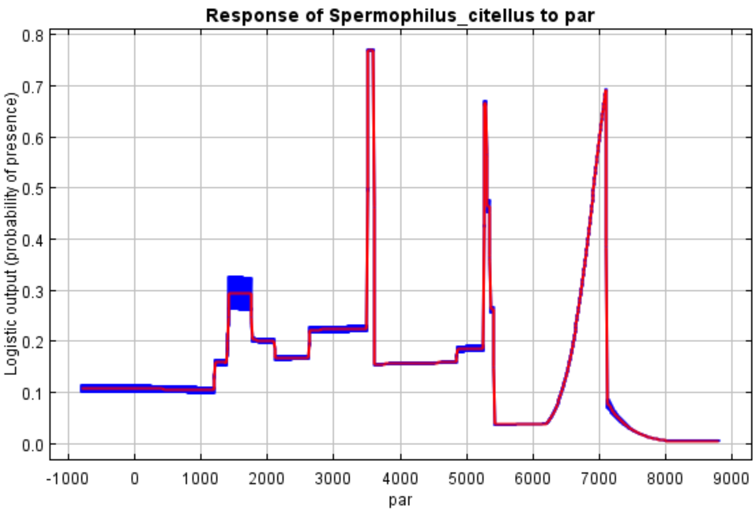
The probability of presence of *Spermophilus citellus* in areas concerning limitations to agricultural use is the highest in environments with coherent and hard rock fragments within 50 cm (≈0,68) and Petrocalcic areas, cemented or indurated calcic horizon within 100 cm (≈0,51) This can indicate urban areas like sport and leisure facilities, golf courses or airports where there is concrete around. The probability of occurrence is also high (≈ 0, 6) in areas where there is no information about limitations to agricultural use, so there has to be a lack of data in a lot of parts of Europe.



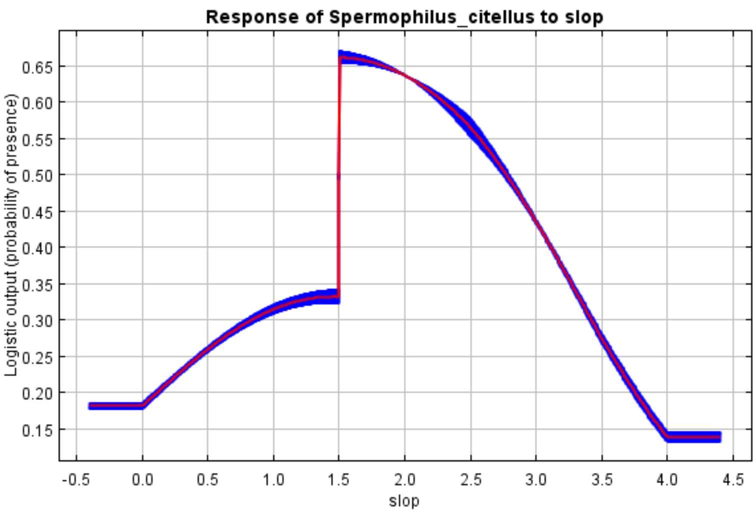
The probability of presence of *Spermophilus citellus* in areas concerning land use is highest in Vineyards (≈0, 8). With a probability of ≈0, 6 EGS can be found on artificial surfaces for example in urban areas like Airports, road and rail network or construction sites. With lower probabilities around 0, 48 EGS are found in agricultural areas like non-irrigated or permanently irrigated land. With probabilities of 0, 4 and 0, 38 they can be found in agricultural land with complex cultivation patterns or agricultural land with natural vegetation. With a very low probability of less than 0, 1 EGS are found in forest areas and wetlands.



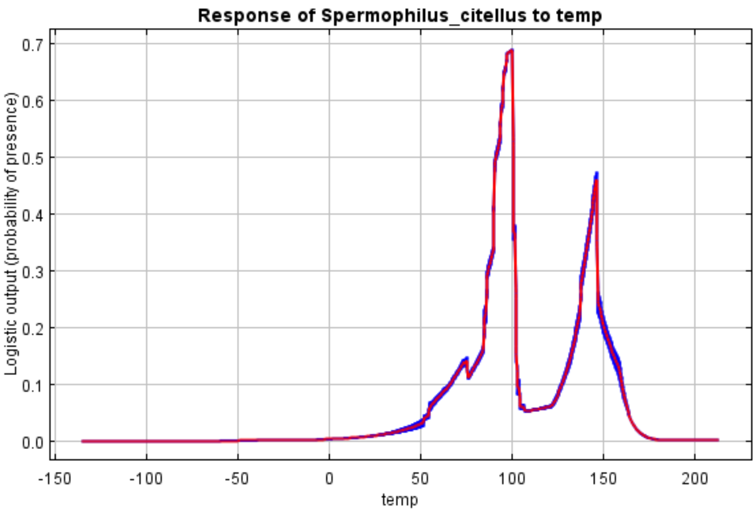
The probability of presence of *Spermophilus citellus* in areas concerning elevation is highest in areas between 0 and 500 meters above sea level. The probability decreasing to almost 0 at elevations >1500m above sea level.



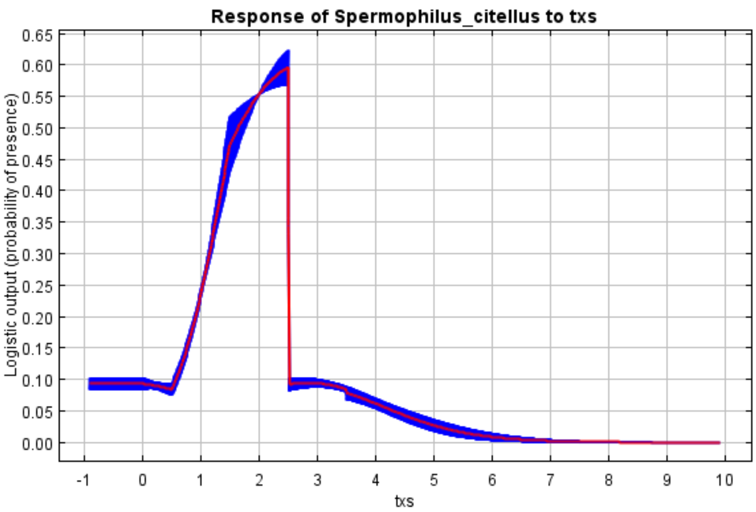
The probability of presence of *Spermophilus citellus* in areas concerning parent material is highest in areas with basalt (≈0, 77), river terrace sand (≈0, 68) and loess (≈0, 7).



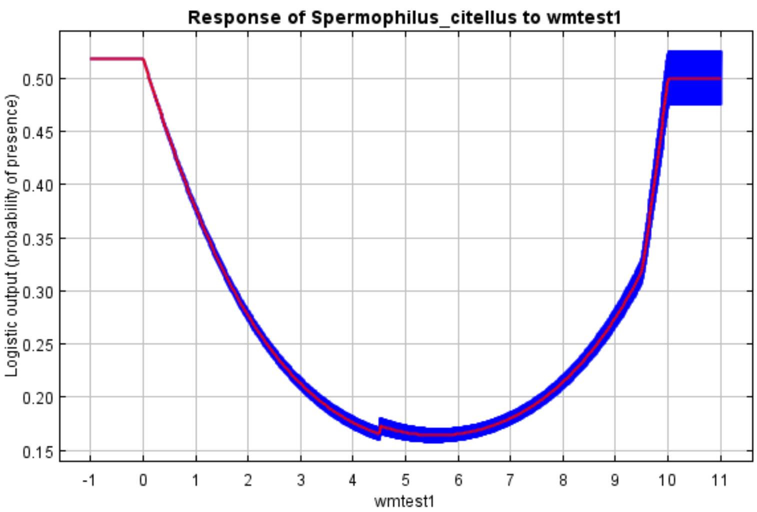
The probability of presence of *Spermophilus citellus* in areas concerning slope is highest in areas with a slope of 8%. The more steep the area gets the less is the probability for EGS to occur there. The probability to find EGS in areas with a slope above 25% is almost 0.



The probability of presence of *Spermophilus citellus* in areas concerning temperature is in areas with an average annual temperature between 5 ºC and 18 ºC. Above this or below this the probability of occurrence is 0. The highest probability is around 10 ºC and around 15 ºC. The decrease of occurrence between 10 ºC and 15 ºC can be an indication of lacking data from those areas.



The probability of presence of *Spermophilus citellus* in areas concerning texture of the soil is highest in areas with a coarse to medium fine soil meaning a range from18% < clay and > 65% sand to < 35% clay and < 15% sand.

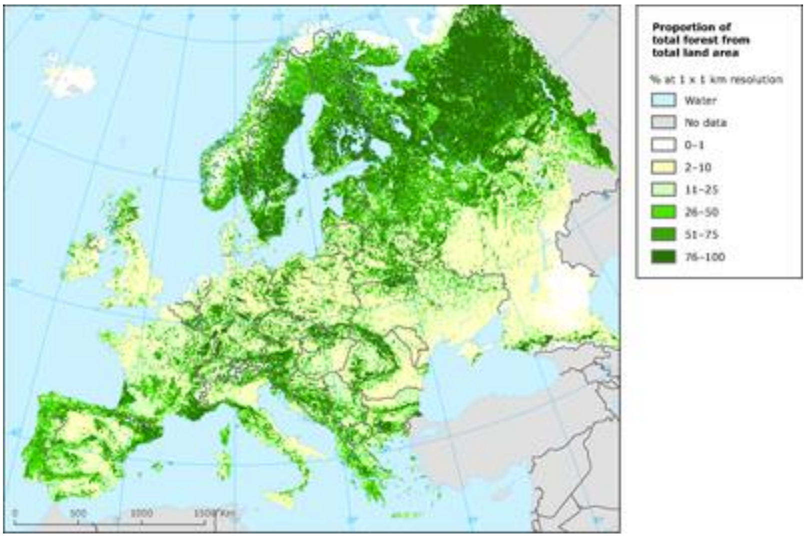


The probability of presence of *Spermophilus citellus* in areas concerning water management is lowest in areas with ditches, network of drain pipes and mole drainage. But also all the other water management systems are not very favourable for the occurrence of EGS. The best is still no water management system (nr.2 with probability of 0, 25) or overhead sprinklers (nr.10 with probability of 0, 45) and trickle irrigation (nr.11 with probability of 0, 5).

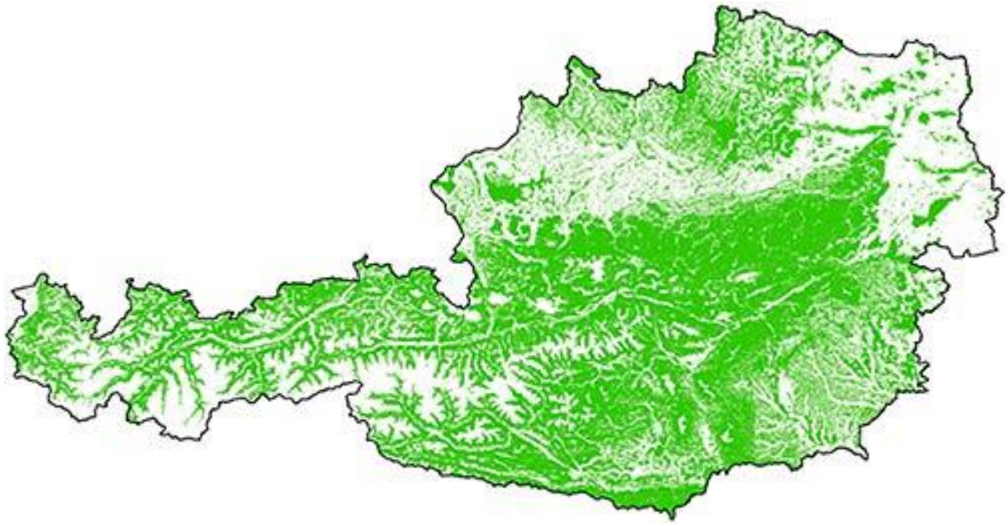
Appendix VI: Geographical barriers

Large rivers in Europe (Worldatlas, 2012)

Mountain regions in Europe (Worldatlas, 2012)



Forest areas in Europe (European Environment Agency, 2012)



Forested areas in Austria (Bauerhansl et al 2007)

Appendix VII: Model of the analysis process