EFFECTS OF CLIMATE CHANGE ON BIODIVERSITY:
A CASE STUDY ON FOUR PLANT SPECIES
USING DISTRIBUTION MODELS

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ABSTRACT

EFFECTS OF CLIMATE CHANGE ON BIODIVERSITY: A CASE STUDY ON FOUR PLANT SPECIES USING DISTRIBUTION MODELS

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Conservation strategies are mainly focused on species existing in an environment shaped by natural and anthropogenic pressures. Yet, evidence shows that climate is changing faster than ever and expected to continue to change in the near future, which can be devastating for plants with restricted ranges.

Turkey harbors many endemic species that might be affected from these changes. However, available data is scarce and biased, complicating the anticipation of future changes. Aim of this study is to improve our understanding of endemic species distributions and forecasting effects of climate change via species distribution modelling (SDM).

The study is based on two Anatolian (*Crocus ancyrensis* and *Crataegus tanacetifolia*) and two Ankara (S*alvia aytachii* and *Centaurea tchihatcheffii*) endemics. Independent presence and absence data (ranging between 19-68 and 38-

61, respectively) for each species was collected through fieldwork in and around the Upper Sakarya Basin in 2008 and 2009.

With the software Maxent, SDMs were performed by using 8 least correlated environmental features and random presence records (of which 25% were used for confusion matrix). SDMs for current distributions of *C. ancyrensis, C. tchihatcheffii* and *C. tanacetifolia* were reliable enough for future extrapolations despite errors originating from scale, non-equilibrium status and biotic interactions, respectively. The model for *S. aytachii* failed due to absence of limiting factor (soil type) in the model.

Future projections of those three species modelled using CCCMA-CGCM2 and HADCM3 climate models indicated three possible responses to climate change: (1) Extinction, especially for habitat specialists; (2) Range expansion, especially for generalist species; and (3) Range contradiction, especially for Euro-Siberian mountainous species.

Species modelling can be used to understand possible responses of plant species to climate change in Turkey. Modelling techniques should to be improved, however, especially by integrating other parameters such as biotic interactions and through a better understanding of uncertainties.

Keywords: species distribution modelling, climate change, biodiversity, endemic plants, Turkey

ÖZ

İKLİM DEĞİŞİKLİĞİNİN BİYOÇEŞİTLİLİK ÜZERİNDEKİ ETKİLERİ: TÜR DAĞILIM MODELLEME YAKLAŞIMI İLE DÖRT BİTKİ TÜRÜ ÜZERİNE ÖRNEK OLAY İNCELEMESİ

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Doğa koruma çalışmaları genellikle türler üzerine odaklanır. Türler ise çevre ve insan etkilerinin harmanlandığı koşullarda hayatlarına devam ederler. Fakat günümüzde insan etkisinin artmasıyla bu koşullar hızla değişmeye başlamıştır. Eldeki veriler son dönemlerde insan etkisiyle artan iklim değişikliğinin daha öncekilerden çok daha hızlı gerçekleştiğini ortaya koymaktadır. Bu değişikliğin önümüzdeki yüzyılda da devam edeceği öngörülmektedir. Böyle bir değişimin özellikle dar yayılış gösteren endemik bitkiler üzerindeki etkilerinin yıkıcı olabileceği düşünülmektedir.

Türkiye bu tür değişikliklerden kötü etkilenebilecek birçok endemik bitki türüne ev sahipliği yapmaktadır. Fakat, böyle bir değerlendirme yapabilmek için türlerin dağılımları hakkında detaylı bilgiye ihtiyaç vardır. Maalesef mevcut bilgi hem yetersiz hem de hata payı yüksek olduğundan iklim değişikliğinin potansiyel etkilerini tahmin etmek oldukça zordur. Bu çalışmanın amacı endemik türlerin dağılımlarını etkileyen faktörler hakkında daha detaylı bilgi sahibi olmak ve iklim değişikliğinin bu türler üzerindeki potansiyel etkilerini “tür dağılım modellemesi (TDM)” yöntemi ile tahmin etmektir.

Bu çalışma iki Anadolu (*Crocus ancyrensis* ve *Crataegus tanacetifolia*) ve iki Ankara (S*alvia aytachii* ve *Centaurea tchihatcheffii*) endemiği üzerine yoğunlaşmaktadır. Yukarı Sakarya Havzası dolaylarında 2008-2009 yılları arasında gerçekleştirilen arazi çalışmaları ile her tür için bağımsız var (19-68 nokta) ve yok (38-61 nokta) verileri toplanmıştır.

TDM’leri düşük korelasyon gösteren 8 adet çevresel değişken ve rastgele seçilmiş var noktaları (geriye kalan %25’i hata matriksinde kullanılmak üzere ayrılmıştır) Maxent programı kullanılarak yaratılmıştır. *C. ancyrensis, C. tchihatcheffii* ve *C. tanacetifolia* türlerinin günümüzdeki dağılımını temsil eden modellerin gelecek tahminlerinde kullanılabilecek kadar güvenilir .oldukları görülmüştür. Fakat, yine de belirtmek gerekir ki, bu modellerde elde olmayan nedenlerden dolayı bazı eksiklikler vardır. Özellikle ölçek, türün bulunduğu çevreyle dengede olmama durumu ve biyolojik etkileşimlere bağlı sapmalar mevcuttur. *S. aytachii* için geliştirien model ise türün dağılımını kontrol eden temel faktörün (toprak yapısı) modelde ifade edilememesi sebebiyle başarısızlığa uğramıştır.

Başarılı olan TDM’ler (3 tür için) CCCMA-CGCM2 ve HADCM3 iklim modelleriyle öngörülen iklim değişkliğinin bu türler üzerindeki potansiyel etkilerini tahmin etmekte kullanıldı. Analizler iklim değişikliğinin tür dağılımları üzerinde yol açabileceği 3 potansiyel etki ortaya koydu: (1) Nesli tükenme, özellikle habitatları özelleşmiştürler için; (2) Yaşam alanı genişlemesi, özellikle generalist türler için; and (3) Yaşam alanı daralması, özellikle Avrupa-Sibirya bölgesindeki dağlık yaşama uyum sağlamış türler için.

Tür dağılım modelleri iklim değişkliğinin Türkiye'deki bitki türleri üzerindeki potansiyel etkilerini tahmin etmekte kullanılabilirler. Fakat, modelleme tekniklerindeki eksikliklerin giderilmesine (örn. biyolojik etkileşimlerin modele entegre edilmesine) ve modellerdeki belirsizliklerin derinlemesine araştırılmasına ihtiyaç vardır.

Anahtar Kelimeler: tür dağılım modellemesi, iklim değişikliği, biyoçeşitlilik, endemik bitkiler, Türkiye

To my father;
I know you would have been proud.

To my family;

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been; one of the best shoulders to cry on as well as having fun. Banu has always managed to show positive sides of any kind of awkward situation; an incredible gift for me. I have always known that Anıl is a breath away providing a feeling of cosy home. Aslı is the first person I met in Ankara and always have been a great friend whom I shared so much time full of fun. Ümit and Başak have been a brother and a sister to me. I have always felt very lucky living together with you two.

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CHAPTER 1

INTRODUCTION

1.1 Biodiversity and Climate

The variety of life in a given ecosystem, biome or on Earth is termed ‘biodiversity’. Biodiversity is comprised of diverged ecosystems (such as, deserts, rainforests and coral reefs), the species residing in these and the genes within these (Gaston and Spicer, 2004).

Biodiversity is not evenly distributed. It is consistently higher in the tropics and in other localized regions such as localised regions of high resource availability (e.g. Cape Floristic Province) and generally lower in polar regions (WCMC, 1992). The distribution of biodiversity is dependent on latitude, climate, altitude, soils and the presence of other interacting species (Pidwirny, 2006a, 2006b). Thus, the ability of a species’ survival is dependent on changes occurring in local conditions and resources, such as the changes in climate.

It is well known that climate has changed throughout the Earth’s history. Biodiversity patterns have also changed according (NASA, 2011) to the changes in climate. It is evident that there have been eight cycles of glacial expansion and contraction through the last 750,000 years (Jansen, 2007, Williams, 2009). Most recent is the abrupt change which occurred at end of the last ice age about 7,000 years ago, which is believed to mark the beginning of human civilization (Brooks, 2004). Most past climate changes are attributed to very small variations in Earth’s orbit which regulates the amount of solar energy received (Jansen, 2007). Meanwhile, species have coped and adapted to these changes. However, current climate change is drawing great attention because it is believed to be highly human-induced, proceeding at an unprecedented and extraordinary rate during the last 1,300 years (Ramaswamy *et al.*, 2006; Solomon, 2007)(Figure 1.1-1 and 1.1-2).

The effects of the more recent rapid climate change are experienced in different domains. Those effects can be listed as follows;

- Sea level rise: Global sea level rose about 17 cm in the last century. Moreover, this value is nearly doubled in the last decade (Church and White, 2006).

- Global temperature rise: All three major global surface temperature reconstructions by National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA) and Climate Research Unit (CRU) show that Earth's temperature has been increasing since 1880 (Fig: 1.1-2). Most of this warming has occurred during last 40 years (following 1970s). The warmest (average global temperature) 10 years on record were observed in the past 15 years (Peterson *et al.*, 2008). A solar output decline during 2000s resulted in an unusually deep solar minimum in 2007-2009, yet mean surface temperatures continue to increase (Allison *et al.*, 2009) (Figure 1.1-2).

- Warming oceans: The oceans have absorbed much of this increased heat, leading to a warming of 16×10^{22} J (8.425×10^{19} °C) in the top 700 meters between 1969 and 2008 (Levitus *et al.*, 2009).

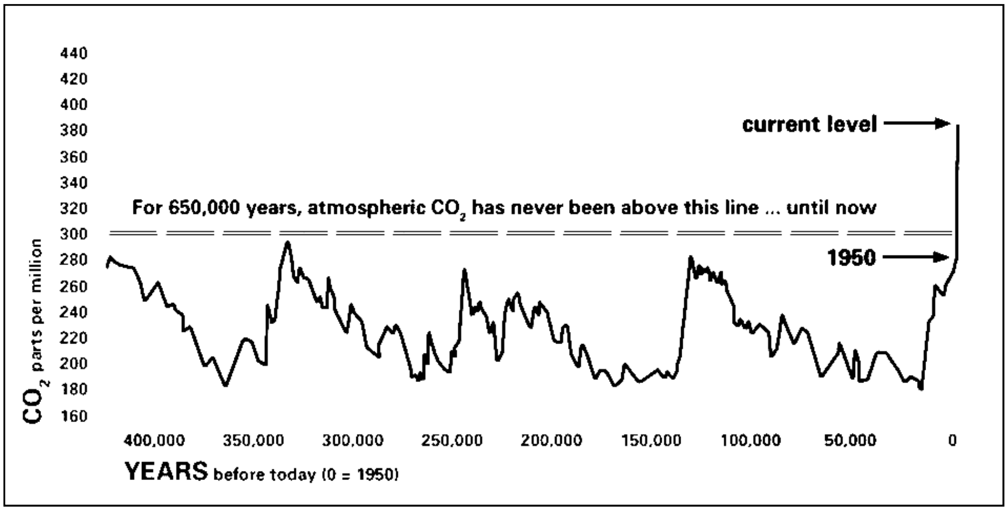


Figure 1.1-1. A representative of the abrupt change in CO_2 levels since the Industrial Revolution: CO_2 levels are collected from atmospheric samples contained in ice cores and (more recent data from) direct measurements. (Source: The National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA))(NASA, 2011).

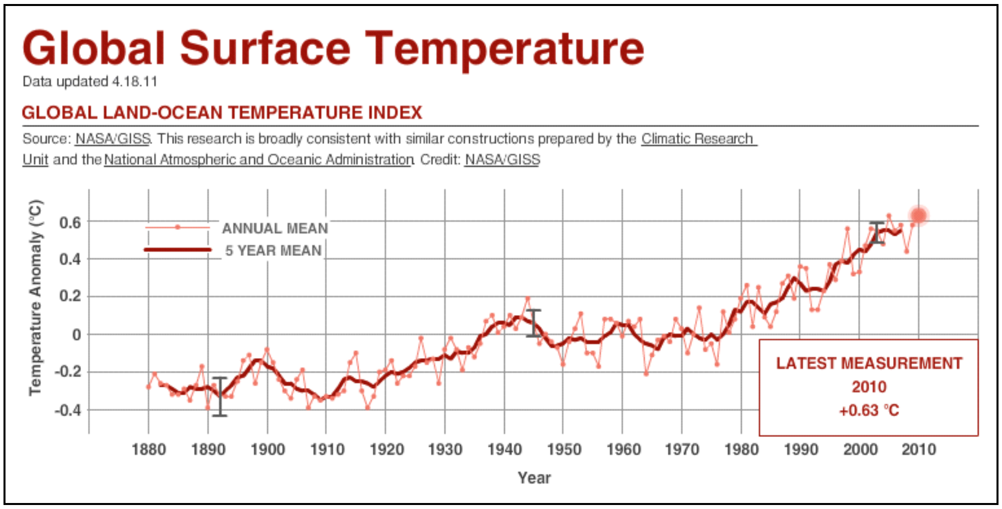


Figure 1.1-2. Change in global surface temperature relative to 1951-1980 average temperatures. Global surface temperatures in 2010 tied 2005 as the warmest on record. (Source: NASA Goddard Institute for Space Studies (NASA/GISS)) The gray error bars represent the uncertainty on measurements. This research is broadly consistent with similar constructions prepared by the Climatic Research Unit (CRU) and the NOAA (NASA, 2011).

- Shrinking ice sheets: The Greenland and Antarctic ice sheets have decreased in mass. Data collected from NASA's Gravity Recovery and Climate Experiment (NASA/GRACE) show that Greenland lost 150 to 250 km^3 (36 to 60 cubic miles) of ice per year between 2002 and 2006, while Antarctica lost about 152 km^3 (36 cubic miles) of ice between 2002 and 2005 (Velicogna and Wahr, 2005, NASA, 2011).

- Declining Arctic sea ice: Arctic sea ice has experienced a rapid decline and lost much of its extent and thickness over the last several decades. (Polyak, *et al.*, 2010; Kwok and Rothrock, 2009).

- Glacial retreat: National Snow and Ice Data Center (NSIDC) and World Glacier Monitoring Service (WGMS) announced that glaciers are retreating almost everywhere around the world — including in the Alps, Himalayas, Andes, Rockies, Alaska and Africa (NSIDC and WGMS, 2011).

- Extreme climatic events: NOAA indicated that U.S. has witnessed increasing numbers of intense extreme climatic events since 1950 (NOAA, 2011).

- Ocean acidification: The carbon dioxide content of the oceans has been increasing since the 1750s, when anthropogenic carbon output escalated, a period termed "the industrial revolution"; NASA declared that the current rate of increase is about 2 billion tons per year (NASA, 2011). This rise in carbon output contributed to about 30 percent higher acidity level in the ocean (Sabine *et al.*, 2004; Secretariat of the Convention on Biological Diversity, 2009).

Nevertheless, a warming of at 0.2-1˚C per decade is estimated for the following two decades in combination with associated changes in precipitation patterns (Solomon, 2007).

As distribution of biodiversity and climate are interdependent, this estimated climate change will surely affect species' charactheristics and distributions. There are several different possible effects listed by various scientists. Primarily climate change is estimated to (a) change species abundances; (b) increase habitat fragmentation; (c) alter the phenology of critical lifecycle events (Blaustein *et al.*, 2001; Chadwick *et al.*, 2006; Blaustein *et al.*, 2010), and (d) increase prevalence of infectious diseases by encouraging spread of parasitic agents, such as chytridiomycete fungi (Pounds *et al.*,. 2006; Bosch *et al.*, 2007; Wake, 2007). Furthermore, the interaction of these possible effects may cause disruptions in population and metapopulation dynamics, which may lead to changes in species distributions (Carvalho *et al.*, 2010). Possible effects of climate change on a species' distribution can be summarized in three major ways: (1) a species can track appropriate conditions spatially by moving in response to changing climate conditions, leading to range shifts, expansions or contractions; or (2) a species can adapt to changes, either physiologically, behaviourally or genetically and maintain its current range; or (3) it can fail either of these and become extinct as conditions become unsuitable for survival (Gibson *et al.*, 2010). These extinctions can be local or global depending on the extent and distribution of climate changes within the range of a given species.

Climate change has already started to affect many aspects of species populations, including their physiology, distribution, phenology, behaviour and vulnerability to destruction (Hughes, 2000; McCarty, 2001; Walther *et al.*, 2002; Root *et al.*, 2003; Parmesan, 2006). Several authors have documented evidence of contractions or shifts in geographic ranges induced by recent climate change (e.g. Hickling *et al.*, 2006; Thomas *et al.*, 2006; Moritz *et al.*, 2008; Rosenzweig *et al.*, 2008; Thomas, 2011). Some species are expected to adapt to these changes through ecological (Root *et al.*, 2005) or evolutionary processes (Bradshaw and Holzapfel, 2006; Skelly *et al.*, 2007). However, other species considered to be less adaptable are likely to undergo local or global extinctions.

A number of key life history traits of a species determine its resilience (the ability of a species to overcome effects of disturbances) to environmental change (Isaac *et al.*, 2009). The most vital of these are narrow geographic range, limited dispersal capacity, low reproductive output and a high degree of habitat specialization (Walther *et al.*, 2002; Thomas *et al.*, 2004; Massot *et al.*, 2008: Isaac *et al.*, 2009; Carvalho *et. al.*, 2010). Range-restricted species, such as regional endemics, often possess most of these traits, so they are expected to be more sensitive to environmental change than others in general (Thuiller *et al.*, 2005). Moreover, these species are already suffering from restricted distributions due to other adverse effects; such as habitat loss, which would be more destructive in combination with climate change. For example; habitat loss leads to small, highly fragmented and isolated populations that are prone to losses in genetic diversity – through genetic bottlenecks, which in return reduces species capacity to adapt itself to changing conditions, leading to a cycle of decreasing resiliance (Isaac, 2009; Williams *et al.*, 2008). Consequently, the impact of climate change on biodiversity is likely to be more severe in regions which are rich in endemic species. Unfortunately, these areas, such as Meditrranean Region, are mostly predicted to be affected by dramatic shifts in climatic conditions in near future (Sala *et al.,* 2000; Malcolm *et al,.* 2006).

Situated in the Mediterranean Basin, Turkey is a biodiversity hotspot home to many endemic species (Figure 1.1-3). It is one of the richest countries for endemic plant species in the temperate world. It has about 11000 plant taxa (in comparison the whole of Europe has about 12500 plant species), more than one third of which are endemic to the country (Vural, 2003). Due to this high biodiversity and high rate of endemism, it is a country with potential to loose a large number of species as a result of current predicted climatic changes.

Figure 1.1-3. Global map of biodiversity hotspots (Conservation International, 2005).

Regions with highest endemism in Turkey are Toros Mountains (especially central parts: between Ermenek, Gülnar and Mut), Amanos, Kaz Mountains, Antitoros (around Saimbeyli ve Maraş), North Passage Region (Ilgaz Mountains), North and South of Eastern Anatolia (covering Van-Siirt-Bitlis ve Hakkâri districts, mountains around Rize and Artvin, the area between Gümüşhane and Erzincan, Munzur Mountains) and Salt Lake Plain (Vural, 2003)(Figure 1.1-4). Levels of endemism are much lower in the Gymnospermae than Angiospermae, while richest genera are *Astragalus* (450 species), *Verbascum* (250 species), *Centaurea* (200 species) and *Hieracium* (100 species) (Atik *et al.*, 2010; Şeherali *et al.*, 2004).

Figure 1.1-4. Map of higest endemism regions of Turkey (white polygons) (Şeherali *et al.*, 2004)

It is estimated that Turkey will be among those countries most affected by climate change (Dalfes *et al.*, 2007; Demir *et al.*, 2007; Önol and Semazzi, 2006, 2009). Demir *et al.* (2007) conducted simulations in order to predict effects of climate change in Turkey using the UK Met Office, Hadley Centre for Climate Prediction and Research's Regional Climate Model, PRECIS (Providing Regional Climates for Impacts Studies). Reference period (1961-1990) and corresponding future period (2071-2100) A2 scenario (Nakicenovic *et al.*, 2000) simulations were compared. Outputs of these analyses indicate that for Turkey there will be:

- 5-6 °C increase in mean temperatures in inland Turkey
- Up to 8 °C increase in summer temperatures
- up to 40% decrease in precipitation regime, through east to west
- reduced snow depth in the Eastern and the Eastern Black Sea regions
- enhanced water loss parallel to decrease in precipitation and increase in temperature

Results of other similar studies support broadly support these findings (Figure 1.1-5 and 1.1-6) (Dalfes *et al.*, 2007; Önol and Semazzi, 2009).

Under these circumstances, governments need to take proactive measures to minimise impacts of climate change on biodiversity. Although Turkey signed the Kyoto Protocol in 2009, there are yet no clear national policies or strategies relevant to loss of biodiversity in the face of climate change. In order to develop appropriate mitigation measures, possible impacts of climate change on biodiversity should be predicted and the ability of biodiversity to adapt to these effects should be evaluated (Carvalho *et al.*, 2010). The combination of this information then could be used to determine biodiversity vulnerability, which in turn becomes the basis for prioritizing species and defining management strategies for biodiversity conservation (CCSP, 2008). This is only possible if we can understand the current spatial and temporal distribution of plants and animals.

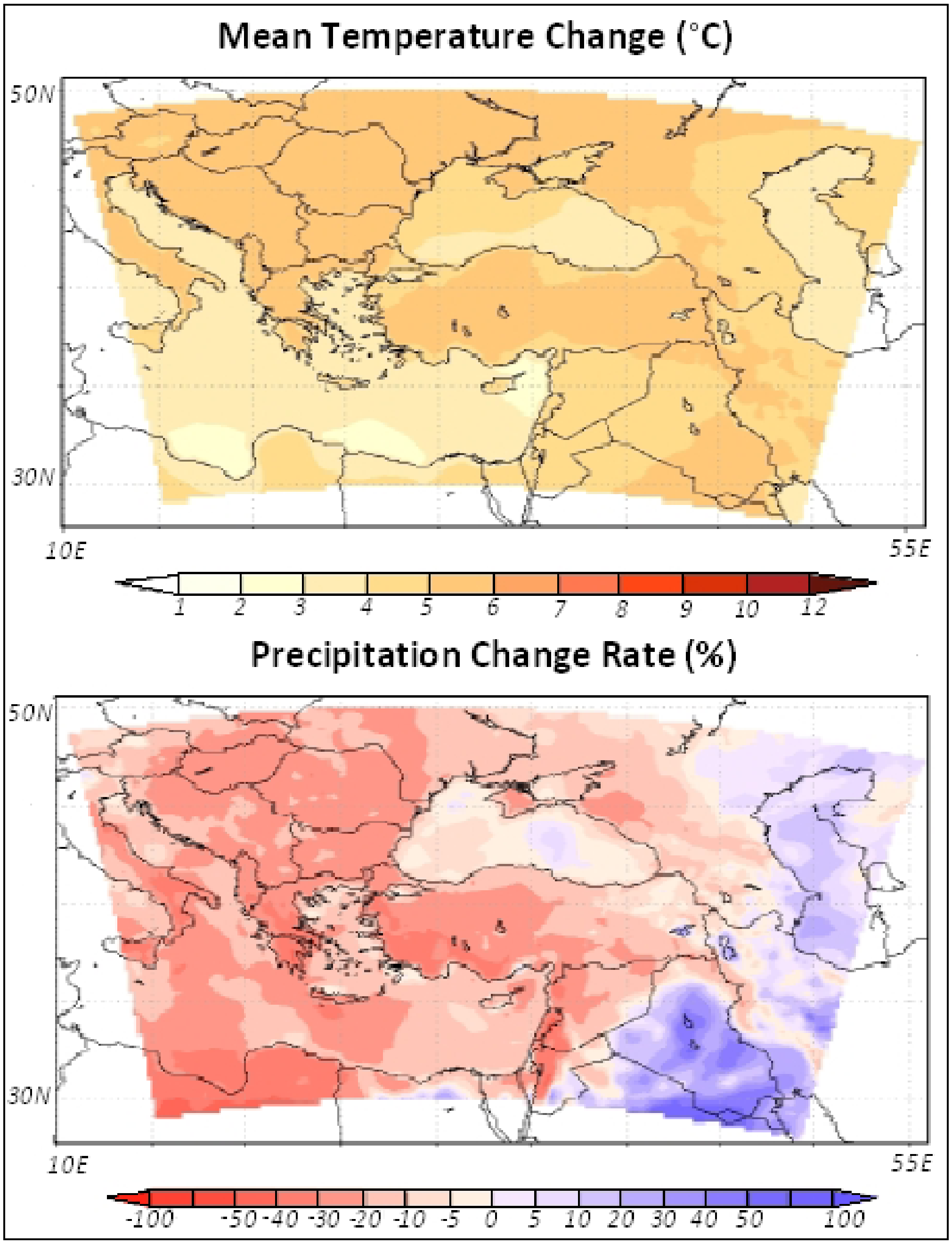
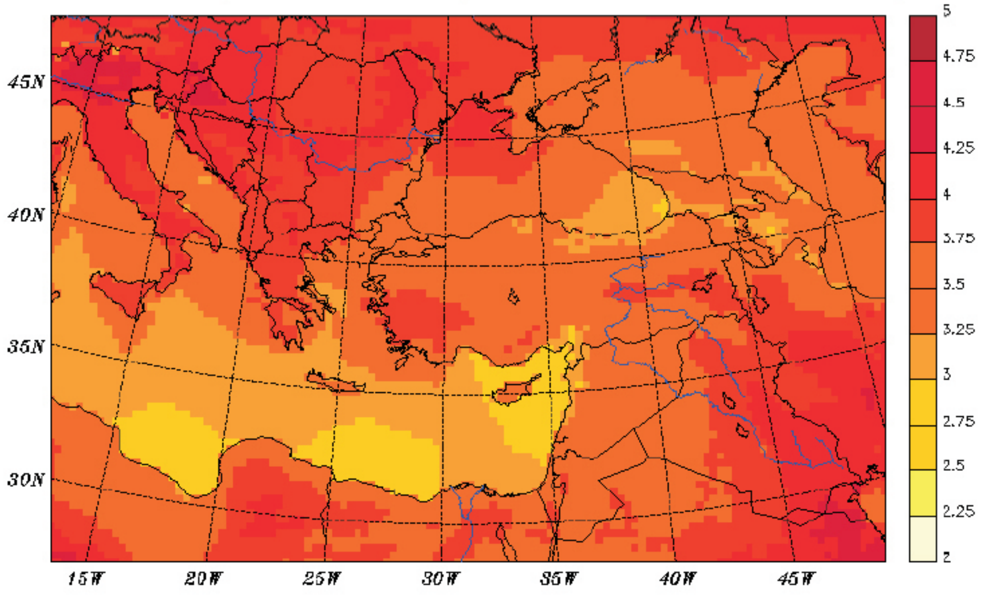


Figure 1.1-5. Differences in annual temperatures and precipitations between reference period (1961-1990) and corresponding future period (2071-2100) A2 scenario (Demir *et al.*, 2007).

Annual Temperature Difference (2071:2100 - 1961:1990 mm)



Annual precipitation difference (2071:2100 - 1961:1990 mm)

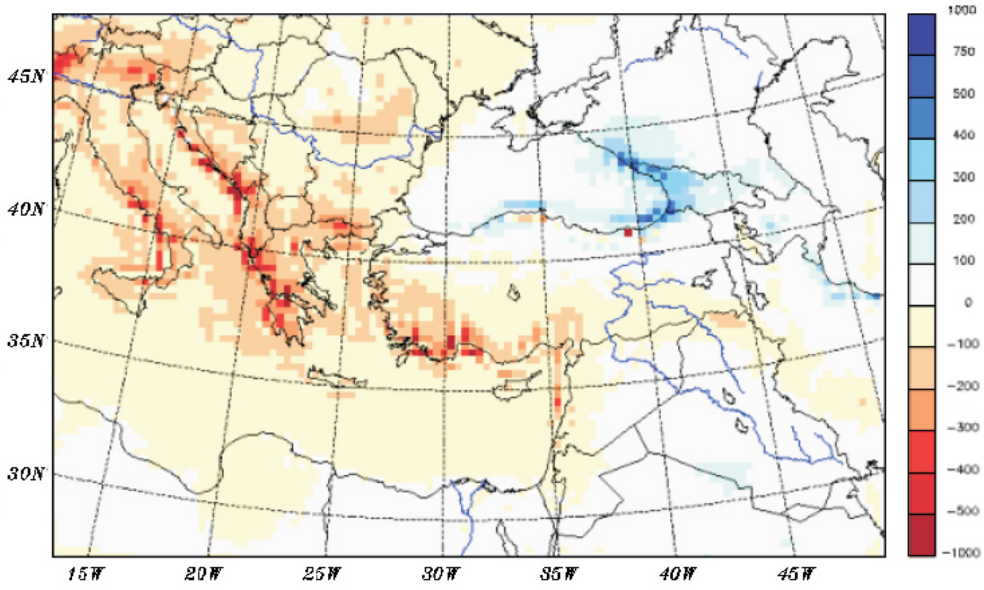


Figure 1.1-6. Differences in annual temperatures and precipitations between A2 run (2071-2100) and control run (1961-1990) (Dalfes *et al.*, 2007).

1.2 Species Distribution Modelling

For centuries, the patterns of species distribution on Earth have attraced academic study. Early scientific studies were mostly qualitative (Grinnell, 1904). For centuries, the patterns of species distribution on Earth have attracted academic study. Now, quantitative methods, such as numerical models, are widely used for describing patterns as well as for making predictions. There are different numerical techniques used for different purposes. One of the most frequently used is a predictive approach called species distribution models (SDMs).

SDM indicates empirical models that relate species distribution data (most of the time presences/abundances and rarely absences) at known locations to environmental and/or spatial characteristics of those locations (environmental predictor variables) (Guisan and Zimmermann, 2000; Elith and Leathwick, 2009). These types of models can be used to give insight about and/or predict the species' distribution across a pre-determined region. A variety of SDM models are described in the literature. These are referred to by a variety of terms, including bioclimatic models, climate envelopes, ecological niche models, habitat models, resource selection functions, range maps, correlative models and spatial models. In this study SDM refers to these kinds of models, but excludes those which are mechanistic, process-based (Kearney and Porter, 2009), or concentrating on community-level processes (see Ferrier and Guisan, 2006 for a review).

Broadly speaking, current SDMs integrate recent developments in statistics and information technology to long-standing ecological concepts. Precursors of SDMs were developed in an attempt to describe biological patterns in relation to surrounding geographical and/or environmental gradients (e.g., Grinnell, 1904; Murray, 1866; Schimper, 1903). Later, convergent developments in field-based ecological studies on species-habitat interactions and physical geography techniques provided new data and information systems (GIS) inducing modern quantitative modelling and mapping of species distribution techniques. On one hand, these developments enabled production of robust and detailed digital elevation models, interpolation of climate parameters, and remote sensing of surface conditions in conjunction with improved statistical modelling techniques. On the other hand, they provided an important tool for storing and manipulating these obtained data for intended use (Foody, 2008; Swenson, 2008). However, even though records of species occurrences were also accumulating, information on species distribution could not keep up with the rapid increase in information about their physical environment. Current SDMs emerged once these two lines, the new statistical methods from field-based habitat studies and GIS-based environmental layers, are linked together. The earliest species distribution modelling attempt found in the literature is the niche-based spatial predictions of crop species implemented by Nix *et al.*, (1977) (Guisan and Thuiller, 2005). These were followed by the pioneering simulations of species distributions conducted by Ferrier (1984) (Guisan and Thuiller, 2005). In his study, Ferrier (1984) used Generalized Linear Models (GLMs) (logistic regression) to predict the distribution of the Rufous Scrub-bird. Basic functions of GLMs (non-normal error distributions, additive terms, nonlinear fitted functions) continue to underpin SDMs as a crucial component of many current methods including the maximum entropy models used in the current study (e.g. Maxent; Phillips *et al.*, 2006)(Elith and Leathwick, 2009).

There are a number of Species Distribution Modelling (SDM) methods that estimate the probability distribution for a species' occurrence based on environmental constraints. The maximum entropy modelling technique (Maxent) (Phillips *et al.*, 2004, 2006; Philips and Dudík, 2008) is one of those, requiring only species presence data (not absence). It has been applied to very different organisms for very different purposes, including modelling distributions of not only common species but also narrowly distributed endemics with the aim of determining population extent, finding new populations or predicting effects of climate change. Studies show that it performs best among many different modelling methods (Elith *et al.*, 2006; Ortega-Huerta and Peterson, 2008), and that it may remain efficient despite small sample sizes (Hernandez *et al.*, 2006; Pearson *et al.*, 2007; Papes and Gaubert, 2007; Wisz *et al.*, 2008; Benito *et al.*, 2009). Also, one of the most recent studies on model comparisons (Giovanelli *et al.*, 2010) pointed out that Maxent is the only method that retrieved consistent predictions across calibration areas, while allowing for some overprediction, a result that may be relevant for modelling the distribution of spatially restricted organisms. In consideration of these advantages, Maxent software (version 3.3.3.a) was used throughout this study.

Figure 1.2-1 shows the general sheme of a species distribution modelling procedure. As indicated, SDM initiates by collating available species distributional data and environmental features through the area of interest. These data are then evaluated for their accuracy and relevance for modelling. Once the model is generated, its accuracy is assessed by certain techniques. All of these assessment techniques and other details about modelling will be discussed in following sections, especially Chapter 2.

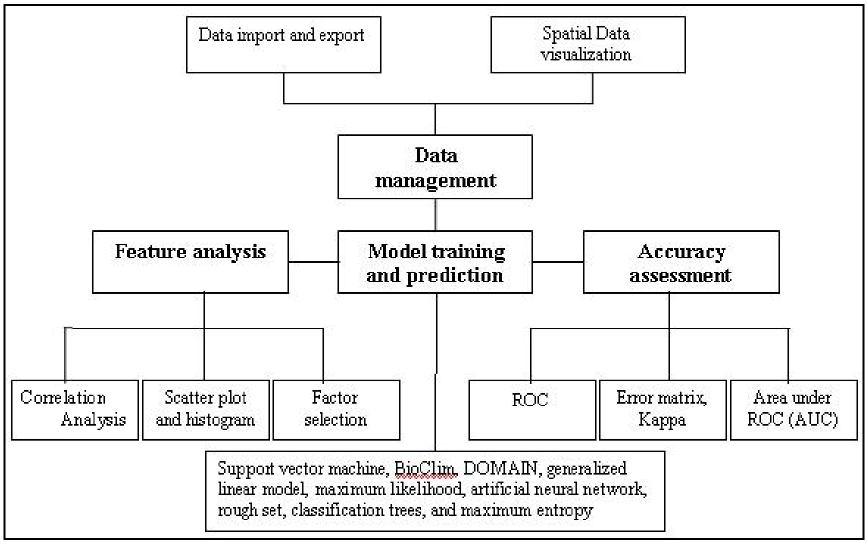


Figure 1.2-1. A schematic illustration of the species distribution modelling methodology (this scheme will be explained in detail in following sections). (Source: Laboratory of Spatial Analysis and Remote Sensing, Sierra Nevada Research Institute, 2011).

SDM represents an important tool in biogeography, evolution, ecology, conservation, and invasive-species management (some examples are: Busby, 1986; Nicholls, 1989; Walker, 1990; Walker and Cocks, 1991; Sindel and Michael, 1992; Wilson *et al.*, 1992; Box *et al.*, 1993; Carpenter *et al.*, 1993; Austin and Meyers, 1996; Kadmon and Heller, 1998; Yom-Tov and Kadmon, 1998; Corsi *et al.*, 1999; Peterson *et al.*, 1999, 2000; Fleishman *et al.*, 2001; Peterson and Vieglais, 2001; Boone and Krohn, 2002; Fertig and Reiners, 2002; Scott *et al.*, 2002, Guisan and Thuiller, 2005, Gamarra and He, 2008, Bradley, 2009 a, b). It supports a rich diversity of applications, yet arguably with varying degrees of success. Rate of success is dependent on various independent factors. The most important ones concerning this study can be summarized as follows.

Scale:

Identifying the appropriate scale for modelling is one of the most central and vital challenges of SDM building, as inappropriate selection can yield misleading results (Wiens, 2002).

Scale is best expressed independently as the extent of the study area and resolution (grain size), since modelling large areas does not necessarily mean using a coarse resolution. Extent indirectly indicates the purpose of the study. For example, those concentrating on global change generally adopt a continental to global scope (e.g., Araújo and New, 2007), while others targeting conservation planning rather prefer local to regional extents (Fleishman *et al.*, 2001; Ferrier *et al.*, 2002 a, b). Meanwhile, resolution gives an idea about the properties of the data or analysis. It is the grid cell size or polygon size of the predictor variables as well as the spatial accuracy and precision of the species records (Dungan *et al.*, 2002; Tobalske, 2002; Elith and Leathwick, 2009). Theoretically, resolution should be consistent with the information content of the data; however, this is generally impossible to achieve in practice (Gusian, 2005; Elith and Leathwick, 2009). Most of the time there is a lack of consistency between resolutions of available information. For example, even if species distribution data is very precise and accurate, a given model would still fail to predict distribution of the species very accurately if the environmental variables are not as detailed (fine scaled data vs coarse data). The model would not be able to reflect microscale interactions.

Theoretically, there is no specific scale at which ecological patterns should be studied (Levin, 1992). Rather, the appropriate scale should be determined according to the study purpose, the technique, and available data. Some researchers compared probable drawback of using coarse versus fine scale data in models (e.g., Ferrier and Watson, 1997). Elith and Leathwick (2009) indicated that different effects of scale depend on the spatial accuracy of the data, characteristics of the terrain and species, and the intended application. A number of modellers pointed out that hierarchy might be important while investigating the effects of environment on species distributions (Allen and Starr, 1982; Cushman and McGarigal, 2002; Pearson and Dawson, 2003). They indicate that in terrestrial systems while climate is the main factor shaping species distributions at the global scale (coarsest resolution, largest extent); topography and rock type create the finer-scale variations in climate, nutrient availability, while water flows influence distributions at finer scales (meso- and toposcales; a few to hundreds of kilometers) (e.g., Mackey and Lindenmayer, 2001). Others indicate that scale can be determined according to the species' viewpoint depending on the concept of selection orders (selection of home range, population block, and geographic range), accordingly the study would focus on the interactions between mobile animals and spatial arrangement of their environments (Addicott *et al.*, 1987). Arguments on these concepts have a long history and debate on how to deal with scale disparities when fitting SDMs is still continuing.

Geographic and Environmental Space: Spatial Autocorrelation

First law of geography stated by Tobler (1970) indicates that "everything is related to everything else, but near things are more related than distant things". This is the basic theory underlaying the ‘spatial autocorrelation’ concept. Spatial autocorrelation occurs when values of a variable at nearby locations are more similar than those at distant locations. It is common in ecological and geological data. Yet, sometimes it may violate the assumption of independence among samples or variables (Liebhold and Sharov, 1998) which would be a major problem for SDM.

The distinction between geographic and environmental space is another important concept for SDMs. While geographic space is represented by two-dimensional map coordinates or three-dimensional digital elevation models, environmental space is represented by a set of features reflecting its multi-dimensional nature (Elith and Leathwick, 2009). As environment is one of the basic driving factors structuring species distributions, it should be included in SDMs. However, if only environmental predictors are used, SDMs can only model the variation in occurrence of the species in environmental space while neglecting geographic space. In other words, a given model would only relate environmental conditions for species existence, ignoring effects of geography.

Species are generally clustered either as a result of their response to spatially autocorrelated environmental factors and/or effects of factors operating primarily in geographic space (Legendre, 1993). So, it is expected and common to observe mapped predictions showing clustered distribution patterns. Yet, SDMs using solely environmental predictors undesirably reflect the spatial autocorrelation of selected environmental variables rather than natural clustering patterns (Figure 1.2-2). In other words, clustered distribution patterns can either be a reflection of the natural conditions or they can be an artifact of poor representation of environmental and geographic spaces added by spatially autocorrelated variables.

If the distribution of a species is largely determined by environmental factors, a properly specified model fitted using an adequate set of predictors will display minimal spatial autocorrelation in its residuals. However, this is not always the case. Sometimes, a strong residual geographic patterning is observed. This kind of result indicates that either key environmental predictors are missing (Leathwick and Whitehead, 2001), or the model is mis-specified (e.g., only linear terms where nonlinear are required), or geographic factors; such as glaciation, fire, connectivity, movement, dispersal, or biotic interactions, are influential on species distribution (Dormann, 2007; Miller *et al.*, 2007). In order to overcome these problems, additional relevant predictors, geographic variables and/or realistic estimates of dispersal distances or movement should be integrated to these models (Ferrier *et al.*, 2002a).

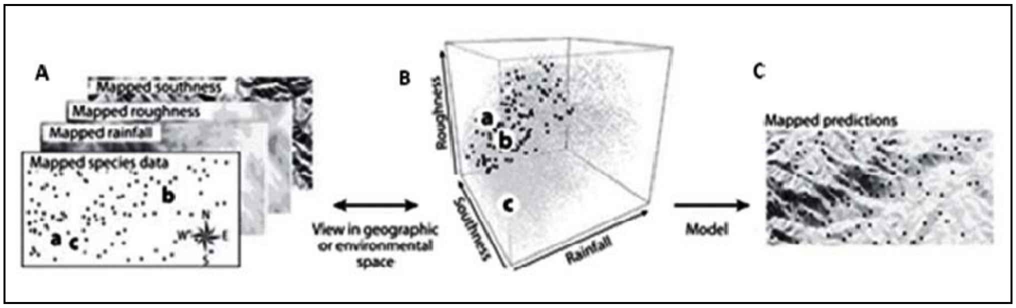


Figure 1.2-2. An Illustration of SDM. A: Relationship between the occuernces of the species and environmental variables, B: Representation of A on environmental space, C: Predicted distribution of the species using only environmental variables Note that, inter-site distances in geographic space might be quite different from those in environmental space — A and C are close geographically, but not environmentally. Predicted distribution pattern (C) represents the patterning of autocorrelation. (Elith and Leathwick, 2009)

Species Distribution Data: Survey Bias (Biased Sampling)

Most of the SDM techniques assume that species occurrence data are unbiased, independent samples from the distribution of the species. Yet, this assumption is easily violated. Species distribution data might harbour biases and errors originating from different sources. Potential sources of this bias and error should be carefully considered while collating species' distribution data. Some of these sources can be summarized as:

Survey Effort: Occurrence data are often biased as collectors tend to sample in easily accessible locations, such as road and river sides especially close to towns or biological stations (Reddy and Dávalos, 2003; Graham *et al.*, 2004). These kind of data exhibit strong spatial bias in survey effort (Dennis and Thomas, 2000; Reddy and Dávalos, 2003; Schulman *et al.*, 2007), meaning simply that some sites are more likely to be surveyed than others; such bias is typically spatially autocorrelated.

Purpose of the Survey: In some cases, available species distribution data might not be diversed or discrete enough, failing to represent all of the available environmental conditions that the species utilizes. This kind of bias is usually faced when historical data, such as museum records, is used. Great care should be taken while utilizing records from such collections. It is very important to keep in mind that these records were not generally collected with the aim of determining species full range or defining factors affecting their distributional patterns; rather, they are generally are biased toward rare and previously unknown species.

Incorrect Identification: Incorrect identification of a species might be another source of bias.

Inaccurate Spatial Referencing of Samples: This is the case when locations are given in respect to local landmarks using vague distance measurements. These can be very biased and misleading as these landmarks generally are not static and are hard to locate by non-locals.

Collection Techniques: Sampling techniques used while collecting data might violate the assumption of independence between records. For example, quadrat sampling widely used in plant studies is usually regarded as statistically independent if the samples collected are sufficiently geographically separated. Conversely, samples located along the same line collected by linear techniques such as continuous tow sampling (marine biology) and transect sampling (terrestrial biology) lose their independence (Elith and Leathwick, 2009).

Species Mobility: As a result of their wide applications, SDMs have been applied to a variety of environments and species from many biological groups; including insects (e.g. Buse *et al.*, 2007; Bässler *et al.*, 2010), birds (e.g. Barbet-Massin, 2009), reptiles and amphibians (e.g. Carvalho *et al.*, 2010), macroinvertebrates in streams (e.g. Durance and Ormerod, 2007) and genetic diversity (e.g. Habel *et al.*, 2011). SDMs from these diverse fields have both common and distinct sides, due to differences in mobility between species. It is relatively easier to characterize a sessile species environment, as it only interacts with the conditions that exist around it in close proximity, which generally can be included to the model by using information available at the sample site. For example, the water flowing into a site can be modelled by using existing topographic information. Conversely, mobile species use patchily and often seasonally distributed resources across a wide area. So, defining their interactions with the environment at any given location can be challenging, especially for some combinations of mobility and life-history characteristics (Elith and Leathwick, 2009). Also, detection of mobile species in the field is generally harder and challenging and time-consuming.

Presence and Absence: Species data can be ‘presence-only’ or ‘presence–absence’. Presence-only data consist of records describing known occurrences (presence) of species, while lacking information about absences; e.g., radiotelemetry data collected in wildlife studies and observations obtained opportunistically, such as museum records.

Mostly, species data is presence-only data derived from museum or herbarium specimens existing in the form of locational descriptions or georeferenced coordinates of latitude and longitude for confirmed localities (Baker *et al.*, 1998;

Funk *et al.*, 1999; Soberón, 1999; Ponder *et al.*, 2001; Stockwell and Peterson, 2002, Hortal *et al.*, 2008). Millions of records compiled from these collections are often used for evolutionary biology, macroecology, conservation, invasive species, and climate change modelling (Graham *et al.*, 2004).

Despite this widespread use, there is not a best way for modelling presence-only data. The most appropriate method for modelling such data is in constant debate amongst modellers. At first, analytical methods were restricted to envelopes and distance measures; currently, methods comparing presence records with background or pseudoabsence points are commonly used (e.g., using GARP, ENFA, MaxEnt, and regression methods) (Franklin, 2010b; Elith *et al.*, 2006).

Attitudes towards the value of presence-only data vary between researchers. Some argue that presence-absence or abundance data would lead to much more robust results. It is very difficult to collect this kind of data. So, this view, if accepted, has substantial implications for the type of data that ecologists should aim to collect. Phillips *et al.* (2009) suggest that presence-absence data is advantageous as it carries valuable information about surveyed locations, enabling analyses of biases and prevalence. Yet, others, concentrating on the concept of potential distributions, such as Jiménez-Valverde *et al.* (2008), argue that absence records can be problematic. The absences can introduce confounding information to the model because species can be absent at a location either if the habitat is unsuitable or it is suitable but unoccupied at the time of sampling, mostly because of inaccessibility for the species (e.g. neoendemics). Also, absence data is sometimes regarded as misleading because it is very hard to detect accurate absence locations. A species might not be detected at a certain location if the species or environment is not at equilibrium (e.g., invasions, climate change, or other environmental changes have prevented succession to equilibrium), A species may be absent even though the environment appears to be suitable, for example due to dispersal limitation, or metapopulation dynamics. A species may also be absent because it is not easily detected. Such cases are referred as ‘false absences’ and environmental conditions at these locations will be regarded as unsuitable, even though they may well be suitable. This condition seriously adds bias to analyses. This bias, referred to as ‘survey bias’ or ‘biased sampling’, can severely impact model quality; however, the effect of such bias has received little attention in the SDM literature (Philips *et al.*, 2009).

Literature discussing the relationships between these different views and ecological and statistical theory is relatively scarce. In light of these, Elith and Leathwick (2009) suggest that not only these topics, but also methods for detecting and dealing with sample bias and for evaluating presence-only models, should be developed.

Equilibrium vs. Non-equilibrium with the Environment:

Data used for SDMs are generally collected during a limited time and/or space, so models using these data can only reflect the interactions relevant to that period. Under these conditions, models generally assume that the species is in pseudo-equilibrium with its environment in order to be prudent (Guisan and Theurillat, 2000). When this assumption is valid SDMs can perform well and succeed in predicting natural distributions of species within a sampled space, in conditions where an appropriately specified model is combined with well-designed survey data and functionally relevant predictors. This kind of analysis can provide useful ecological insight with its robust predictive capability. By contrast, violation of this assumption adds controversies to the models, complicating the modelling applications and leading to equivocal results (Elith and Leathwick, 2009).

Biotic Interactions

In general, biotic interactions are conditions in which the distribution of one species influences the distribution of other species. It can be within (e.g. due to competition, facilitation and parasitism in plants) or between groups, such as relationships in food webs (e.g. herbivory, predation and symbiosis). Most models tend to ignore these interactions, linking species distribution only to environmental constraints. This topic was widely debated amongst academics which led to evaluation of the effects of biotic interactions on SDMs. Studies showed that, while biotic interactions do not have any significant effect on predictions at continental scale (Araújo, 2007), inclusion of additional predictor variables representing biotic interactions (e.g. presence–absence of known competitors) can significantly increase the predictive power of models at finer scales (Leathwick and Austin, 2001; Anderson *et al.*, 2002). However, it should be noted that: even though these results indicate that existence of a competitor might be influential on a species distribution both at local and regional scales, they do not prove that this is the case in reality (Guisan and Thuiller, 2005). Rather, addition of other species distributions as predictors might provide information about physical conditions that are not represented by included environmental descriptors.

Determining the appropriate biotic predictors to include, and at which spatial and temporal scales, is therefore very challenging. For example, Huston (2002) suggests that competitive interactions may act at more localised scales than other types of interactions. As one might expect that the results of experimental studies adressing biotic interaction would provide some clarification; however, such experiments have only rarely been performed outside laboratory conditions (Silvertown, 2004). Diversity of biotic interactions, including facilitation, pollination, herbivory, predation, parasitism or symbiosis, further complicates applicability of those kinds of studies (Guisan and Thuiller, 2005). Therefore, inclusion of biotic interaction to SDMs is a very challenging topic generally limited by the scarcity of available information.

There are different factors effecting success of SDMs. Yet, this does not limit the usage of SDMs. The application of SDMs experienced a slight but important shift over time. While most of the preliminary SDMs were focused on ecological concepts, trying to understand natural drivers of species distributions (Mac Nally, 2000), current studies mostly focus on predicting species distributions (Elith and Leathwick, 2009).

Prediction is used in two main approaches: One of them is called the ‘model-based interpolation to unsampled sites’. These basically use the collected data to predict a species’ full distribution within the same range and during the time frame in which the sampling occurred. This kind of analysis is typically used for mapping global distributions of species, mapping within a region for conservation planning or resource management, and identifying suitable habitat for rare species (Guisan and Thuiller, 2005). Elith and Leathwick (2009) state that such analysis can be very informative and reliable for effective decision making if the data and model are shown to be accurate, and correlations between predictor variables are stable across the studied region.

The second approach is generally termed ‘extrapolation’ or ‘forecasting’ (Araújo and New, 2007; Miller *et al.*, 2004). These are predictions using collected data for predicting species probable distribution over new and unsampled geographic regions (e.g. invasions) and/or times (e.g. future or past climates). Environmental conditions in these new times and places should be carefully assessed as new environments can show new combinations of predictor variables and/or predictor variable with values outside their original ranges in the current distribution data (Elith and Leathwick, 2009). Also, there is no information directly supporting the realibility of these predictions, so they should be handled with great care.

Figure 1.2-3 illustrates an example of SDM preformed for predicting possible climate change effects on the distribution of a tree species, *Picea abies.* Basically, this procedure initiates by collecting available data about species current distribution. Then a model is generated depending on this knowledge. Finally, this model is further used for predicting possible effects of climate change on the species distribution.

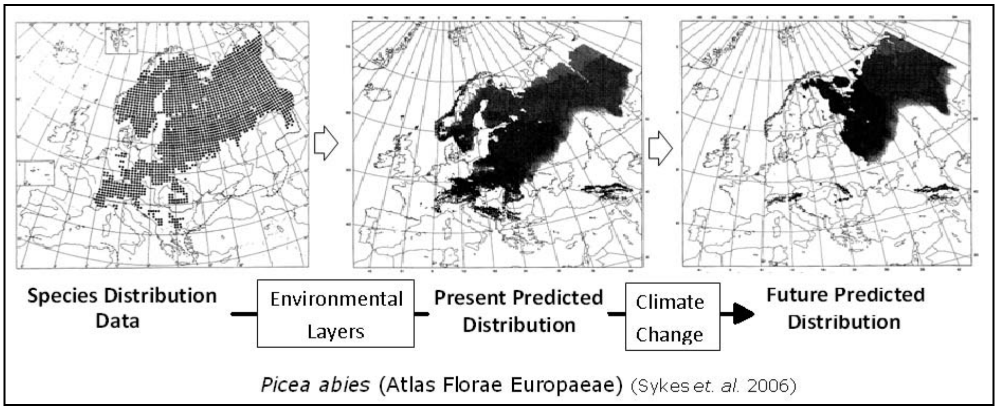


Figure 1.2-3. An example to use of SDM for future extrapolation (Sykes *et al.*, 2006)

Broadly, models try to fit a predicted distribution area to the available distribution data as realistically as possible. Their success in achieving this reflects their reliability. So, in order to reduce the unreliability of the prediction, different evaluation methods are applied during the model-fitting process and for testing predictive performance of a model. (Hastie *et al.*, 2009). Evaluations by these methods give ideas about the successes of different cases and allow comparisons between different modelling applications. Recent comparisons have shown that new developments in SDMs coupled with improvements that enable ensemble forecasting can reduce prediction uncertainties significantly (Elith *et al.*, 2006; Pearson *et al.*, 2006; Araújo and New, 2007; Marmion *et al.*, 2009; Carvalho *et al.*, 2010). With the integration of ensemble forcasting, modellers able to overcome the problem of prediction variability caused by different modelling techniques and/or different climate models. However, validation of models predicting effects of climate change on species distributions is still challenging and is rarely done (Franklin, 2010b). Consequently, researchers should strive to develop robust modelling techniques and validation methods in order to obtain more realistic extrapolations (Elith and Leathwick, 2009).

In order to be able to conserve biodiversity especially in the face of climate change we need to help them to survive and provide time to adapt. This is only possible if we first understand how they will respond to effects of environmental change, particularly those effects of climate changes. Although extrapolations of SDMs are still controversial (Figure 1.2-4), they are one of the few tools that can give us some idea about the possible impacts of forecasted climate change, that can be applied to a wide range of species and ecological systems (Huntley *et al.*, 2004). So, actually these applications can be regarded as a first step in assessing a species' vulnerability to climate change, informing us about the range of likely consequences under various scenarios (Araújo *et al.*, 2005a; Heikkinen *et al.*, 2006; Lawler *et al.*, 2006; Yates *et al.*, 2010; Bässler *et al.*, 2010; Gibson *et al.*, 2010).

Such extrapolations of climate-change scenarios, predict dramatic changes for many species (e.g. Williams *et al.*, 2003; Thomas *et al.*, 2004; Beaumont *et al.*, 2005). Actually, some of recent pole-ward and elevational shifts of the species distributions due to climate change (Root *et al.*, 2003) mirror result of SDM predictions (Beaumont, 2008).

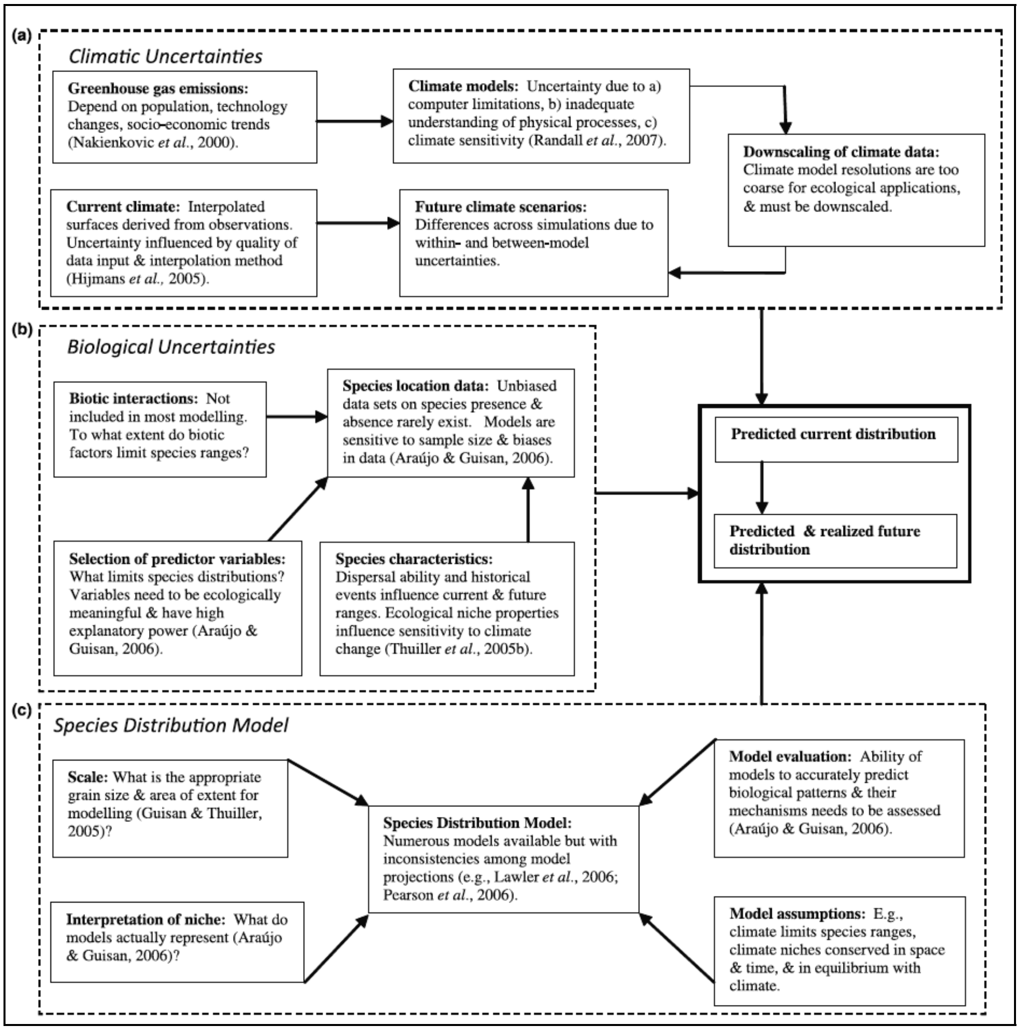


Figure 1.2-4. Some major sources of uncertainty in projections of current and future ranges of species. These can be categorized into those resulting from (a) climate scenarios, (b) characteristics of species and species- location data, and (c) species distribution models (Beaumont *et al.*, 2008).

1.3 Aim of the Study

Locally endemic species are prioritised for conservation research because of their vulnerable nature. However, these species are often understudied or information is lacking specifically regarding their full distributions. In this regard, Turkey is not an exception; some knowledge gaps are certainly related to its high levels of endemism. Basic distribution data available for such species are generally limited to herbarium data which are scarce and highly biased. It is very important to be able to fill these gaps in order to be able to implement appropriate conservation measures in the future.

The profound significance of climate change urges conservationists to account for its probable affects. However, possible effects of climate change have not yet been fully integrated into protocols for reserve selection or conservation strategies in Turkey. In order for this integration to occur, conservation decision makers requires reliable information on which species are threatened and their habitats, in combination with assessments of the uncertainties involved in these studies. However, this information is currently very challenging to provide due to the lack knowledge regarding species distributions.

The current study attempts to address the limitations, caused by the lack of data on endemic species distributions and knowledge on which species and habitats are threatened by climate change, to the development of correctly targeted conservation strategies. There are two interconnecting aims of this study:

Aim 1**:** Understanding and modelling the distribution of endemic species successfully;

- firstly by developing an appropriate way of data collection methodology for locally endemic plant species suitable for modelling purposes,
- and then by modelling current distributions of species in combination with rigorous validation techniques.

Aim 2: Predicting effects of climate change on the biodiversity of Turkey;

- by predicting expected changes in distribution of species under available climate change scenarios.

CHAPTER 2

MATERIALS AND METHODS

Key steps in good modelling practice include the following: gathering relevant data; assessing its adequacy (the accuracy and comprehensiveness of the species data; the relevance and completeness of the predictors); deciding how to deal with correlated predictor variables; selecting an appropriate modelling algorithm; fitting the model to the training data; evaluating the model including the realism of fitted response functions, the model's fit to data, characteristics of residuals, and predictive performance on test data; mapping predictions to geographic space; selecting a threshold if continuous predictions need reduction to a binary map; and iterating the process to improve the model in light of knowledge gained throughout the process (Elith and Leathwick, 2009). These main steps with detailed information about them are explained in this chapter, with particular reference to the current study.

2.1 Study Species

2.1.1 Selection of Species

Endemic or rare species distributions are of primary concern in mapping boundaries of proposed conservation areas. This is particularly so in Turkey with its high rate of plant endemism.

For the purposes of this study and given the resources allocated, the species distributions to be modeled should be a) representative of the plant life of Turkey b) known to exist in a sufficiently broad area c) including only species which are identifiable in the field by a moderately experienced person and thought to occupy a restricted range. Therefore, the selection of species to be modelled has been a meticulous process.

The province of Ankara had a central role in this study due to environmental as well as logistic reasons. Not only does the Ankara province span a variety of different topographic and environmental features, but it is where the supporting research institute and author are based, facilitating efficient and economic fieldwork practices. The region supports a variety of plant species with various climatic and edaphic requirements, which lend themselves ideally to this study. Of the Spermatophyta, 1365 species from 99 families have been recorded in the study region (unpublished data, M. Vural). While 271 (equating to 19.85%) of these are endemic to Turkey, 22 of them are endemic to Ankara (unpublished data, M. Vural).

For the reasons explained above, all endemic species recorded within the Ankara province were subject to an evaluation for use in this study. The evaluation process considered the following basic characteristics:

1. Known distribution: Species with their known range towards the north central Turkey (Ankara province) were preferred. Both species with very restricted and those with wider (regional) distributions were selected to represent both restricted and widely distributed (within study region) types.

2. Life history characteristics: Species were selected to represent the dichotomies of both annual/perennial and woody/herbaceous.

3. Clarity of the taxonomic status: Taxa with controversial status as a good species were left out.

4. Ease of identification: Only species that could be safely identified from other similar species by the author were considered.

5. Detectability in the field: Species that were cryptic, growing very low or in inaccessible places were omitted.

6. Availability of the distributional data: If sufficient distribution data were not already available (e.g. recorded from only 2 locations), those species were not considered.

Following the points listed above, first, we determined the provinces at which 271 species were known to be present with the help of TÜBIVES (Turkish Plants Data Service, http://wwweski.tubitak.gov.tr/tubives/) database. The species were categorized into different groups according to their differing life history characteristics such as growth form, height, life span etc (Davis, 1988). These characters were deemed to be adaptations to their habitats. This list was shortened further to include only those species with narrower distributions and contrasting life history characters, in order to include as a diverse variety of species as possibly can. As a result, a set of 24 potential study species was reached. A panel of experienced systematic biologists (Prof Dr. Mecit Vural, Prof. Dr. Musa Doğan and Prof. Dr. Ali Dönmez) reviewed this list further and removed 11 species on the basis that they were taxonomically under dispute or difficult to identify.(leaving 13 candidate species (Table 2.1-1, Appendix A).

To delimit variation between these species their known altitudinal ranges were plotted (Figure 2.1-1). It should be noted at this stage that, due to the uncertainty of data availability, some similar species, such as. *V. heterobarbatum* and *V.*

ancyritanum, remained within the list but were later omitted during further analyses.

Next we determined the exact known distribution and number of available records of listed species. For this we consulted all accessible published records from literature and herbaria. Therefore, the first exercise, was a review of all available publications, especially Flora of Turkey (Davis, 1988), and others such as Baytok (2008). Then Gazi University, Ankara University and Hacettepe University herbaria as well as private herbaria, such as those of Dr. Ali Dönmez and Dr. Galip Akaydın were searched for available records.

Table 2.1-1. List of selected 13 candidate species

Family	**Species**
Apiaceae (=Umbelliferae)	*Prangos denticulata* FISCH. et MEY.
Asteraceae	*Centaurea tchihatcheffii* FISCH. et MEY.
Brassicaceae	*Aethionema dumanii.* VURAL et ADIGUZEL
Caryophyllaceae	*Dianthus ancyrensis* HAUSSKN. et BORNM.
Chenopodiaceae	*Salsola grandis* FREITAG et al.
Dipsacaceae	*Scabiosa pseudograminifolia* HUB.-MOR.
Fabaceae	*Astragalus coodei* CHAMB. et MATTHEWS
Fabaceae	*Astragalus panduratus* BUNGE
Iridaceae	*Crocus ancyrensis* (HERBERT) MAW
Lamiaceae	*Salvia aytachii* VURAL et ADIGUZEL
Rosaceae	*Crataegus tanacetifolia* POIR. PERS.
Scrophulariaceae	*Verbascum ancyritanum* BORNM.
Scrophulariaceae	*Verbascum heterobarbatum* HUB.-MOR.

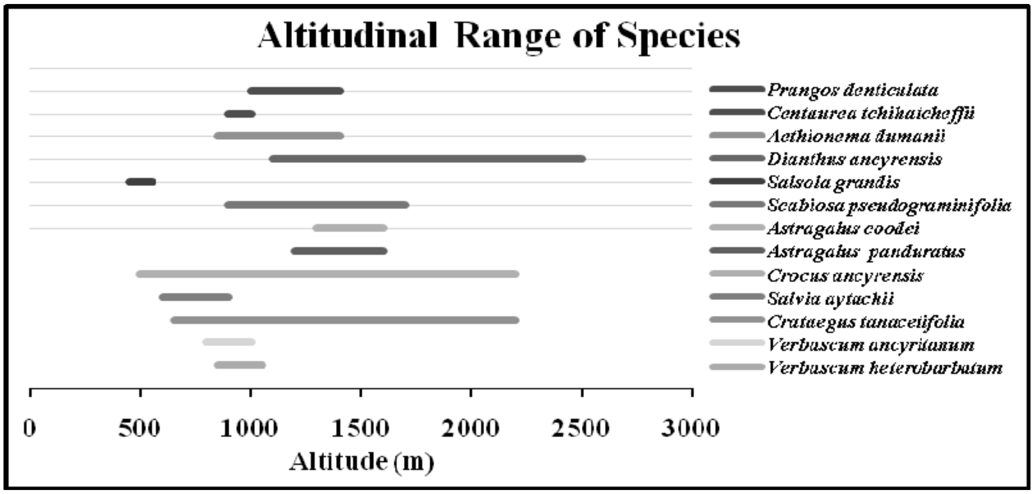


Figure 2.1-1. Altitudinal range of each candidate species.

Several such records did not have exact location information. Indeed, only the most recent records of *Crataegus tanacetifolia* had coordinate information, as the species had recently been studied in detail by Dönmez (2004, 2005, 2007, 2008). In addition, some species had been recorded only from a few locations and/or had very old records from certain locations. In order to overcome these problems, preliminary field work was carried out through 2007 to determine the validity of these records or to confirm exact locations of those species suggested by the available data (Table 2.1-2). This preliminary fieldwork, concentrating only on presence locations, gave an idea about the detectability of several candidate species in the field. The final eligibility of our study species following preliminary fieldwork is presented in Table 2.1-3.

In light of these results and following joint assessment with the panel of systematic biologists, *Centaurea tchihatcheffii*, *Crocus ancyrensis*, *Salvia aytachii* and *Crataegus tanacetifolia* were determined as the most appropriate species for the study. These four species represent two very restricted-range species and two with wider distributions; also they include both perennial (3 species) and annual (1 speices) subjects. From a plant life form perspective, they are composed of a phanerophyte, a geophyte, a chamaephyte and a therophyte.

Table 2.1-2. Summary of data obtained during preliminary fieldwork showing the number of records obtained vs. effort per day and their locations.

Species	**Presence Data Obtained during Preliminary Fieldwork**			
	# of records	**# of locations (Coarser Scale)**	**Fieldwork Interval**	**Effort (days)**
Prangos denticulata	1	1: Ankara (Hüseyin Gazi)	May-July	4
Centaurea tchihatcheffii	1	1: Ankara-Gölbaşı	April	1
Aethionema dumanii	3	1: Ayaş (Aysantı Passage)	May	2
Dianthus ancyrensis	1	1: Bolu (between Abant Lake and Mudurnu, other places are covered as well but none found)	July	7
Salsola grandis	5	1: Ankara (Çayırhan Bird Paradise)	August	3
Scabiosa pseudograminifolia	3	1. Ankara (Memlik Village, also Polatlı region is covered but none found)	June-July	7
Astragalus coodei	Not found	None (especially looked around Çubuk-Karagöl and Kızılcahamam National P.)	May-June	7
Astragalus panduratus	3	1: Ayaş (roadside close to Ayaş, other places are covered as well but none found)	June	3
Crocus ancyrensis	5	2: Ankara (Eymir Lake and Hüseyin Gazi)	March-April	4
Salvia aytachii	5	2: Ankara (Ayaş-Beypazarı and Polatlı Sivrihisar)	May	4
Crataegus tanacetifolia	38	8: Ankara (Çubuk-Karagöl, Beypazarı-Keltepe, Işık Dağı) and Bolu (Abant Lake, Yenice Forest, Dereören Village, Bolu-Abant Road, Gerede-Ankara Road)	July and October	7
Verbascum ancyritanum	Not found	None (especially looked around Dikmen and Beştepe regions)	May-June	5
Verbascum heterobarbatum	5	1: Ankara (around Beynam)	June	3

Table 2.1-3. Assessing eligibility of each species through evaluation of preliminary fieldwork findings. (loc: location, rec: records)

Species	Provinces where presence was documented	# of Herbarium Records	Preliminary fieldwork results	Eligible (Yes/No)
Prangos denticulata	2: Ankara, Kastamonu (1894)	4 loc (10 rec)	1 loc (1 rec)	**NO:** 2 of locations are old, so very few records and very close locations
Centaurea tchihatcheffii	1: Ankara	2 loc (10 rec)	1 loc (1 rec)	**YES:** distribution very well known
Aethionema dumanii	1: Ankara	2 loc (5 rec)	1 loc (3 rec)	**NO:** very few records and locations
Dianthus ancyrensis	5: Ankara, Çankırı, Bolu, Kastamonu, Bursa (1932)	13 loc (22 rec)	1 loc (1 rec)	**NO:** fieldwork was relatively unsuccessful
Salsola grandis	1: Ankara	1 loc (4 rec)	1 loc (5 rec)	**NO:** recorded from only 1 location
Scabiosa pseudograminifolia	3: Ankara, Eskişehir, Sivas	7 loc (13 rec)	1 loc (3 rec)	**NO:** 3 locations in Sivas, discrete distribution
Astragalus coodei	5: Ankara, Çankırı, Bolu, Kahramanmaraş, Adana	11 loc (16 rec)	Not found	**NO:** fieldwork was unsuccessful
Astragalus panduratus	4: Ankara, Kastamonu, Kırıkkale, Isparta	6 loc (7 rec)	1 loc (3 rec)	**NO:** very old records and discrete distribution

Table 2.1–3. Continued.

Crocus ancyrensis	19: Ankara, Kırıkkale, Kırşehir, Çankırı, Sivas, Kaysri, Kahramanmaraş, Kastamonu, Bolu, Yozgat, Eskişehir, Niğde, Çorum, Karabük, Zonguldak, Amasya, Samsun, Aksaray, Afyon	64 loc (83 rec)	2 loc (5 rec)	**YES:** very efficient fieldwork, wide but continuous distribution, many records, ease of identification
Salvia aytachii	2: Ankara, Eskişehir	2 loc (14 rec)	2 loc (5 rec)	**YES:** Very efficient fieldwork, main distribution limiting factor is gypsum soil
Crataegus tanacetifolia	20: Ankara, Bolu, Çankırı, Kastamonu, Eskişehir, Afyon, Amasya, Bilecik, Karabük, Kayseri, Kütahya, Malatya, Erzincan, Gümüşhane, Samsun, Sinop, Sivas, Tokat, Yozgat, Zonguldak	57 loc (71 rec)	9 loc (38 rec)	**YES:** clear systematic status revised recently, so many records and some with coordinates, very efficient fieldwork, wide but continuous distribution
Verbascum ancyritanum	2: Ankara Eskişehir	6 loc (10 rec)	Not found	**NO:** fieldwork was unsuccessful
Verbascum heterobarbatum	1: Ankara	3 loc (3 rec)	1 loc (5 rec)	**NO:** very few records and locations, and relatively unsuccessful fieldwork

2.1.2 Selected Species

2.1.2.1 *Centaurea tchihatcheffii* FISCH. et MEY.

Kingdom: *Plantae*
Division: *Magnoliophyta (Angiosperms)*
Class: *Magnoliopsida (Eudicots)*
(Clade): *Asterids*
Order: *Asterales*
Family: *Asteraceae*
Tribe: *Cynareae*
Genus: *Centaurea sect. Cyanus*
Species*: C. tchihatcheffii*
Binomial name: *Centaurea tchihatcheffii* FISCH. et MEY.

Figure 2.1-2. *Centaurea tchihatcheffii* photographed by Damla Beton and its place in the systematics (Ann. Sci. Nat. Ser. 4, 1:31, 1854).

Genus *Centaurea L.*, belonging to the *Asterace* family, contains 530 to 550 species and is distributed from Spain across southern Europe to Turkey and Iran (Klokov *et al.*, 1963). Wagenitz (1986) emphasized that Turkey, especially the south-western and eastern parts, is one of the main centres of diversity for this genus. Interdependently, it is the third largest genus in terms of the number of species in Turkey. 189 taxa have been reported from the Mediterranean and Irano-Turanian regions of Turkey (Wagenitz, 1975; Davis *et al.*, 1988; Wagenitz *et al.*, 1998; Guner, 2000; Duran and Duman, 2002; Turkoğlu *et al.*, 2003; Uzunhisarcıklı *et al.*, 2005; Vural *et al.*, 2006, Martin *et al.*, 2009). 112 of these, contributing to 60% of the genus, are endemic to Turkey (Martin *et al.*, 2009), and some of them are limited to a relatively small area such as a single mountain. *Centaurea tchihatcheffii* (Figure 2.1-2) is one of these restricted ranged endemic species.

Figure 2.1-3. *Centaurea tchihatcheffii* (Çakaroğulları, 2005; Tan and Vural, 2007).

C. tchihatcheffii is an annual sun-loving steppic species, occurring also as a segetal in cultivated fields and field margins. The species has some unique features not existing in any other *Centaurea* such as its funnel-shaped marginal florets with crenate margins as well as their attractive colours, most frequently red, pinkish red, pink, and rarely white (Wagenitz, 1975; Ekim, 1994; Tan and Vural, 2007)(Fig 2). Moreover, the anther-tube is provided with glands at the tips of the appendages (Wagenitz, 1975; Tan and Vural, 2007)(Figure 2.1-3) During vegetative period, the plant is branched from base and grows to height of 30 - 40 cm. Flowering period starts from mid April and May, and last until end of June depending on the environmental conditions. During flowering season several inflorescence stems develop from the main stem. Its fertile seeds disperse soon after ripening, yet they can not germinate easily as they need long vernalization treatment to break dormancy (Özel, 2002 and Özel *et al.*, 2006). It is mainly bee-, bug- and beetle-pollinated. Ants play an important role in seed dispersal and the fully ripe fat achenes are a delight for pigeons which settle down to feed in large flocks.

C. tchihatcheffii is distributed mainly around Gölbaşı-Ankara (Central Anatolia) extending up towards Konya (Figure 2.1-4). Records showed that its altitudinal range is only around 900 to 1000 m.

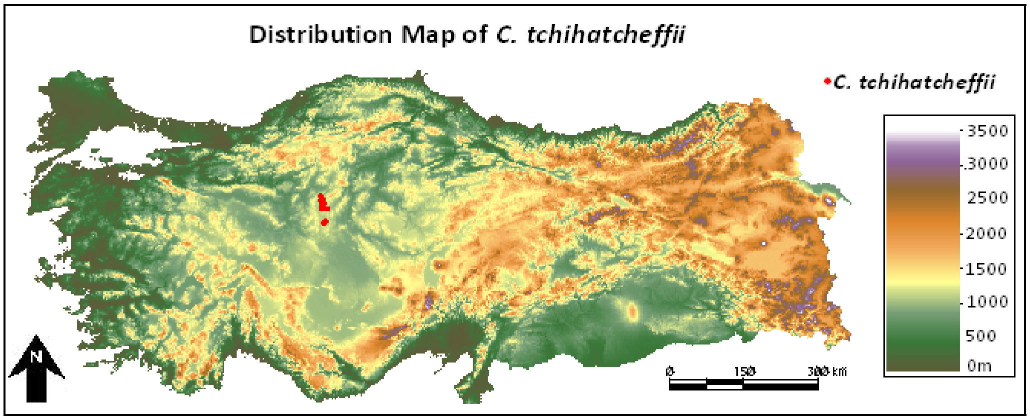


Figure 2.1-4. Distribution map of *Centaurea tchihatcheffii*.

This species is reported to be threatened with extinction due to its highly variable population trends. Even though 1–2 million were observed in 1999, its number dwindled down to only 85 individuals in 2001 but this trend was followed by a remarkable recovery reaching up to 900,000 individuals in 2003 (Çakaroğulları, 2005; Boşgelmez, 2005). Although there are usual periodic fluctuations in numbers frequently observed in most weeds from year to year, actual cause of the registered decline was attributed to changes in arable habitat and excessive use of herbicides

(Tan and Vural, 2007). Also, it had been sold in some quantity by street florists in Ankara, until this was prohibited a while ago. Consequently, it is simultaneously protected by the Convention on the Conservation of European Wildlife and Natural Habitats (Berne Convention). Moreover, there have been ongoing efforts to protect the plant. There is now an annual festival in Gölbaşi to provide public awareness for protection.

2.1.2.2 *Crocus ancyrensis* (HERBERT) MAW

Kingdom: *Plantae*
Superdivision: *Spermatophyta*
Division: *Magnoliophyta (Angiosperms)*
Class: *Liliopsida (Monocots)*
Order: *Asparagales*
Family: *Iridaceae*
Subfamily: *Crocoideae*
Genus: *Crocus*
Species: *C. ancyrensis*
Binomial name: *Crocus ancyrensis* (HERBERT) MAW

Figure 2.1-5. *Crocus ancyrensis* photographed by Damla Beton and its place in the systematics (Gard. Chron. N.s. 16:528, 1881).

Genus *Crocus L.* is composed about 85 bulbous perrenial species belonging to Iridaceae family. The genus *Crocus* includes about 80 species distributed from southwestern Europe, through central Europe to Turkey and southwestern parts of Asia, as far east as western China (Alavi-Kia *et al.*, 2008). Yet, it is mainly found in Mediterranean basin, especially in Balkans and Turkey (Mathew, 1984). Total of 73 of these taxa show distribution in Turkey (Mathew, 1982, 1984, 2000a, 2000b; Kerndorff and Pasche, 2004a, 2004b, 2006; Yüzbaşıoğlu and Varol, 2004; Candan *et al.*, 2008). 40 of these, 19 species and 21 sub- species, are endemic to Turkey (Kravkaz et. al., 2006). *Crocus ancyrensis* is one of these endemic species

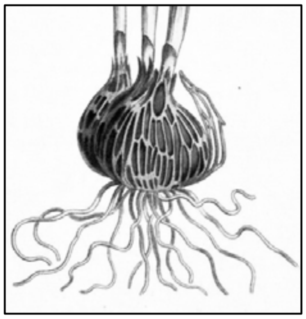


Figure 2.1-6. Tunic coarsly reticulate-fibrous corm.

Crocus ancyrensis (Figure 2.1-5) is a perrenial species easily distinguished with its tunic coarsely reticulate-fibrous corm (Figure 2.1-6) and golden flowers (Mathew, 1984). Blooming starts from second half of February till first half of March. Flowers survive for about 15 days depending on climate. Leafs initiate in just a couple of days before or with flowering. Its capsule can be observed in mid April above the soil as seed maturation is at the end of May which is about 45 days after flower disappearance (Kravkaz and Vurdu, 2010).

It is widely distributed in the Central Anatolia and the Western Black Sea region of Turkey (Figure 2.1-7). Herbarium records showed that it has a wide elevational range starting from 500m altitude up to 2200m. It is generally observed in dry and semi-dry grass and mixed deciduous forest areas and noted to prefer open rocky places, in scrub and in *Pinus* woods (Mathew, 1982, 1984).

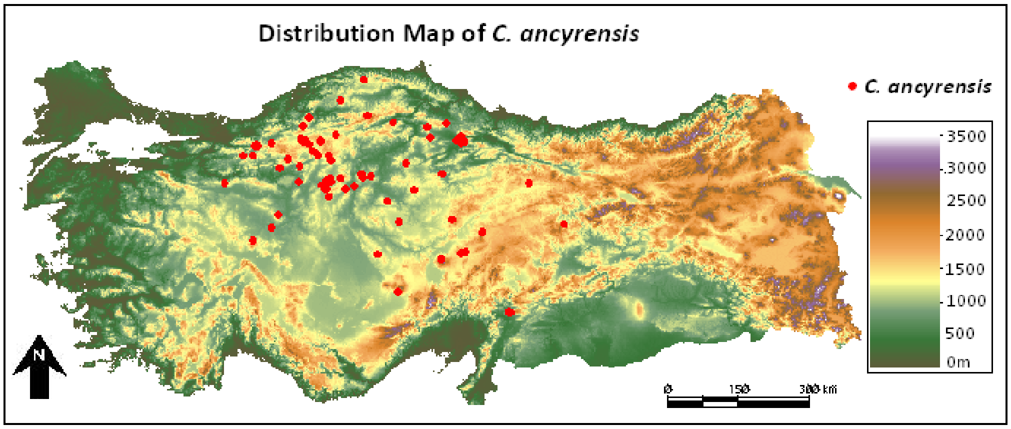


Figure 2.1-7. Distribution Map of *C. ancyrensis.*

Even though it has been domesticated, used and known by gardeners all around the world as the Golden Bunch, *C. ancyrensis* is threatened by heavy grazing, uncontrolled gathering, recreational pressure and many different kinds of land disturbances (personal observations, Özhatay, 2002; Kravkaz *et al.*, 2006; Kravkaz and Vurdu, 2010) through most of its natural range. Yet, it is categorized as Least-Concern within IUCN risk categories (Ekim *et al.*, 2000; IUCN, 2001). This controversy is either due to changes after the publication of the IUCN lists or reduced threats leading to a high abundance within its range.

2.1.2.3 *Salvia aytachii* VURAL et ADIGÜZEL

The largest genus of the mint family, *Salvia* (tribe *Mentheae*, *Lamiaceae*) consists of nearly 1000 taxa of annuals, perennials, and soft-wooded shrubs, distributed through most parts of the world except very cold regions and tropical rainforests (Walker *et al.*, 2004). The two largest centres of the genus are in America and in South-West Asia (Hedge, 1960, 1992; Duman, 2000; Walker and Elisens, 2001; Özkan *et al.*, 2008). Turkey is a major centre for Salvia in Asia (Vural and Adıgüzel, 1996). Thus far, 95 species have been described from Turkey except cultivars (Hedge, 1982; Huber-Morath, 1982; Vural and Adıgüzel, 1996; Dönmez, 2001; Hamzaoğlu *et al.*, 2005; İlçim *et al.*, 2009; Celep and Doğan, 2009; Celep *et al.*, 2009; Kahraman *et al.*, 2009; Behçet and Avlamaz, 2009; Karabacak *et al.*, 2009) More than 50% of these are endemic to Turkey, including *Salvia aytachii* (Figure 2.1-8).

Kingdom: *Plantae*
Division: *Magnoliophyta (Angiosperms)*
Class: *Magnoliopsida (Eudicots)*
(Clade: *Asterids*)
Order: *Lamiales*
Family: *Lamiaceae*
Genus: *Salvia L.*
Species: *S. aytachii*
Binomial name: *Salvia aytachii* VURAL et ADIGÜZEL

Figure 2.1-8. *Salvia aytachii* photographed by Damla Beton and its place in the systematics (Tr. J. Bot., 20: 531-534, 1996).

Salvia aytachii (Figure 2.1-8) is a caespitose perennial herb with a woody rootstock (Figure 2.1-9) and whitish pink flowers. Its stems can reach up to 20-50 cm. It is significantly different from its closest relatives mainly by its glabrous stem. Also, it has relatively smaller and narrower leaves, longer bracts and broadened calyx with subentire upper lip than *S. tometosa* Miller; and relatively more distant verticil lasters, longer glandular hairy calyx and longer corolla and pedicel than *S. cryptantha* (Vural and Adıgüzel, 1996).

S. aytachii is one of the narrowly distributed endemic species of Turkey. It is mainly a steppe species preferring marl places and gypsum soils. Its available records were only from two main locations; Ayaş-Beypazarı-Nallıhan and Polatlı-Sivrihisar regions (Figure 2.1-10).

Figure 2.1-9. *Salvia aytachii* M. Vural et N . Adıgüzel A-habit. B-stamen, C-corolla, D. E-calyx.

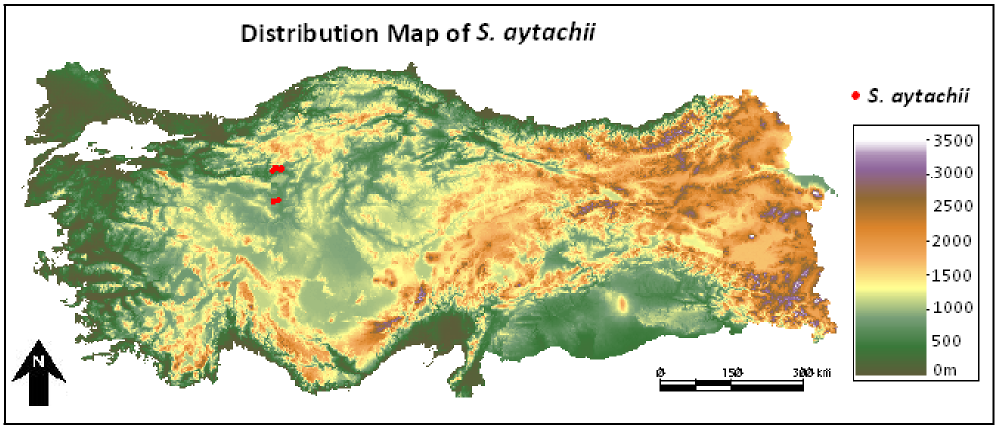


Figure 2.1-10. Distribution Map of *S. aytachii*.

2.1.2.4 *Crataegus tanacetifolia* (POIR.) PERS.

Kingdom: *Plantae*
Division: *Magnoliophyta*
Class: *Magnoliopsida*
Order: *Rosales*
Family: *Rosaceae*
Genus: *Crataegus*
Series: *Tanacetifoliae K.I.Chr.[1]*
Species: *C. tanacetifolia*
Binomial name: *Crataegus tanacetifolia* (POIR.) PERS.

Figure 2.1-11. *Crataegus tanacetifolia* photographed by Damla Beton and its place in the systematics (Synops. Pl. 38, 1805).

Crataegus L. (hawthorn) is a taxon of *Rosaceae* family, including shrubs or small trees with small pome fruit (Figure2.1-11 and 2.1-12) and (usually) thorny branches. There are approximately 200 *Crataegus* species worldwide, mostly found in the northern hemisphere; particularly through Europe, Asia, Central and North America. The taxonomy of the genus is rather problematic due to biological and historical factors (Dönmez, 2008). There is a debate about the number of species in this genus. Even though there are 200 species determined, some researchers increased this number up to 1200. 17 species of *Crataegus* are listed in the Flora of Turkey (Browicz, 1972). Yet, in 1992, Christensen (1992) revised this list, creating a new list with 21 species. Nevertheless, recent studies widened this list is up to 31 species (Dönmez, 2004, 2005, 2007; Dönmez and Dönmez, 2005). *C. tanacetifolia* is one of these tree species endemic to Turkey.

Figure 2.1-12. Fruit of *C. tanacetifolia*.

It reaches up to 15m in height. It is a taxonomically distinct species, which is differentiated from its relatives by its persistent bracts (Dönmez, 2004)(Figure 2.1-13). Its blooming period starts from May until June, and has fruits from September to October. *C. tanacetifolia* is found around openings around deciduous scrubs, as it prefers relatively humid conditions.

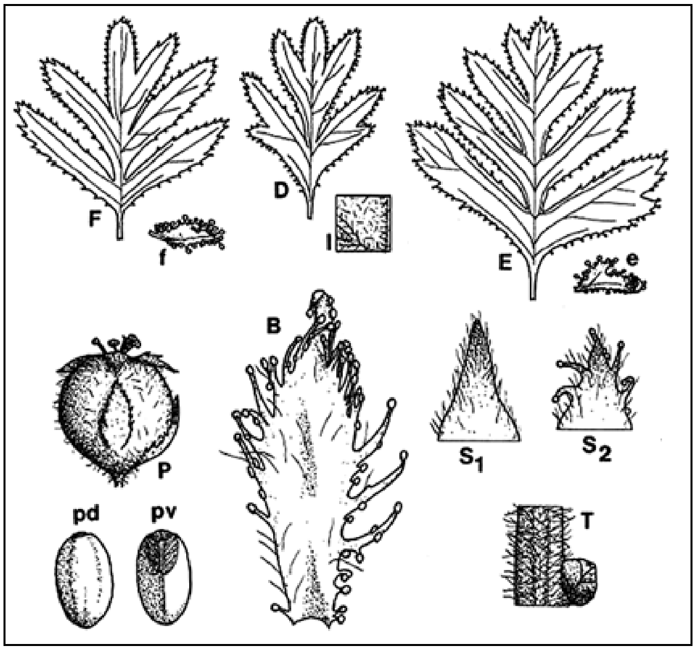


Figure 2.1-13. Characteristics of *C. tanacetifolia*: B: Bract; D: subterminal leaf of short shoot; E: leaf of central portion of elongated shoot; e: stipule of leaf of elongated shoot; F: subterminal leaf of flowering shoot; f: stipule of leaf of flowering shoot; I: Indumentum of abaxial leaf surface; P: pome; pd: dorsal surface of pyrene; pv: ventral surface of pyrene; S1, S2: sepal; T: part of twig, Solid bar=5mm; double bar=1mm (P, Pd, pv, T: Balls 1482a; B, D, E, c, F, f, I, S1, S2: Bornmüller 1023b)(*Artist: Knud Ib Christensen. Sys. Botany Mongraphs 35, 1992*).

Records collected show that its main distribution is around 680 to 2200 m altitude, through the transition zone between the Euro-Siberian and Irano-Turanian phytogeographic regions extending to Inner Anatolia (Figure 2.1-14). There is only one record collected within a deciduous forest (Yenice Forest), but it is also found within a small opening without many big trees around. Fruits of this species are a good source of energy for various mammal and bird species spreading their seeds around (Figure 2.1-12). They are commonly used by local people as well. As a result, some of them are conserved by locals around their fields, which are relatively drier during summer periods. It should be noted that, this species is categorized as Least-Concern within IUCN risk categories (Ekim *et al.*, 2000; Anonymous, 2001), which might indicate its high abundance within its range.

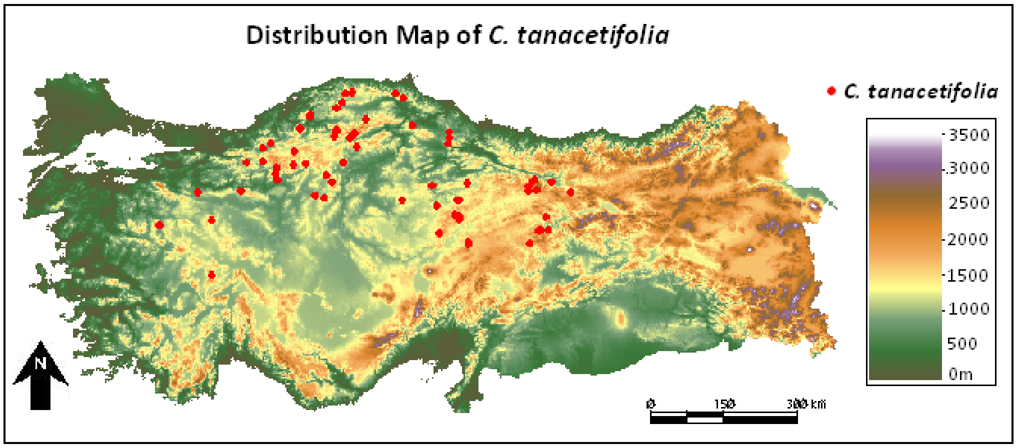


Figure 2.1-14. Distribution Map of *C. tanacetifolia*.

2.2 Study Area

North-central Anatolia stretches north from the flat, dry Salt Lake (Tuz Gölü) plain to the forested mountain ranges lying on an east-west axis, which finally roll down towards the humid Black Sea coastland. Two high mountain chains, Ilgaz Mountains (2587 m) and Köroğlu Mountains (2400 m), coupled with smaller ones, create a barrier between sea and inner parts of Anatolia. Along with Sultan Mountains (2581 m) and Emir Mountains (2281 m) in the southwest they form the two highest parts of the region. In between lies the relatively lower lands of Upper Sakarya Basin in the west. Haymana and Cihanbeyli Plateaus follow this basin towards the east forming a platform (average altitude 1000m-1200m). Finally, these plateaus are bound in the southeast by the Salt Lake (Tuz Gölü)(average altitude 905 m)(Figure 2.2-1). All these components combine to create a great variety of topographic, environmental and climatic conditions.

Figure 2.2-1. Physical Map of Study Area.

Fieldwork and modelling were carried out at different geographical extents, with the latter area encompassing the former one. This is both due to logistic reasons and in order to better assess the potential outcome of projected climate change.The modelling area was determined such that it would cover various types of topographic and environmental conditions, as this will contribute to the validity of modelling; especially the effects of climate change. In fact, fieldwork and modelling area boundaries were determined by a similar reasoning. Yet, modelling area selection was not limited by time and cost efficiency. Therefore, it gives an opportunity to widen the area that can lead to more intact distribution models and emphasize the effects of climate change.

Modelling was carried out on the full extent of the study area bounded by coordinates N41˚01´032″-E34˚29´005″ in the NE and N38˚19´056″-E29˚52´055″ (WGS84) in the SE. This area comprises 11 provinces and parts of another 17 with a total coverage of 141,760 km^2 (Figure 2.2-2).

Since data on the exact localities of the selected species were scarce, confirmation and improvement of low resolution locality data as well as obtaining additional new presence records was necessary through field work.

The boundaries of the area for fieldwork was determined according to the available data on distribution of the species of concern, the variety of topographic and environmental components it covers, and the extent where a reasonable sampling coverage was possible without being overwhelmed (Figure 2.2-2). While, it includes the whole distribution of the two narrowly distributed species, *Centaurea tchihatcheffii* and *Salvia aytachii*, it covers only a part of the ranges of the widely distributed endemics, *C. ancyrensis* and *C. tanacetifolia*.

A core region of 52,050 km^2 (36.7% of the actual study area) within the modelling area, covers a wide altitudinal range between 184 to 2362 meters, coinciding largely with the upper Sakarya basin. Its northern parts (and the far southwest district) have the highest altitudes while middle parts have mid-elevations, and the Sakarya valley in the north-west has the lowest. This variation leads to many different environmental features, from relatively dry plains to cold mountain tops as well as rivers, wetlands etc. Consequently, it also features various climatic conditions.

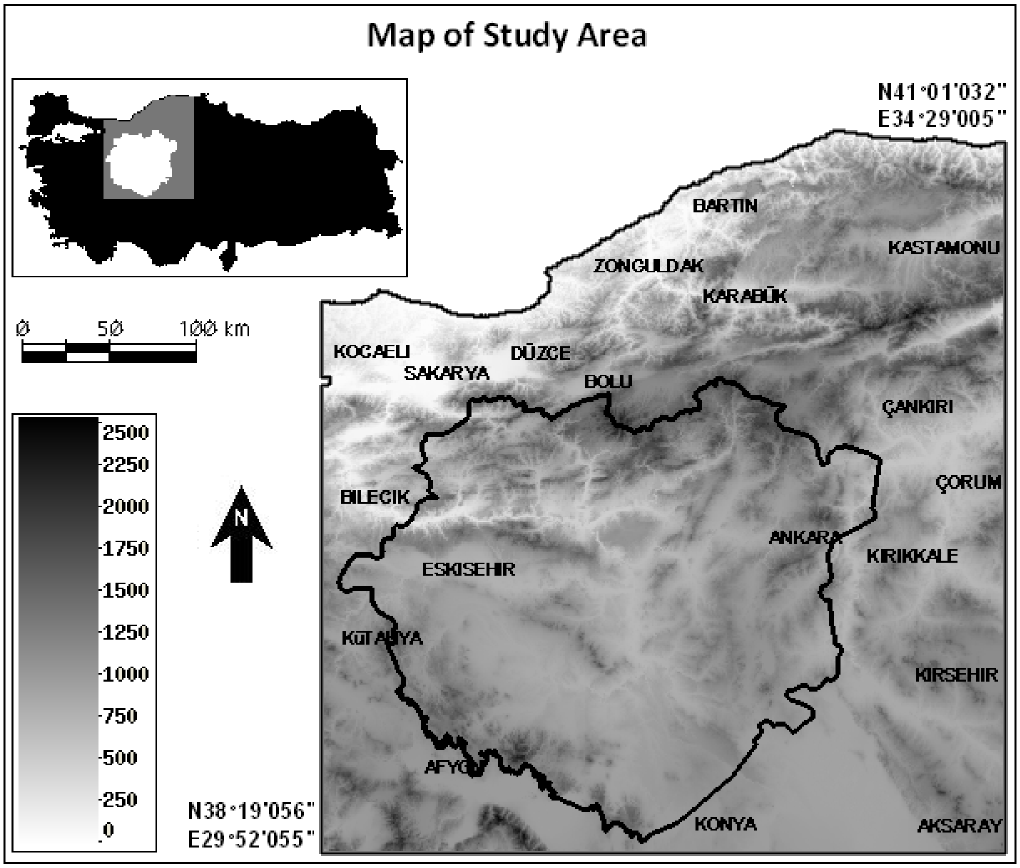


Figure 2.2-2. Map of the Study Area; showing relative positions of Modelled Area (=Study Area) and the Fieldwork Area (black bordered region within the study area). Legend of the map indicates the altitudinal (m) characteristics of the area. Provinces are listed in the order relative to their size within the study area. (Study Area covers Ankara, Eskişehir, Kastamonu, Bolu, Çankırı, Kırıkkale, Sakarya, Zonguldak, Karabük, Düzce, Bartın as well as parts of Konya, Afyon, Aksaray, Kırşehir, Çorum, Kütahya, Bilecik, Kocaeli, Nevşehir, Yozgat, Sinop, Isparta, Bursa, Uşak, Denizli, Niğde, İstanbul)

In order to model species distributions accurately, one needs to cover as many different combinations of available environmental conditions as possible for the presence of the species. Therefore, the study area serves this objective well. Moreover, all of the study species have their main distributions around the inner parts – none is delimited to the coastal range.

2.3 Modelling

2.3.1 Data for Modelling

2.3.1.1 Species Distribution Data

There are 3 types of presence data used throughout. The sources for the first two types (literature and preliminary fieldwork data) have been explained in detail in previous sections. That information was mainly used to determine the species to be modelled. However, even though some of the selected species had detailed distribution data, field work was essential for the purposes of this thesis. The third type of data, presence/absence data, is collected via this fieldwork.

For preparing the maps and selecting units to sample during fieldwork, GIS software was used. Particular software include Microimages TNT 6.9 (Microimages Inc., 2003), Idrisi Kilimanjaro (Clark Labs., Clark University, 2003) and ArcGIS 9.2 (Environmental Systems Research Institute - ESRI, 2007).

2.3.1.1.1 Sampling in the Field

This procedure is composed of 3 steps, and includes delimiting the fieldwork area, determining grid size, and deciding on the sampling scheme. After general explanations for each step, the process is explained in detail for each study species.

2.3.1.1.1.1 Limiting Extent of the Fieldwork Area

Determination of the area for field survey started by delimitation of the altitudinal range in the area (Table 2.3-1). First, altitudinal range of each species was drawn out of records. Since these records might have some inaccuracies or since yet undiscovered populations may occur at altitudes beyond at either extremes, this range was expanded by a certain percentage of the altitude interval (Table 2.3-1).

This enlarged extent was then reduced by using the known distribution data of the species, leading to the final survey area (Table 2.3-1, Figure 2.3-1-C). Major underlying idea during this process was that altitude is a strong limiting factor on dispersal of a species.

2.3.1.1.1.2 Determining Grid Mesh Size

Using relatively small areas as sampling units enables detailed fieldwork. However, since these areas are still too big to cover as a whole, a (stratified) random sampling technique was adopted.

This process needs to use a grid mesh that is created on a GIS environment. The size of the grids are decided depending on the size of the survey area, detectability of the species during field surveys, population trend of the species and financial resources (Table 2.3-1, Figure 2.3-2). If the survey area is small, it would not be efficient to have relatively big sized grids, such as 5x5 or 10x10 km^2. Moreover, detectability of the species makes a big grid harder to survey. In addition, the general aim is to cover the largest area possible with the limited financial resources.

2.3.1.1.1.3 Sampling Scheme

A grid mesh of suitable size constituted the basic sampling units. A certain proportion of those grid squares are selected by either ordinary random (Figure 2.3-2) or stratified random sampling to eliminate sampling bias (Table 2.3-1). In the latter case, stratification is based on dividing the area into two parts with and without records, respectively, and putting relatively more effort to surveying the part with records. In order to find the exact locations, the grid is transferred to Google Earth 6.0.2. and suitable tracks for vehicle access to the sample squares are determined. Printed outputs of each sample squares with coordinates are created. With the help of such maps and Global Positioning System (GPS) (Garmin eTrex) these squares are located on the ground. Once located, it is covered as much as possible by car and on foot. If a specimen of the target species is found, the survey is intensified at localities with similar environmental conditions. However, it was not always possible or easy to reach the grids. In some circumstances, weather conditions or sometimes vegetation and terrain avoided access to a grid square. In such a case, the nearest accessible habitat around the unvisited grid square was surveyed.

2.3.1.1.1.4 Details for each study species

Since each species has its own characteristics, there were slight differences in the procedure followed between species. The parameters used for each are summarised in Table 2.3-1.

a. *Centaurea tchihatcheffii*

For this species, 10 records with coordinates were available in the literature (Baytok, 2008)(Appendix B). These records ranged between 980 m to 1090 m.

This range was expanded by half of the altitude interval (Range Interval = 1090-980 = 110; Half of the Range Interval = 110/2= 55 ≈ 60 m), to between 910 m to 1150 m. Land lying between these altitudes was determined by GIS (Figure 2.3-1_A, B). Then, the area was further reduced by using the available distribution data of the species (Figure 2.3-1-C, D). The reason for the considerable reduction in the last step is because the species was subject to intensive study by various researchers (Vural and Tan, 2007; Çakaroğulları, 2005; Baytok, 2008; Boşgelmez, 2005) so it was quite unlikely that there were many undiscovered populations in the neighboring land. This procedure led to a final survey area of about 2560 km^2 (Figure 2.3-1-C, D).

Table 2.3-1. Details of the fieldwork area determination procedure of each species. (SA: Study Area, RI: Range Interval, NA: Not Applied, (N:S): Northern Part vs Southern Part)

Procedure		***C. tchihatcheffii***	***S. aytachii***	***C. ancyrensis***	***C. tanacetifolia***
Limiting Extent of the Fieldwork Area (FA)	**Total # of records with coordinates**	10	5	83 (58 in SA)	110 (83 in SA)
	Altitude Range (AR)(m)	980 - 1090	550 - 900	550 - 2200	680 - 2200
	Rationale of Extension	1/2 of RI (≈ 60 m)	1/4 of RI (≈ 90 m)	NA	NA
	Extended AR (m)	910 - 1150	460 - 990	600 - 2400	600 - 2400
	Final Area Size (km^2)	2,560	22,800	263,000	263,000
Grid Mesh Size (km)		2x2	4x4	4x4	4x4
Sampling Scheme	**Stratified Sampling**	NA	22:8 (N:S)	20:10 (N:S)	NA
	Selected # of grids	30	30	30	44
	Percent of Total Area Surveyed	4.7%	2.1%	0.18%	0.27%
Fieldwork Duration		April-May 2008	May 2009	February-March 2009	August-September 2008

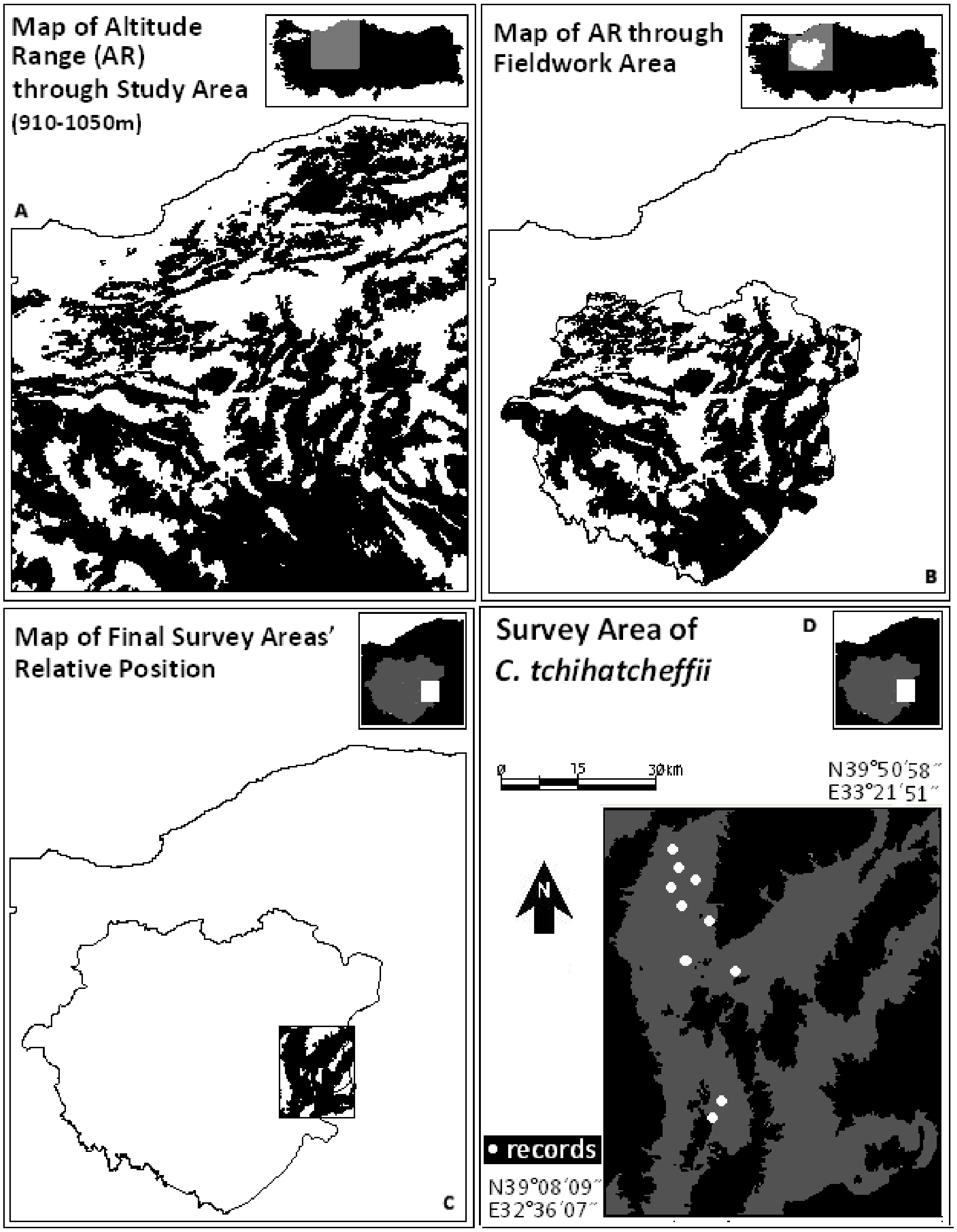


Figure 2.3-1. Illustrative representation of fieldwork area determination procedure for *C. tchihatcheffii*.

As the determined survey area is very small (only 2560 km^2), it would not be efficient to have relatively big sized grids, such as 4x4 or 3x3 km^2. Even though the unique and attractive colour of *C. tchihatcheffii* makes it rather easy to detect from a distance, exceptions of this generalization had been noticed. Moreover, as explained under the species account, abundance of this species throughout the study area is very variable from one year to another, necessitating a cautious survey effort. On the other hand, very small grid sizes would be too costly. Therefore, a 2x2 km^2 grid mesh was decided as the optimal size for surveying *C. tchihatcheffii* (Figure 2.3-2-A).

After the delimitation of the survey area and setting up a grid mesh with 2 km size, 30 of these grid squares, covering about 4.7% of total area, were selected randomly for surveys (Figure 2.3-2-B). Stratified sampling was not a case for *C. tchihatcheffii* as the survey area was narrowed considerably.

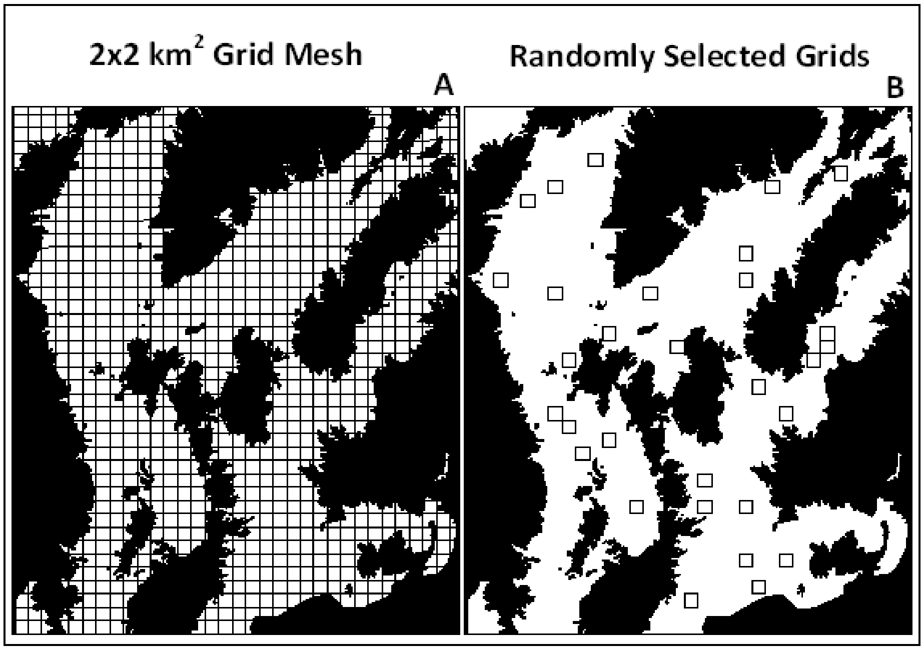


Figure 2.3-2. Grid map used during fieldwork studies of *C. tchihatcheffii* laid over fieldwork area.

b. *S. aytachii*

There were 11 available records distributed around two known locations for *S. aytachii* (Appendix C). Only one of these had coordinates. However, these records gave us directions to find locations of the species. Five coordinates were collected by the preliminary fieldwork carried out around some of these locations during species selection procedure. These records and literature notes showed that distribution of the species is limited to two areas: One around Ayaş-Beypazarı-Nallıhan district covering about 130 km^2,the other only 60 km south and covering about 60 km^2 between Polatlı and Sivrihisar (Figure 2.3-3). Similar to *C. tchihatcheffii*, the relative position of these two populations suggested that these might be connected. However, the main correlate of this species' distribution seems to be gypsum soils.

The available records had a range between 550 m and 900 m. This range was widened by quarter of the altitude interval (Range Interval = 900-550 = 350; Quarter of the Range Interval = 440/4= 87.5 ≈ 90 m). The new range was determined as 460 to 990 m. Unlike for *C. tchihatcheffii*, here a quarter of the interval was used as processing with half would have expanded the altitude range too much. Moreover, soil type (rather than altitude-mediated climate) is believed to be the limiting factor for *S. aytachii*. Therefore, a reduced expansion factor (0.25 instead of 0.50) is justified here.

A 4x4 km^2 grid mesh was created. 30 of these grids were selected in stratified random sampling design. Survey area was divided into a northern (with records) and a southern (without records) part. Then 22 squares from the north and 8 squares from the south were surveyed (Table 2.3-1).

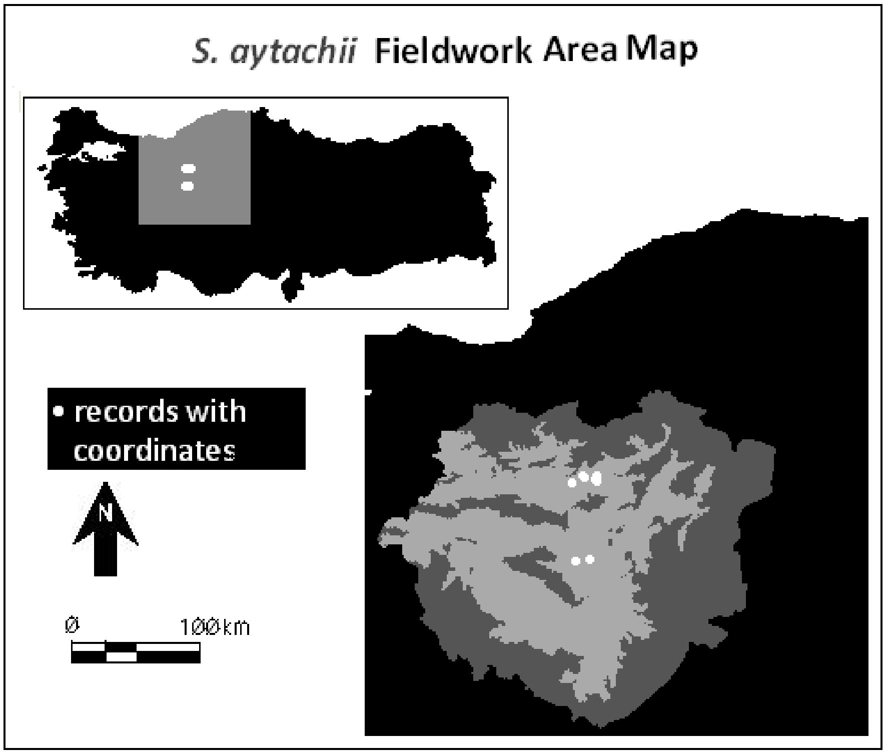


Figure 2.3-3. Illustrative representation of Fieldwork Area determined for *S. aytachii* in respect to both Modelled (black) and Study (dark grey) Areas.

c. *C. tanacetifolia*

The literature yielded 88 records for this species. However, some of these records were very coarse, such as Davis (1988) implying that it occurs around Ankara, or very suspicious, such as a record from Bitlis. After a detailed evaluation of all of these records, only 71 of them were found to be useful (Appendix D), 37 falling into the survey area modelled. 19 of the 71 had coordinates, but only 8 fell within the survey area modelled. In addition to these 8, there were 36 records with coordinates that had been collected during primary fieldwork (adding up to 44 records with coordinates) (Appendix D). However, many records were very close to each other, representing only 8 distinct locations. (Figure 2.3-4).

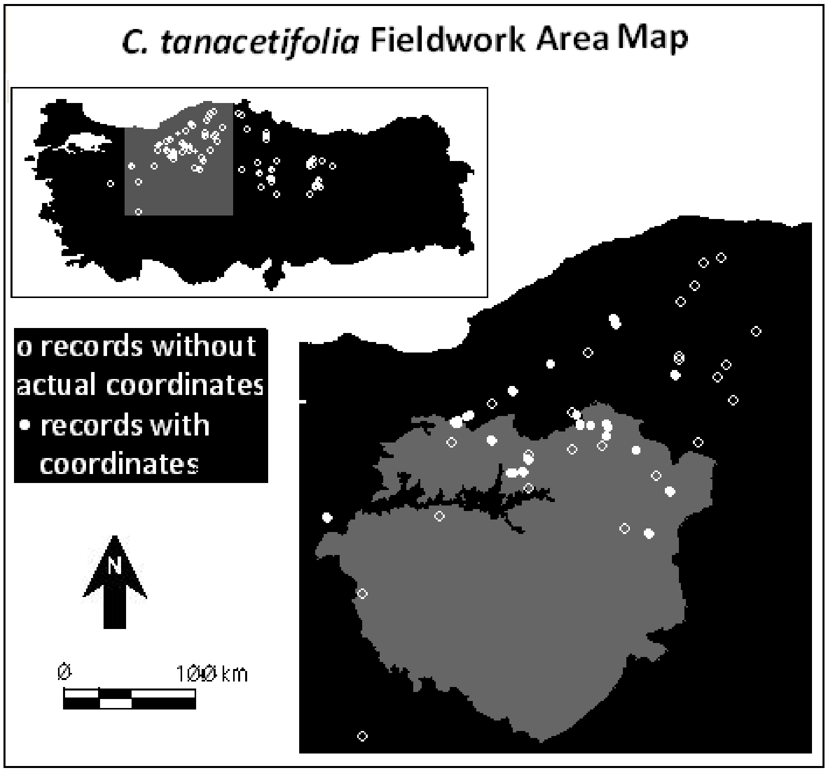


Figure 2.3-4. Illustrative representation of Fieldwork Area determined for *C. tanacetifolia* in respect to both Modelled (black) and Study (dark grey) Areas.

Records started from 680 m (Bolu) altitude reaching up to 2200 m (Yozgat). Therefore, 600-2300 m was determined to be the altitude range. Since our fieldwork area has few areas higher than 2300 m, only parts lower than 600 m were left out of the fieldwork study, yielding an area about 263,000 km^2. Then, a grid mesh of 4x4 km^2 grids was created. 44 squares, covering about 0.27% of the total area, were randomly selected for field surveys.

d. *C. ancyrensis*

99 records were available through the literature. After a detailed evaluation of these records, only 75 of them were found to be useful (Appendix E). In addition, there were 8 records with coordinates that had been collected during primary fieldwork

(totally 83 records) (Appendix E). Yet, only 58 fell into the survey area modelled (Figure 2.3-5).

Records started from 550 m (Amasya) altitude reaching up to 2200 m (Niğde and Kayseri). As the parts below 550 m coincided with Çayırhan Bird Paradise (a wetland), the lowest elevation is accepted as 600 m. Since this elevation range coincided with that of *C. tanacetifolia,* the same fieldwork area and grid mesh is used for *C. ancryensis*. Survey squares were selected by stratified random sampling, where 20 squares from the northern part, including available records, and 10 squares from the south were selected.

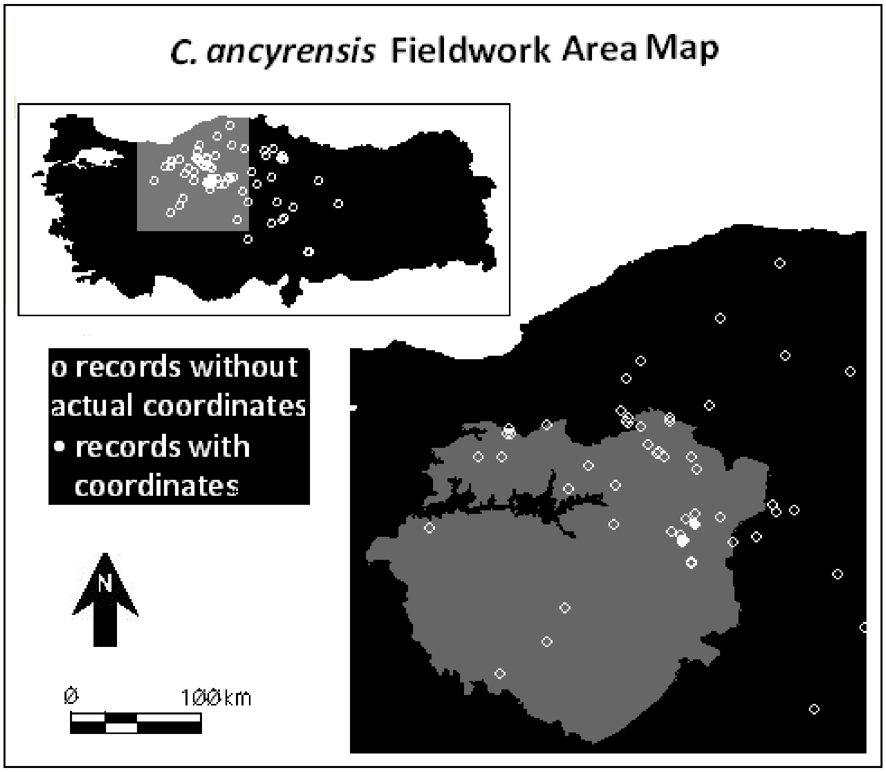


Figure 2.3-5. Illustrative representation of Fieldwork Area determined for *C. ancyrensis* in respect to both Modelled (black) and Study (dark grey) Areas

2.3.1.1.2 Distribution Data for Modelling

All species were sampled once during its blooming period, at the appropriate time of the year for each species (Table 2.3-1). During field surveys, all observed presence locations were recorded. Some squares had a lot of presence records as the species occurred in several discrete populations throughout. In contrast, there were also cases when no individuals were detected. However, it is really difficult to claim absence of a species in any particular area. For example, *C. tchihatcheffii* populations show great fluctuations from one year to another. As a result, not detecting it through a short survey period certainly does not indicate its absence in that square. In the case of *C. tchihatcheffi*, it is possible to consider the effects of its population dynamics on its presence/absence as it is well studied. However, for the other three species, there is no published study on their population dynamics. Therefore, only presence data is used for modelling purposes. Nevertheless, absence data collected cautiously are used while hypothesis testing. It should be noted that collection of absence data is a controversial issue. It is very easy to create false absences leading to sampling bias. Absences are only recorded, if habitat or environmental conditions of the habitat are really different from the actual species' habitat or if there aren't any individuals observed all through the grid square surveyed. As it is very hard to determine such areas, relatively more time was spent through these grids. Observations were done with great care, also evaluating the intensity and probable effects of human activities at the same time.

Surveys were not limited only to survey grids. Presence locations observed by chance in non selected grids while doing the surveys were also added to the dataset. It should be pointed out that independence of observations is a fundamental prerequisite for applying most statistical methods. Yet, spatial dependence of true biological origin (dispersal, demography or behaviour) is certainly observed in ecological data. Solutions to this problem include: (i) correcting the number of degrees of freedom used in model inference tests; (ii) adding a spatial autocorrelation (SAC) term to the linear predictor until no more spatial structure can be detected in the residuals (Lichstein *et al.*, 2002); or (iii) (re)sampling plots at sufficient spatial distance to avoid autocorrelation (Guisan and Theurillat, 2000). In this study, most appropriate technique is the latter. So, all data collected was filtered in a GIS environment to leave only one presence record within each grid square. This filtering process aimed to reduce spatial autocorrelation and "over fitting" by the model. These final datasets were then used as input for the modelling software.

2.3.1.2 Environmental Features

Environmental variables used during modelling are called 'features' Features can be either categorical or continuous layers. There are different databases obtaining these kinds of data. They provide a great variety of maps with different resolutions and accuracies. Consequently, researchers should evaluate convenience of these data for their actual purpose cautiously and determine the most effective features available for use.

2.3.1.2.1 Available Features

A Digital Elevation Model (DEM) map with 68x92 m resolution (downloaded from United States Geological Survey (USGS) official website (http://www.usgs.gov/) was used for producing aspect, slope and shading layers by TNTmips 6.9 software (Table 2.3-2). Main blooming/fruiting intervals for the species are around February-till-May and September. Turkey receives sun light with a 50 degrees elevation angle (solar elevation angle of the sun) from 45 degrees (solar azimuth angle of the sun) around these periods (21st of March and 23rd of September). Therefore, these maps are produced by assuming this sun angle and direction over the study area. Slope is expressed as an angle measured from the horizontal in degrees (0 to 90) and rescale to range [0...255] in order to spread the output values across the entire 8-bit data range and increase detail. Aspect values increase clockwise from north, so that northeast-facing slopes are darkest and northwestfacing slopes are brightest. In order to fit the output values in the default 8-bit data range, it is rescaled to range [0...240]. As a result, 0 = north, 60 = east, 120 = south, and so on. On the other hand, shading has a value of 180 for level terrain, while nonlevel terrain will have higher than 180 (up to 255) for sunfacing slopes and will be lower than 180 (down to 1) for shadowed slopes.

Hard copies of parent rock maps from General Directory of Mineral Research & Exploration (MTA) were obtained. However, since they had very low resolution, they were not used. This meant no soil or parent rock features were used in this study.

Climate maps for both the present and the future were obtained from 'WorldClim-Global Climate Data' database (http://www.worldclim.org/; Hijmans *et al.*, 2005). WorldClim is a set of global climate layers (climate grids) with a spatial resolution of 30 seconds which is roughly one kilometer square (0.93 x 0.93 = 0.86 km^2 at the equator). Recorded data is composed of monthly precipitation, minimum, mean and maximum temperature values through 1960-1990 (Table 2.3-2). Bioclimatic variables are derived from these monthly temperature and rainfall values with the aim of generating more biologically meaningful variables. In general these variables represent annual trends (e.g., mean annual temperature, annual precipitation), seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters)(Table 2.3-2). Hijmans *et al.* (2005) explain in detail the methods used to generate the climate layers and the units and formats of the data.

Table 2.3-2. List of available ecological features (bio: bioclimatic variables derived from the tmean, tmin, tmax and prec). topographical and climatological features have been based on the USGS Official Web Site and Worldclim Database, respectively.

Topographical Features	
Variable Name	**Definition**
Digital Elevation Model (DEM)	Altitude (m)
Slope (slp)	Slope (degree)
Aspect (asp)	Aspect (degree)
Shading (shd)	Shading

Climatological Features	
Variable Name	**Definition**
tmean	Average Monthly Mean Temperature (of each month)(°C)
tmin	Average Monthly Minimum Temperature (of each month)(°C)
tmax	Average Monthly Maximum Temperature (of each month)(°C)
prec	Average Monthly Precipitation (of each month)(mm)
bio1	Annual Mean Temperature
bio2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
bio3	Isothermality (bio2/bio7)(* 100)
bio4	Temperature Seasonality (standard deviation *100)
bio5	Max Temperature of Warmest Month
bio6	Min Temperature of Coldest Month
bio 7	Temperature Annual Range (bio5-bio6)
bio 8	Mean Temperature of Wettest Quarter
bio 9	Mean Temperature of Driest Quarter
bio 10	Mean Temperature of Warmest Quarter
bio 11	Mean Temperature of Coldest Quarter
bio 12	Annual Precipitation
bio 13	Precipitation of Wettest Month
bio 14	Precipitation of Driest Month
bio 15	Precipitation Seasonality (Coefficient of Variation)
bio 16	Precipitation of Wettest Quarter
bio 17	Precipitation of Driest Quarter
bio 18	Precipitation of Warmest Quarter
bio 19	Precipitation of Coldest Quarter

Two datasets were used: One for modelling current distributions and one for modelling future distributions. Maps of current conditions are derived from meteorology station records from 1960-2000. Future conditions are predicted by different researchers using different circulation models. They also reflect various future climate change scenarios. Here two of the most widespread and complete datasets were used. One is developed by Canadian Centre for Climate Modelling and Analysis (CCCMA) and is called 'CCCMA-CGCM2' (the Second Generation Coupled Climate Model). Flato and Boer (2001) describe production of CGCM2 in detail. CGCM2 results were used in the Intergovernmental Panel on Climate Change Third Assessment Report (2001) and in the Arctic Climate Impact Assessment (ACIA) Report (Symon *et al.*, 2005). Another is developed by the Hadley Centre for Climate Prediction and Research and is called HCCPR-HADCM3 (Hadley Centre Coupled Model, Version 3). It was one of the major models used in the IPCC Third and Fourth Assessment Reports (2001, 2007). Gordon *et al.* (2000); Pope *et al.* (2000), Collins (2001) and Reichler and Kim (2008) give more detail about the production processes and prediction successes of the maps. Both of these future climate models have future projections for the years 2020, 2050 and 2080, all of which were used during this study. Figure 2.3-6 illustrates the differences between future predictions of these models.

How the future will unfold is very controversial and there are many disagreements about this issue. As a result, IPCC tried to put together all views by assuming that individual scenarios have different tendencies, such as emphasizing stronger economic values versus stronger environmental values, and assuming increasing globalization versus increasing regionalization. Combining these choices yielded four different scenario families that can be summarized in a two dimensional graph as shown on Figure 2.3-6.

The titles of the four scenario storylines and families are A1, A2, B1, and B2. These are explained through the IPCC SRES Report (Nakicenovic *et al.*, 2000) as:

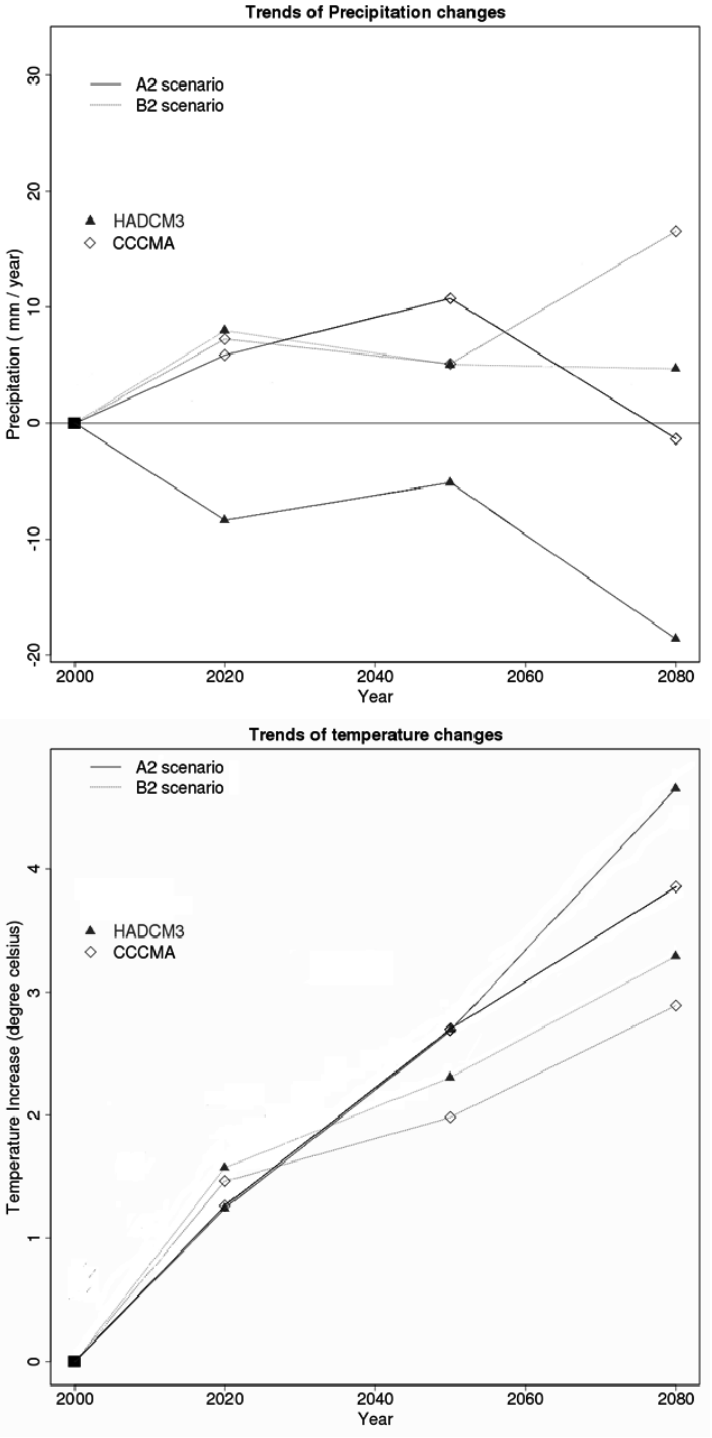


Figure 2.3-6. Changes in European mean annual accumulated precipitation (upper panel) and mean temperatures (lower panel) for the next century according to the two different models CCCMA (Canadian Centre for Cimate Modelling and Analysis) and HADCM3 (Hadley Centre Coupled Model, Version 3) and A2 and B2 IPCC scenarios used through the study.

- The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income.

- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.

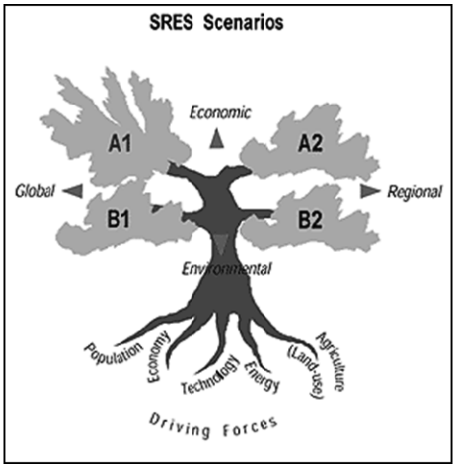


Figure 2.3-7. Schematic illustration of SRES scenarios. The four scenario "families" are shown, very simplistically, for illustrative purposes, as branches of a two-dimensional tree. The two dimensions shown indicate global and regional scenario orientation, and development and environmental orientation, respectively. The schematic diagram illustrates that the scenarios build on the main driving forces of greenhouse gas emissions. Each scenario family is based on a common specification of some of the main driving forces (IPCC Third Assesment Report, Working Group III: Mitigation, 2001).

- The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures towards a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

- The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with a continuously increasing global population at a rate lower than in A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Full details on these scenarios can be found in the IPCC Special Report on Emissions Scenarios (Nakicenovic *et al.*, 2000).

A2 and B2 scenarios are adopted through this study because they were considered more realistic, being regional models rather than global. Consequently, in this study A2 represents the worst case scenario while B2 represents the best.

There were totally 71 different environmental features (Table 2.3-2) that can be used for modelling. However, a correlation analysis performed with the help of TNTmips 6.9 and Idrisi Kilimanjaro showed that most of these features were highly correlated (Appendix F and G). Although, this does not cause a major problem for some of the modelling techniques, it complicates evaluation of the results and makes direct interpretation rather controversial. Also, some modelling algorithms do not perform very well with a lot of features as this complicates the model determination procedure and its predictions. Therefore, we decided to decrease the number of features used such that only weakly correlated layers be used for modelling. The correlation threshold was determined as 0.8 (i.e. only one of a pair of parameters correlated at 0.8 or higher were allowed in the model). This is still a relatively high value, yet further reduction of this value would limit the number of features far too much leading to reduced model success. On the other hand, depending only on correlation values may not be sufficient since using features not affecting species distribution would lead to unsuccessful and misleading models. Therefore, the reduction procedure was carried out not only by evaluating the correlations but also considering the possible effectiveness of the parameter over species distributions. For example, slope rather than altitude is selected, because all of the climatic and topographical features are derived from altitude data leading to high convergences. Also, slope shows the lowest correlation among topographical variables (Appendix). Additionally, it is observed to be effective on selected species distributions. As a result of this evaluation, 7 climatic and 1 topographic features were found to be most appropriate for modelling purposes of the selected species (Table 2.3-3). These include Annual Mean Temperature (Bio1), Mean Diurnal Range (Bio2), Isothermality (Bio3), Max Temperature of Warmest Month (Bio5), Mean Temperature of Wettest Quarter (Bio8), Annual Precipitation (Bio12), Precipitation Seasonality (Bio15) and Slope.

Table 2.3-3. Correlation Matrix of 8 least correlated evironmental features

Correlation Matrix								
Features	**Bio1**	**Bio2**	**Bio3**	**Bio5**	**Bio8**	**Bio12**	**Bio15**	**Slp**
Bio1	**1.000**	0.206	0.536	0.747	0.243	-0.129	-0.043	-0.262
Bio2	0.206	**1.000**	0.684	0.763	0.082	-0.787	0.693	-0.446
Bio3	0.536	0.684	**1.000**	0.640	-0.043	-0.250	0.319	-0.293
Bio5	0.747	0.763	0.640	**1.000**	0.282	-0.694	0.431	-0.480
Bio8	0.243	0.082	-0.043	0.282	**1.000**	-0.283	-0.187	-0.153
Bio12	-0.129	-0.787	-0.250	-0.694	-0.283	**1.000**	-0.545	0.436
Bio15	-0.043	0.693	0.319	0.431	-0.187	-0.545	**1.000**	-0.394
Slope	-0.262	-0.446	-0.293	-0.480	-0.153	0.436	-0.394	**1.000**

2.3.2 Modelling Technique: Maximum Entropy Modelling (MAXENT)

Maxent is based on a machine learning response that is designed to make predictions from incomplete data (Baldwin, 2009). The deterministic maximum entropy algorithm, adopted by Maxent, tries to create a maximum entropy (the most uniform) probability distribution. Pixels of the study area make up the space on which this prediction is made. A probability distribution through this area is defined depending on pixels with known species occurrence, the environmental variables called ‘features’, and functions thereof (Philips *et al.*, 2006). In summary, Maxent fits a probability distribution of occurence of the species over the extent of modelled region such that a value is attributed to each pixel included. Meanwhile, it adopts the idea that ‘the best explanation to unknown phenomena will maximize the entropy of the probability distribution, subject to the appropriate constraints’ (Peterson *et al.,* 2007). Here, constraints consist of the values of those pixels at which species known to exist (Phillips *et al.*, 2004, 2006). Phillips *et al.* (2004, 2006; Phillips and Dudík, 2008) and Elith *et al.* (2010) provide very detailed and clear information about the underlying processes and concepts of this modelling technique.

The basic measure of performance administrating the modelling procedure of Maxent is log loss. Log loss is the negative log likelihood of the test data, i.e. the sum of the negative log probabilities that the model assigns to test sites. Maxent does its predictions over optimizing log loss (Dudik *et al.*, 2004). It is always a nonnegative value which can be arbitrarily large. The smaller these values are (higher likelihood), the better the prediction is. In other words, the true distribution is the one with the minimum log loss (maximum likelihood), which contributes to the true entropy. This value can be equal to the actual true entropy if only the model fits perfectly. In other words, actual log loss of true entropy is always smaller than or equal to (in a perfect fit situation) the value calculated for the model (Philips *et al.*, 2008).

Roughly, Maxent starts by building a model of species occurrence with a uniform distribution of probability values over the entire study area. Then it performs an optimization schedule that iteratively improves model fit. This model fit measure is called 'gain', which can be seen as a simpler representation of log loss. As, Maxent is a presence only model lacking any absence data, it does these calculations by using background data (also called pseudo-absences) chosen uniformly at random from the study area, in place of true absences. In other words, Maxent tries to maximize the probability of the presences in relation to the background data (as a substitute of absences) by minimizing the log loss which corresponds to maximizing the gain. This process leads to correction of the first model where the probabilities of all pixels were equal (uniform). Following this process, gain increases to an asymptote, and the final probability distribution becomes the basis for fitted predictor variable coefficients. Then it takes the exponent of the final gain which gives the mean probability of the presence samples compared to random background pixels.

Philips and Dudík (2008) indicated that Maxent is prone to overfitting, resulting in predicted distributions that are clustered around location points. Therefore, the authors have added a relaxation component, called regularization, in order to constrain the estimated distribution. Thereby it allows the average value of each sampled variable to approximate its empirical average but not equal it. In other words, Maxent tries to minimize the log loss (maximize the log likelihood) of the data associated with the presence sites minus a penalty term. This penalty term is calculated such: each feature gets weighted according to how much it adds complexity to the model; the sum of these weightings - including the regularization parameter, determines how much the likelihood should be penalized to prevent overfitting (Philips and Dudik, 2008). Regularization is an adjustable component depending on the sampling area. However, recent simulations have indicated that default settings perform as well as adjusted settings (Elith *et al.*, 2010).

The "replicates" option is used to do multiple runs for each species through the study. The form of replication used is called ‘cross-validation’. This assures that the occurrence data is randomly split into a number of equal-size groups called “folds”, and models are created leaving out each fold in turn. Then the left-out folds are used for evaluation of the model. While this left-out fold acts as ‘test data’, used folds are called ‘training data’. Cross-validation has one big advantage. It uses all of the data for validation, thus making better use of small data sets. Number of most efficient replicates is investigated previous to modelling. Two different models with 4 and 10 replications have been run and resulting maps have been compared. Results have not shown any significant difference apparently or statistically. Also, general logic of cross validation procedure leads to more reliable statistical test results with less replications. In conclusion, models with 4 replicates have been used through this study and each replicate is run 500 times (iterations).

Regularization and replicates are the two most important setting used during model calibration. The rest of the settings are not as effective as these two can be. The rest of the settings are calibrated by the developer, using the model for many different organisms and choosing the most efficient parameters. These default settings are tested and found to be efficient for this study as well.

Resulting continuous map represents the estimate of probability of presence of the species. The most efficient output type is a logistic output, varying from 0 to 1, while 0 represents the lowest and 1 represents the highest probability of occurrence. This map is more likely to show the fundamental niche of the target species as no data about representing source availability and possible competition is included (Soberón and Peterson, 2005).

Once a model is fitted, testing or validation of this model is required to assess its predictive performance. Validation is a process that results in an explicit statement about the behaviour of the model. It indicates that the model is acceptable for use, not that it embodies any absolute truth, nor even that it is the best model available (Rykiel, 1996).

In general, the value of a model is directly proportional to its accuracy. The accuracy of a model includes two aspects: discrimination capacity and reliability. Discrimination capacity is the power of the model to differentiate presences from absences. Reliability refers to the capability of the predicted probabilities to reflect the observed proportion of sites occupied by the subject species.

Accuracy measures typically used in ecology can be divided into two groups: threshold-dependent (for evaluation of binary prediction maps) and threshold independent (for evaluation of continuous prediction maps). Although, Maxent gives out continuous prediction maps, they can be transformed to binary ones by employing a specific threshold. This enables the use of both the threshold-dependent and independent accuracy measures for Maxent models.

All threshold dependent indices are based on some or all of the elements of the confusion table matrix. There are four elements in a confusion matrix (Table 2.3-4). Element a (true positive) represents known distributional areas correctly predicted as present, and d (true negative) reflects regions where the species has not been found and that are classified by the model as absent. Briefly, a and d are correct classifications. In contrast, c and b represents omission (false negatives or underprediction) and commission error (false positives or overprediction), respectively. Omission rate is the proportion of presences predicted absent, while commission rate is the proportion of absences predicted present. A confusion matrix is a typical way of showing relative proportions of these errors (Fielding and Bell, 1997)(Table 2.3–4).

Table 2.3-4. Confusion Matrix

Confusion Matrix		
	Recorded present	**Recorded (or assumed) absent**
Predicted present	a (true positive)	b (false positive)
Predicted absent	c (false negative)	d (true negative)
Omission Rate: c/(a + c)		**Commission Rate: b/(b + d)**

The threshold-dependent indices used in SDM field include sensitivity, specificity, positive predictive value, negative predictive value, overall accuracy, Cohen's Kappa, odds ratio and F-measure. Sensitivity (Se) and specificity (Sp) are widely used in SDM (Table2.3-5). Sensitivity is the probability that the model correctly predicts an observation of a species at a site and specificity is the probability that a known absence site is correctly predicted. While Se and Sp are probabilities conditional on the observed pattern, positive predictive value (PPV) and negative predictive value (NPV) are their counterparts that are conditional on the predicted pattern. PPV is the probability that a site predicted as present is actually present and NPV is the probability that a site predicted as absent is actually absent. Se and Sp are referred to as producer's accuracy, and PPV and NPV are called user's accuracy (Liu *et al.*, 2007). The pair Se and Sp and the pair PPV and NPV are complementary to each other (Hand, 2001). Single global measures of model performance are generally preferred by researchers. Overall accuracy (OA) is the most common one (e.g. Fielding and Bell, 1997), which is the probability that a site (either presence or absence) is correctly predicted. Cohen's (1960) Kappa is another widely used measure. It has been adopted to overcome the problem of over estimating accuracy with OA. It measures the extent to which the agreement between observed and predicted is higher than that expected by chance alone. The Cohen's Kappa is basically the measure of agreement between the two maps (actual and model maps). Kappa value has a scale between 0 and 1 (where <0.20 indicates a poor, 0.21-0.40 indicates a fair, 0.41-0.60 indicates a moderate, 0.61-

0.80 indicates a Good and 0.81-1.00 indicates a very good model fit (Landis and Koch, 1977)). Odds ratio (OR) is defined as the ratio of the odds of positivity in predicted presences relative to the odds of positivity in predicted absences. F-measure, which is the harmonic mean of precision and recall (Daskalaki *et al.*, 2006), has been used in SDM (e.g. Drake *et al.*, 2006). Traditionally F-measure reaches its best value at 1 and worst value at 0. Prescribed in the way shown below, the F-measure will be undefined when all sites are predicted as one category (either presence or absence), as it is encountered by Drake *et al.* (2006)(Table 2.3-5).

One of the most widely used threshold-independent accuracy indices is the area under the receiver operating characteristic (ROC) curve (Area Under the ROC Curve; AUC)(Figure 2.3-8). A: ROC graph, formed by plotting sensitivity against '1 – specificity' is shown on Figure 2.3-8; where B and C are frequency distributions of probabilities predicted by a model for observed 'presences' and 'absences'. While B represents a successful model that can differentiate presences from absences, C represents a relatively unsuccessful model with more overlapping presence and absence frequency distributions. ROC graph (A) indicates that a model with a signifying superior predictive ability (B) will have a higher ROC curve (corresponds to a higher AUC value) than one with a poorer ability. In general, AUC measures the quality of a ranking of sites, such that the probability that a randomly chosen presence site will be ranked above a randomly chosen absence site (Fielding and Bell, 1997; Pearce and Ferrier, 2000). A random ranking has on average an AUC of 0.5, and a perfect ranking achieves the best possible AUC of 1.0. Models with values above 0.75 are considered potentially useful (Elith, 2002; Philips and Dudík, 2008). Yet, Lobo *et al.* (2008) indicated that AUC provides information about the generalist or restricted distribution of a species along the range of predictor conditions in the study area, but it does not provide information about the good performance of the model. Because of this, it is used cautiously in combination with other indices through this study.

Table 2.3-5. Threshold-dependent indices for model evaluation

Index	Formula
Sensitivity (Se)	$\frac{a}{a+c}$
Specificity (Sp)	$\frac{d}{b+d}$
Positive Predictive Value (PPV)	$\frac{a}{a+b}$
Negative Predictive Value (NPV)	$\frac{d}{c+d}$
Overall accuracy (OA)	$\frac{a+d}{n}$
Cohen's Kappa (*k*)	$\frac{(a+d)-\left(\frac{[(a+c)(a+b)+(b+d)(c+d)]}{n}\right)}{n-\left(\frac{[(a+c)(a+b)+(b+d)(c+d)]}{n}\right)}$
Odds ratio	$\frac{ad}{cb}$
Traditional F-measure	$\frac{2a}{2a+b+c}$

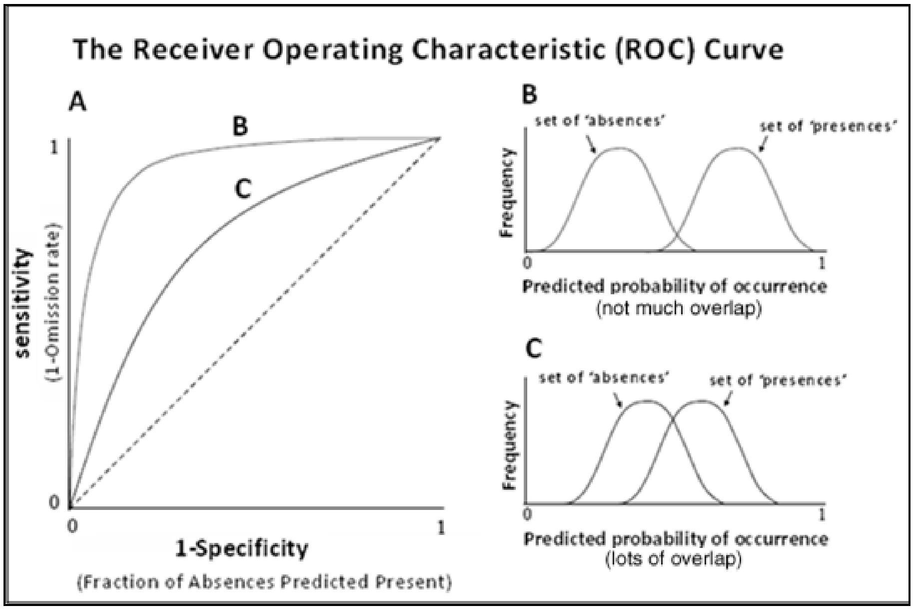


Figure 2.3-8. Illustration of Receiver Operating Characteristics Curves and Frequency Distributions. (Biodiversity Informatics Facility, 2011)

In order to evaluate model performance, Maxent runs an analysis of omission/commission that evaluates model performance/bias as a function of predicted occurrence values. There are three basic outputs of this analysis. First one is the evaluation of omission vs. commission values in respect to different thresholds. This threshold leads to modelling 'habitat' vs. 'non-habitat' and making the presence/absence prediction, which is the final step in SDM. A binary map rather than a continuous map is necessary while estimating species range and assessing impact of climate change (Liu *et al.*, 2005). Maxent obtains 11 different threshold values depending on omission and commission errors, so that researchers can determine the most appropriate threshold depending for their study on desired error values. For studies concentrating on climate change predictions, omission and commission errors are equally important (Liu *et al.*, 2005). Correspondinly, three most relevant threshold values have been calculated and evaluated for the success of the models one by one. None of these thresholds showed significant difference in success of the models. Therefore, the 'equal training sensitivity and specificity' threshold, which gives no preferences to the error types is used through this study. Here, sensitivity (true positive fraction) is the proportion of observed presences correctly predicted, while specificity (true negative fraction) is the proportion of observed absences correctly predicted (Table 2.3-5). Second one evaluates the potential sample bias, indicating the relationship between predicted values of occurrence probability and the proportion of occurrences selected. Third one is the AUC value. As Maxent uses background pseudo-absences, AUC here shows the probability that a randomly chosen presence site is ranked above a random background site (Phillips *et al.*, 2006, 2008). As a result, Maxent uses "fractional predicted area" (the fraction of the total study area predicted present) instead of the more standard commission rate (fraction of absences predicted present). Using the replicates process during modelling results in ROC curves with error bars and average AUC across models.

Unfortunately, when true absence points are not available, problems arise with some measures derived from the omission and commission errors calculated

(Fielding and Bell, 1997). Therefore, other validation procedures, independent from the validation processes implemented by Maxent, are done. Ideally, an independent data set should be used during this process; however, in many cases this might not be available, particularly for threatened or narrowly distributed species. Alternatively, the most commonly used approach is to partition the data randomly into ‘training’ and ‘test’ sets, thus creating quasi-independent data for model testing (Fielding and Bell, 1997; Guisan and Zimmerman, 2000). Therefore, we randomly put a side 25% of the available presences while running the models. After modelling and threshold selection processes, these relatively independent presences and collected absences are used to create a confusion matrix. Then we used different test to evaluate the success of the model depending on this new confusion matrix. Small sample size left for modelling is a handicap of this process, especially when it comes to restricted range species with few records available. However, recent studies (Pearson *et al.*, 2007) and our personal analyses showed that the models have high success rates and statistical significance with sample sizes as low as five when the Maxent model was applied.

Maxent also evaluates the features’ contributions in order to determine the most important feature for the model. These analyses include two methods for ranking the importance of features used. One of these shows the relative gain achieved by each feature. In order to do this, Maxent evaluates how much the overall model gain is improved when small changes are made to each coefficient value associated with a particular feature during optimization process. Once the modelling procedure is over, all these small gains associated with each feature are summed and taken as a proportion of all contributions. Yet, these are sensitive to the correlation between features. If variables are highly correlated, the percent contribution of those variables used later in the optimization will have underestimated importance. This issue makes ranking of the variables important. In order to understand the effect of ranking, order of the features are changed and models run repeatedly. Yet, results were in all cases very similar. So, we can say that feature contributions are not affected by correlation interactions in this case.

Second one is relating to 'jackknife' contributions. It accounts for dependencies between predictor variables by building two sorts of models; one relating the model to the given feature by itself and the other relating all features except the given feature. Jackknife analysis can indicate either strong (but perhaps non-unique) or unique contribution to presences, or if the variable is independently predictive (Philips, 2010).

Maxent also performs response curves in order to understand how the prediction depends on each feature. Response curves are also affected by correlation (Philips, 2010). Yet, curves evaluated here show the probability of species occurrence, given each value of analyzed feature while all other features are excluded from the model. Therefore, they are relatively more independent of correlations.

CHAPTER 3

RESULTS

3.1 *Centaurea tchihatcheffii*

3.1.1 Results of Fieldwork

Field surveys were concentrated on 30 randomly selected grid squares. At the same time, opportunistic observations were recorded from other (not selected) grid squares as well. As a result, 64 grid squares have been surveyed from 30.04.2008 to 31.05.2008. Totally 76 presence (and 44 absence) records were obtained. With 10 literature records with coordinates, the total number of presences reached up to 86. Yet, some of these presence records are clumped around some core areas (Figure 3.1-1). Clumped data leads to misleading models, except when actual distribution of the species is clumped. Yet, it is a real problem if it is a bias caused by heterogeneous sampling effort, as is in this case. Correction of this bias is possible by filtering the data. Filtering is performed, by using the grid mesh generated during fieldwork studies, such that only one presence or absence record per grid is left. After filtering, 39 presences and 28 absences remained for modelling and model evaluation (Figure 3.1-1).

3.1.2 Results of Modelling

25% percent of the 39 presences were randomly chosen and set a side for constructing confusion matrix. So, only 29 presences were used during the modelling procedure, while 10 presences and 28 absences were used during confusion matrix calculations (Appendix H).

3.1.2.1 Present Distribution

3.1.2.1.1 Continuous Model: Model Success, Feature Contribution and Response Curves

3.1.2.1.1.1 Model Success:

As explained in the previous section, Maxent models a continuous map of distribution probability and its standard deviation (Figure 3.1-2). Fit of this model is primarily evaluated by Maxent itself, giving an idea about the general success of the modelling technique in respect to the presence data used. Figure 3.1-3 shows that the omission on test samples is a very good match to the predicted omission rate, indicating a well fitted model.

The ROC curve graph indicates a well fitted model as well (Figure 3.1-4). The average test AUC for the replicate runs obtained through this ROC curve is 0.982, indicating a very successful model, with a very low (0.014) standard deviation.

Yet, it is important to realize that AUC values tend to be higher for species with narrow ranges relative to the study area described by the environmental data. This does not necessarily mean that the models are better; instead, this behaviour is an artefact of the AUC statistic analysis technique. Therefore, evaluation of the model with independent data, such as confusion matrix dependent techniques, gives results that are more reliable in such cases.

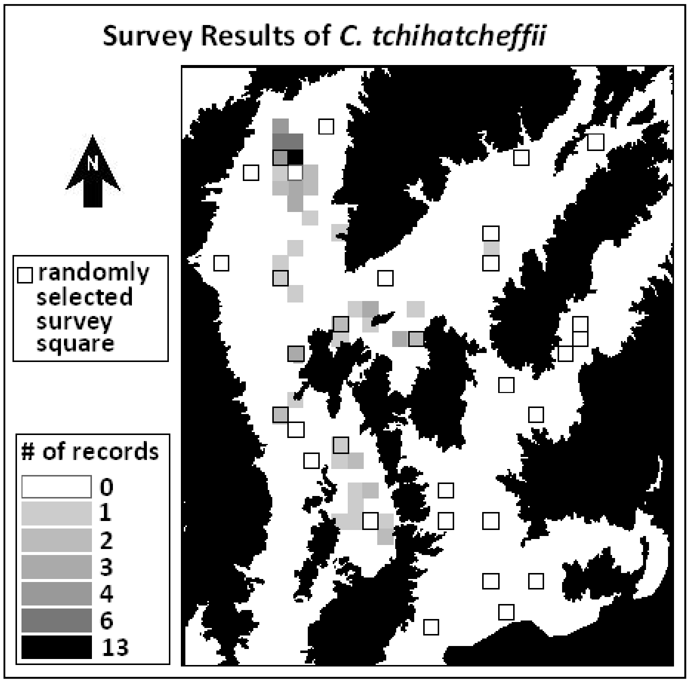


Figure 3.1-1. Survey results map of *C. tchihatcheffii* represented with a density grid mesh.

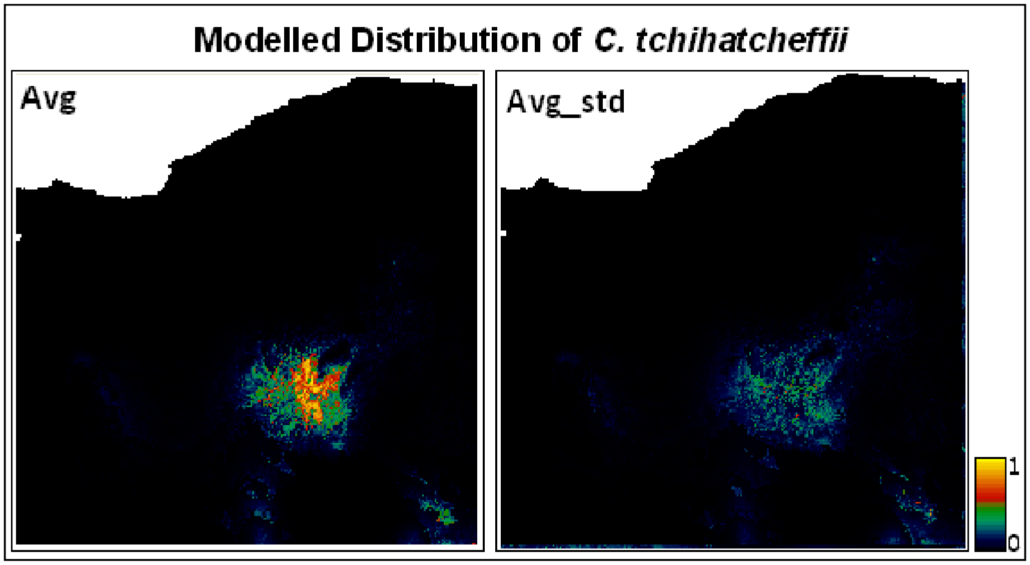


Figure 3.1-2. Modelled distribution map of *C. tchihatheffii:* Continuous probability map in logistic format.

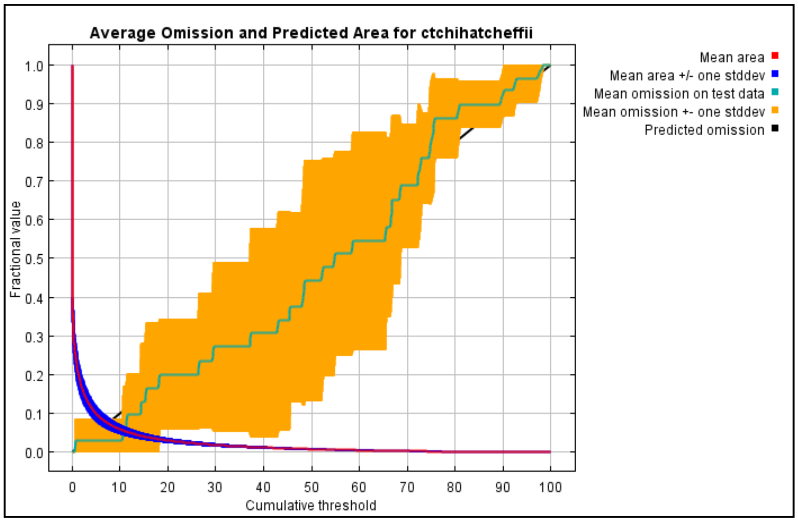


Figure 3.1-3. Graph showing how the test omission rate and predicted area vary with the choice of cumulative threshold (Averaged over 4 replicate runs). Closeness of the omission rate to the predicted omission rate (the omission rate for test data drawn from the Maxent distribution itself) gives an idea about the success of the model.

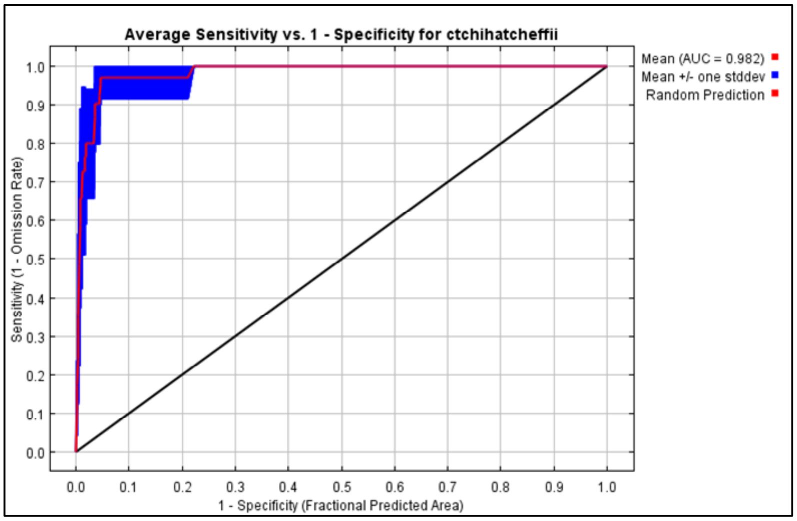


Figure 3.1-4. ROC curve averaged over the replicate runs: Red (training) line shows the “fit” of the model to the training data. Blue (testing) line indicates the fit of the model to the testing data, and is the real test of the models predictive power. Black line shows the line that you would expect if your model was no better than random. The further towards the top left of the graph the blue line is (the further it is from the black line), the better the model is at predicting the presences contained in the test sample of the data.

3.1.2.1.1.2 Feature Contributions:

Table 3.1-1 shows relative contributions of the environmental variables to the Maxent model. Results of this analysis indicate that Annual Precipitation and Isothermality have relatively the most important contribution on model.

Figure 3.1-5 show the results of the jackknife test of variable importance of both training and testing gain. The environmental variable with highest gain when used in isolation is Annual Precipitation (bio_12), which therefore appears to have the most useful information by itself. Also, it is the environmental variable that decreases the gain the most when omitted, which therefore appears to have the most information that isn't present in the other variables.

Table 3.1-1. Feature Contributions; values shown are averages over replicate runs.

Variable	**Percent contribution**
Annual Precipitation (bio_12)	57.5
Isothermality (bio_3)	22.5
Annual Mean Temperature (bio_1)	9.3
Mean Diurnal Range (bio_2)	3.6
Precipitation Seasonality (bio_15)	3.5
Slope	3.2
Max Temperature of Warmest Month (bio_5)	0.4

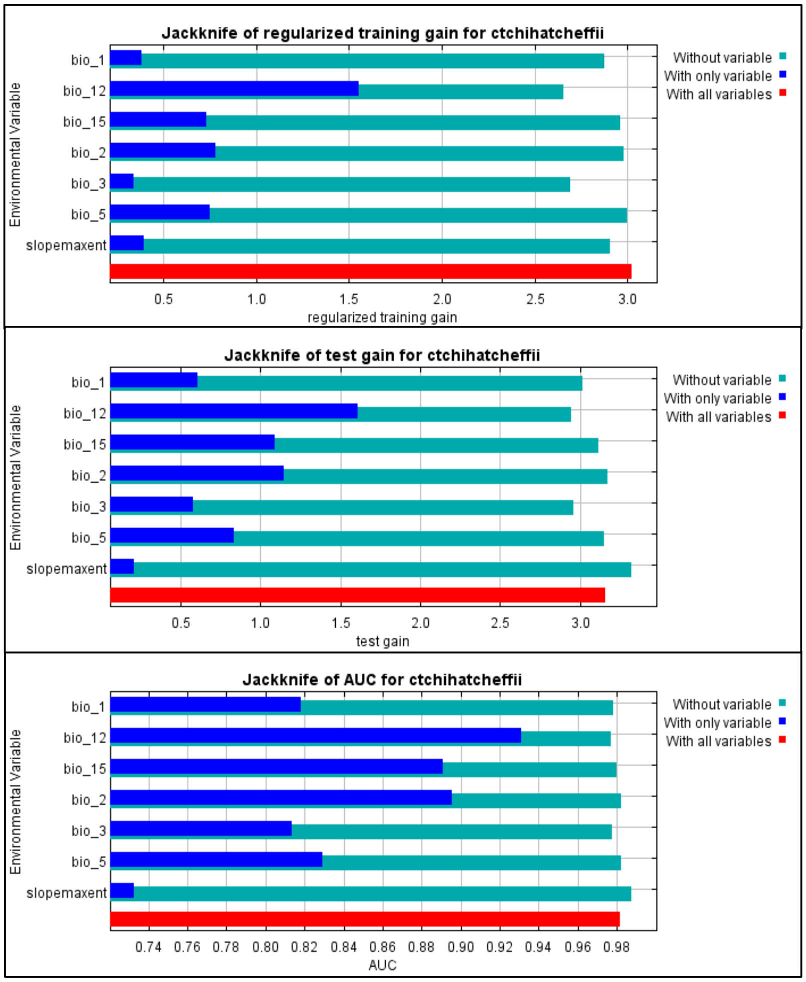


Figure 3.1-5. Jackknife test using training gain; Jackknife test using test gain; Jackknife test using AUC on test data, respectively (values shown are averages over replicate runs).

3.1.2.1.1.3 Response Curves:

Figure 3.1-6 indicates that *C. tchihatcheffii* is distributed through areas with an average precipitation between 300 and 400 mm per year. Places receiving more precipitation are not suitable for this species within the study area.

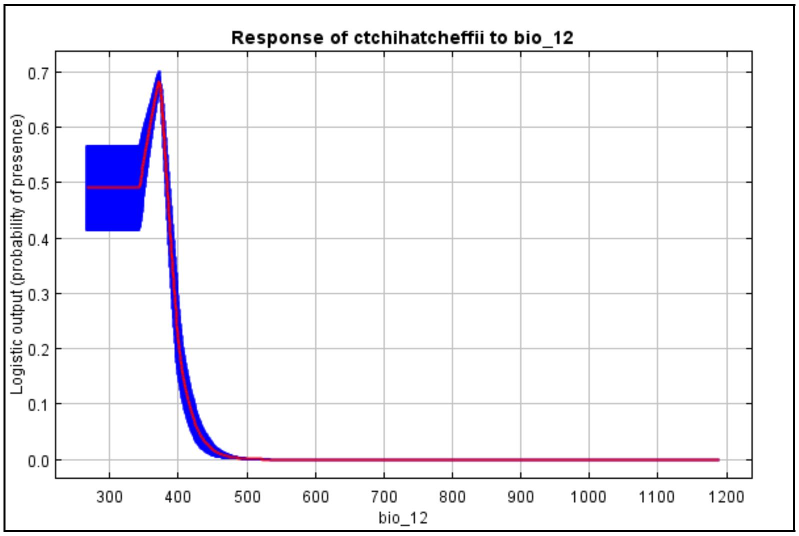


Figure 3.1-6. Response Curves: the mean response of the 4 replicate Maxent runs (red) and the mean +/- one standard deviation (blue, two shades for categorical variables).

3.1.2.1.2 Binomial Model: Map Composition and Model Success

The equal training sensitivity and specificity threshold (ths) value calculated by Maxent is 14.973 (which equals 0.1577 as logistic threshold) is used while modelling ‘habitat’ vs. ‘non-habitat’. According to this distribution (presence/absence) map, the species is estimated to have a 5,030 km^2 potential range, covering about 3.7% of the total area (Figure 3.1-7).

3.1.2.1.2.1 Tests Performed by Maxent:

Binomial tests gives P values lower than 0.005 for each 4 replicate, indicating a significantly better fit than random predictions in each replication (1 sided binomial test p-values<0.005: 0.2x10^{-5}, 0.4x10^{-9}, 0.4 x10^{-9}, 0.2x10^{-7}).

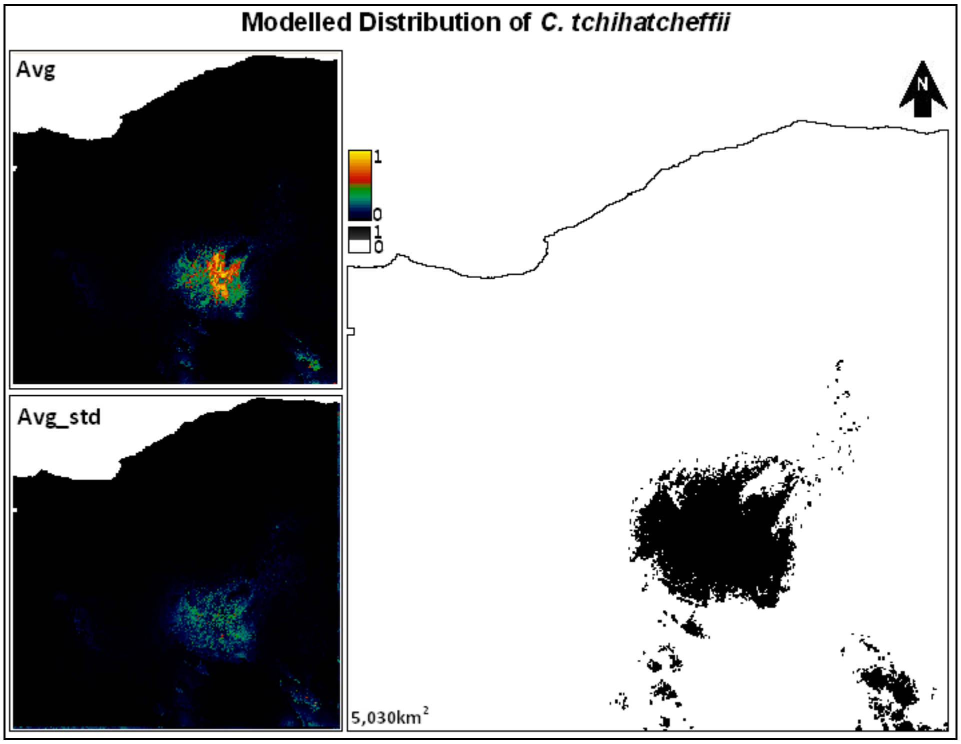


Figure 3.1-7. Modelled distribution of *C. tchihatcheffii*, including both continuous and binomial (log ths: 0.16) distribution maps.

Table 3.1-2. Confusion matrix performed for binomial map (ths: 0.16)

Confusion Matrix			
Average Model	**Recorded Presence**	**Recorded Absence**	**Sum**
Predicted Presence	9	21	**30**
Predicted Absence	1	7	**8**
Sum	**10**	**28**	**38**
Omission Rate: 0.1		**Commission Rate:** 0.75	

3.1.2.1.2.2 Tests Performed via Confusion Matrix:

Confusion matrix constructed by evaluating the averaged model output of 4 replicate runs with the specified threshold and results of accuracy tests for this distribution map are as shown in Tables 3.1-2 and 3.1-3.

In general, tests indicate that the model succeeded in predicting absences, but not much in predicting presences.

Table 3.1-3. Threshold dependent test performed for binomial (ths: 0.16) map.

Index	Value	Model Evaluation
Sensitivity (Se)	0.9	Very Good
Specificity (Sp)	0.25	Poor
Positive Predictive Value (PPV)	0.3	Poor
Negative Predictive Value (NPV)	0.875	Very Good
Overall accuracy (OA)	0.421	Moderate
Cohen's Kappa (k)	0.913	Very Good
Odds ratio	3.0	Moderate
F-measure	0.45	Moderate

3.1.2.1.2.3 Reconfiguration

Even though model evaluation gives acceptable values, the general distribution of the model is unsatisfactory as it indicates that the species distribution is wider than its actual range (Figure 3.1-8). This is not reflected to the model evaluation as fieldwork did not cover west of the study area. In order to overcome possible misleading effects of this situation, another threshold with a respectively better fit to the current distribution is intentionally used. This threshold is 0.6 (logistic threshold). Map of this new distribution and its evaluation are shown by figure 3.1-8 and tables 3.1-4 and 3.1-5.

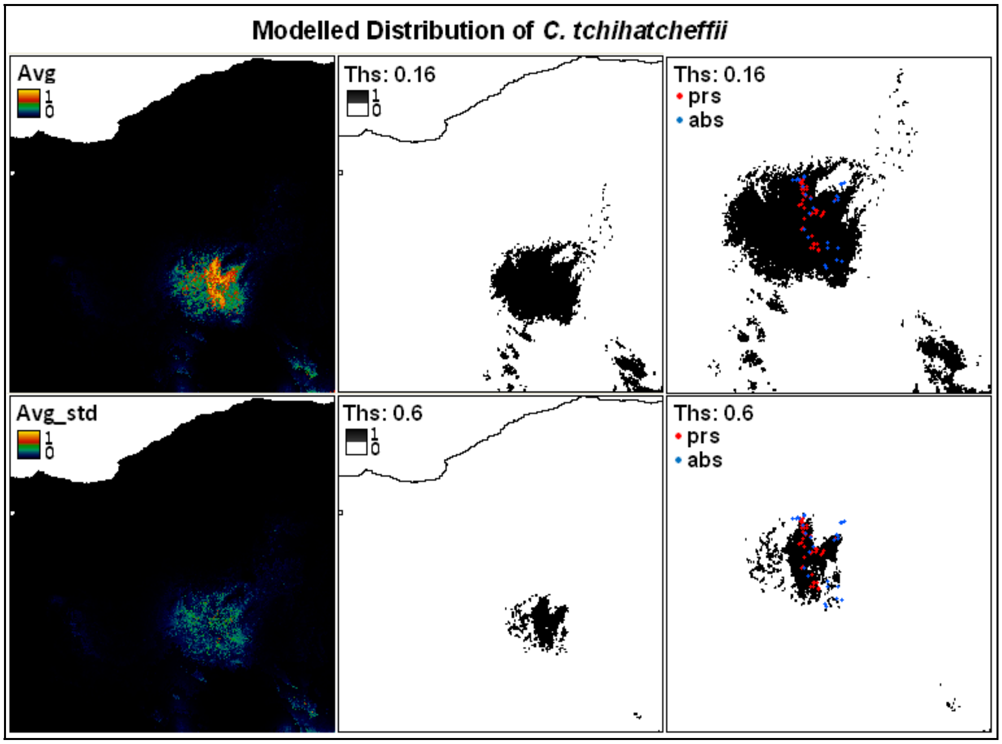


Figure 3.1-8. Illustration of binomial maps constructed with different thresholds (ths: 0.16 and 0.6)

Confusion matrix and tests in concordance with binomial distribution versus presences/absences map show a much better fit than the previous map (Table 3.1-4 and 3.1-5). This threshold is considered more reliable in projecting possible future distributions. Therefore, further analysis carried out with this higher threshold. Distribution of the species modelled as such covers 821 km^2, making up about 0.6% of the total area.

Table 3.1-4. Confusion matrix performed for binomial (ths: 0.6) map.

Confusion Matrix			
Average Model	**Recorded Presence**	**Recorded Absence**	**Sum**
Predicted Presence	8	6	**14**
Predicted Absence	2	22	**24**
Sum	**10**	**28**	**38**
Omission Rate: 0.2		**Commission Rate:** 0.214	

Table 3.1-5. Comparison of threshold dependent tests performed for two binomial (ths: 0.16 vs. 0.6) maps.

Index Value	(Th=0.157)	(Th=0.6)	Model Evaluation (Ths=0.6)
Sensitivity (Se)	0.9	0.8	Good
Specificity (Sp)	0.25	0.786	Good
Positive Predictive Value (PPV)	0.3	0.571	Moderate
Negative Predictive Value (NPV)	0.875	0.917	Very Good
Overall accuracy (OA)	0.421	0.789	Good
Cohen’s Kappa (k)	0.913	0.519	Moderate
Odds ratio	3.0	14.667	High
F-measure	0.45	0.667	Good

3.1.2.2 Future distribution map and expected change

Once current distribution is modelled then future scenarios for 2020, 2050 and 2080 are projected under two different models. Then binomial maps of predicted distribution are created using the set threshold. Predicted distribution area are calculated and plotted as shown by the graphs below (Figure 3.1-9).

Results indicate that on average, total area suitable for this species distribution is going to increase towards 2020, but will decrease, gradually shrinking into a smaller range than its current one by 2080 (Table 3.1-6 and Figure 3.1-9). This general scheme creates a linear trend indicating a constant decrease (dashed line on Figure 3.1-9. Predictions indicate a rapid expansion of suitable area in 2020 followed by a fast decline till 2080. This pattern is due to decrease in precipitation. As previous analysis (Figure 3.1-6) indicates that *C. tchihatcheffii* prefers areas with an average precipitation between 300 and 400 mm per year and does not occur in areas with higher values; once precipitation in surrounding areas decline by 2020, lowering to 300-400 mm, they will be suitable. However, any further decline in precipitation will make these areas unsuitable again in the following decades.

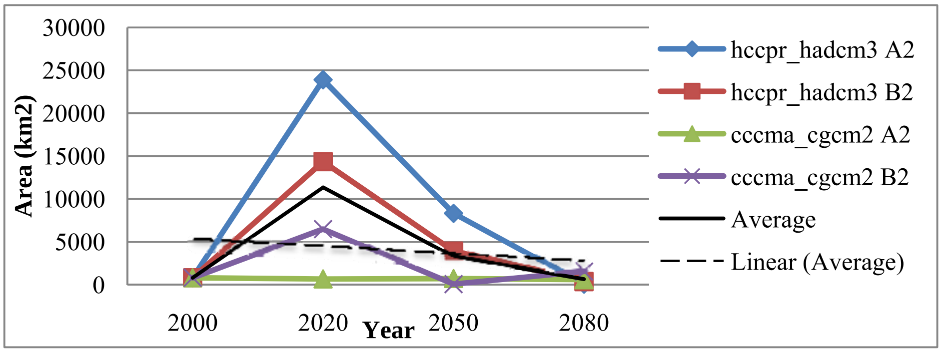


Figure 3.1-9. Change in predicted distribution area of *C. tchihatcheffii* in relation to climate scenarios.

The predicted suitable area for 2080 does not coincide much with the actual range of the species (Figure 3.1-10). In fact, this species is very well adapted to nature friendly agricultural activities (Çakaroğulları, 2005). This is a clear advantage for expansion as the species currently distributed among agricultural lands. However, it is very adversely affected by herbicide use which is very common through these agricultural lands causing a conflict for its dispersal. Moreover, change between the present and predicted distribution regions is rapid rather than gradual. In other words, the area suitable for the species rapidly shifts from one part of the area to another. Such circumstances do not give much chance for natural dispersal or range shift. Under these circumstances, it is very unlikely that this species will be able to survive the predicted future conditions. This can be evaluated as extinction of the species especially under assumption of no or limited migratory capability through this time period.

Table 3.1-6. Relative change in predicted distribution range of *C. tchihatcheffii* in respect to expected climate change. (↑: increase in relative size of total suitable area compares to current range; ↓: decrease in relative size of total suitable area compares to current range)

Model	**Year**	**Predicted Area (km^2)**	**% Change in Size of Total Dist. Area**	**Size of Projected Area**	**Intersection**		
					Area (km^2)	**% of Current Distribution**	**% of Projected Distribution**
Current	2000	821					
Hccpr_hadcm3 Model A2 Scenario	2020	23,887	2,910	↑	821	100	3
	2050	8,322	1,014	↑	660	80	8
	2080	78	90	↓	0	0	0
Hccpr_hadcm3 Model B2 Scenario	2020	14,355	1,749	↑	815	99	6
	2050	3,926	478	↑	208	25	5
	2080	379	54	↓	2	0	1
Cccma_cgcm2 Model A2 Scenario	2020	682	17	↓	505	62	74
	2050	730	100	↑	136	17	19
	2080	596	27	↓	136	17	23
Cccma_cgcm2 Model B2 Scenario	2020	6,488	790	↑	811	99	13
	2050	80	90	↓	2	0	2
	2080	1,543	188	↑	60	7	4

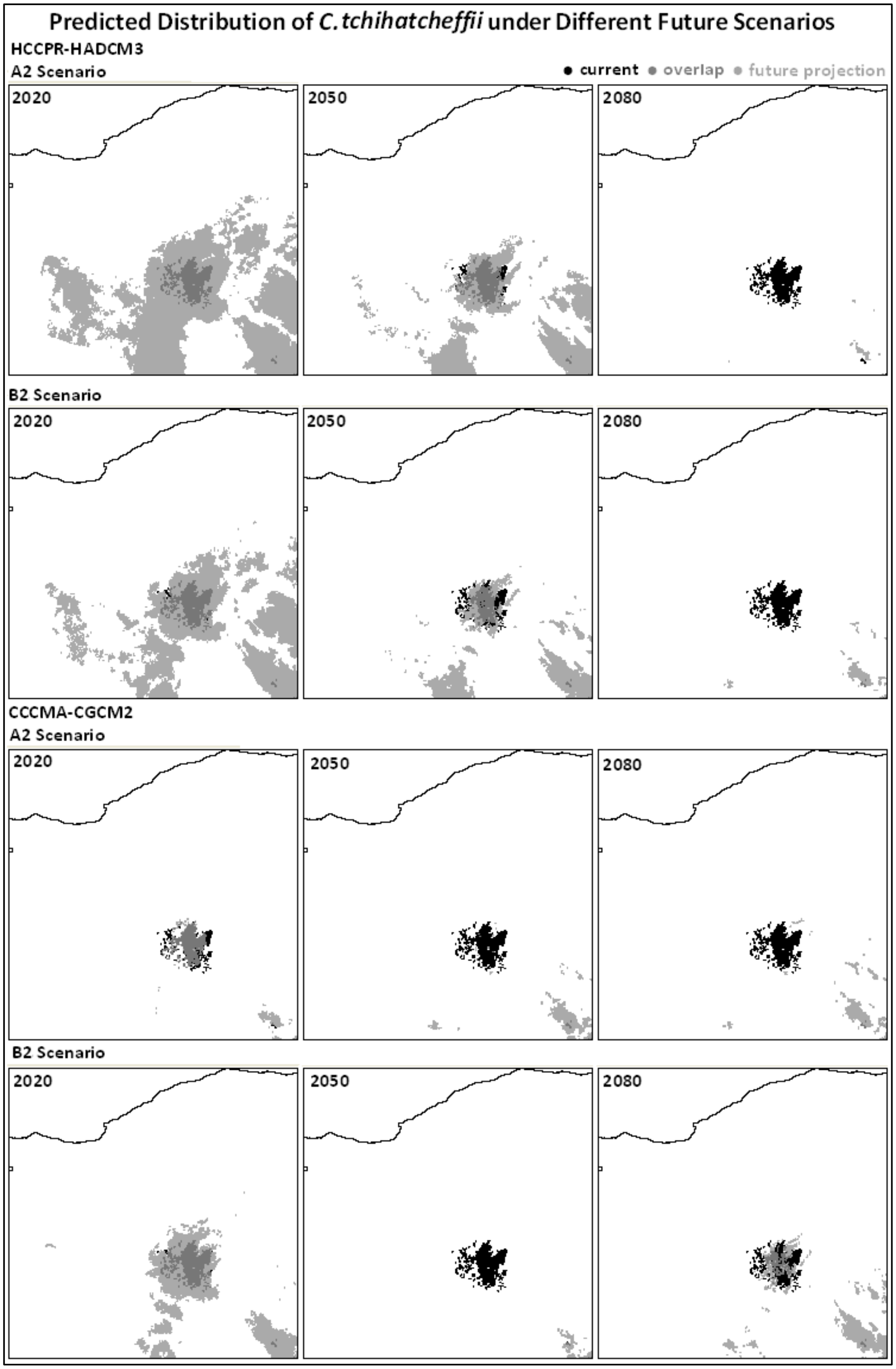


Figure 3.1-10. Illustration of change in predicted distribution range of *C. tchihatcheffii* relative to expected climate change.

3.2 *Salvia aytachii*

3.2.1 Results of Fieldwork

Together with opportunistic records from unselected survey squares, 40 grid squares have been surveyed during May 2009. Totally 29 presence (and 53 absence) records were obtained through the field surveys. With the records from preliminary fieldwork studies, they add up to 35 presences. However, only 19 of these presences (and 40 absences) were left for modelling after filtering (Figure 3.2-1).

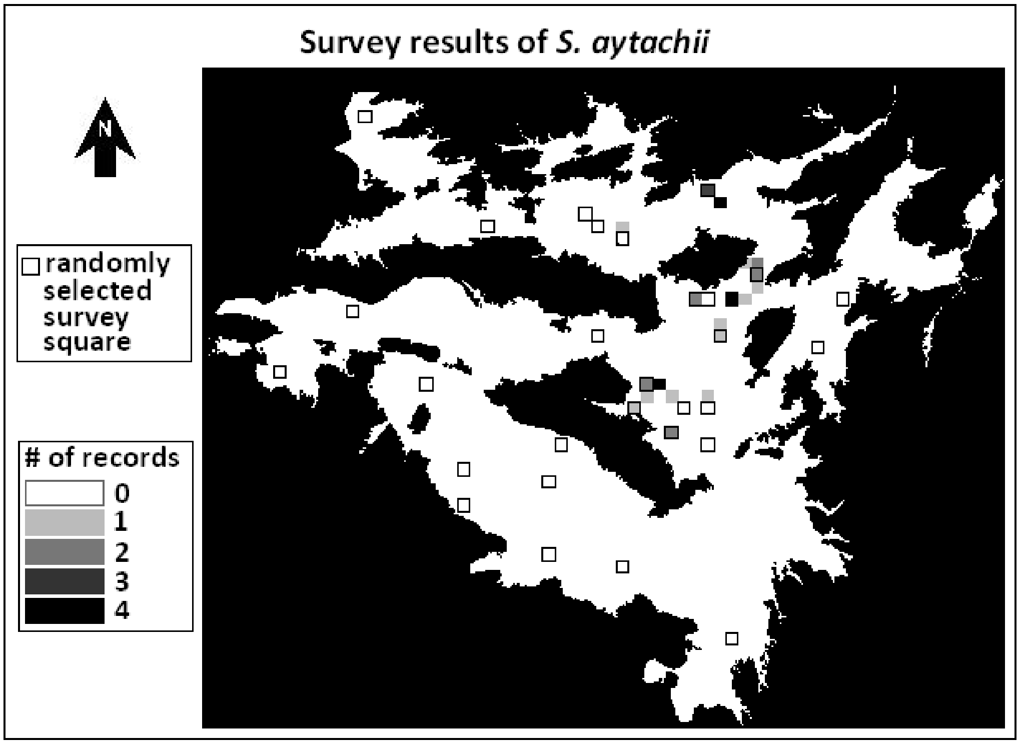


Figure 3.2-1. Survey results map of *S. aytachii* represented with a density grid mesh.

3.2.2 Results of Modelling

After setting a side 25% percent of the presences, 14 presences are left for modelling with Maxent. Rest of the presences (5) along with 40 absences are used during the construction of confusion matrix (Appendix H).

3.2.2.1 Present Distribution Map

3.2.2.1.1 Continuous Model: Model Success and Feature Contribution

3.2.2.1.1.1 Model Success:

Continuous map of presence probability is as shown by Figure 3.2-2. Figure 3.2-3 shows that the omission on test samples is a good match to the predicted omission rate, indicating a nicely fitting model.

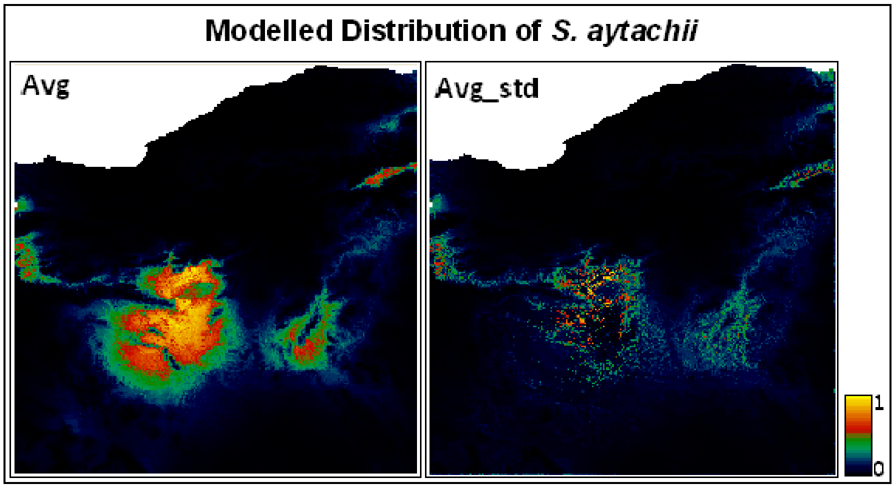


Figure 3.2-2. Modelled distribution map of *S. aytachii:* Continuous probability map in logistic format.

The ROC curve graph indicates a good fitting model as well (Figure 3.2-4). Average test AUC for the replicate runs obtained through this ROC curve is 0.92 indicating a very successful model, with a 0.066 standard deviation.

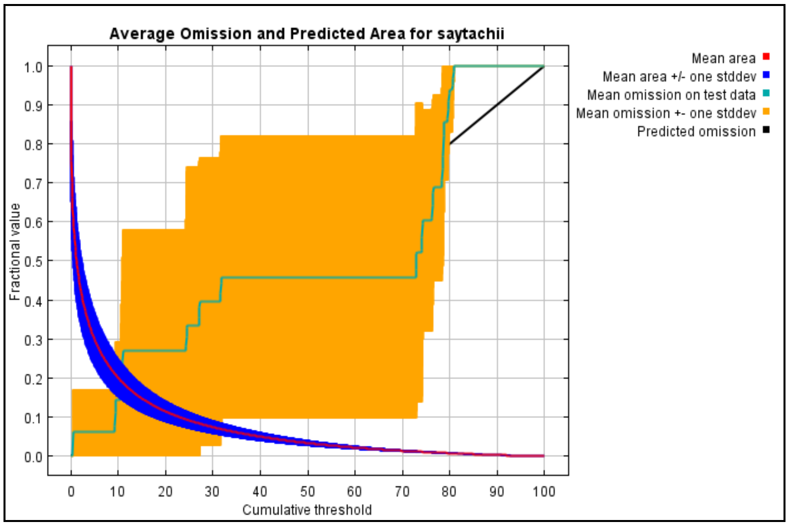


Figure 3.2-3. Graph showing how the test omission rate and predicted area vary with the choice of cumulative threshold (Averaged over 4 replicate runs). Closeness of the omission rate to the predicted omission rate (the omission rate for test data drawn from the Maxent distribution itself) gives an idea about the success of the model.

3.2.2.1.1.2 Feature Contributions

Table 3.2-1 gives estimates of relative contributions of the environmental variables to the Maxent model. Results of this analysis indicate that Isothermality (mean diurnal range/temperature annual range), Annual Precipitation and Max Temperature of Warmest Month have relatively the most important contribution on model.

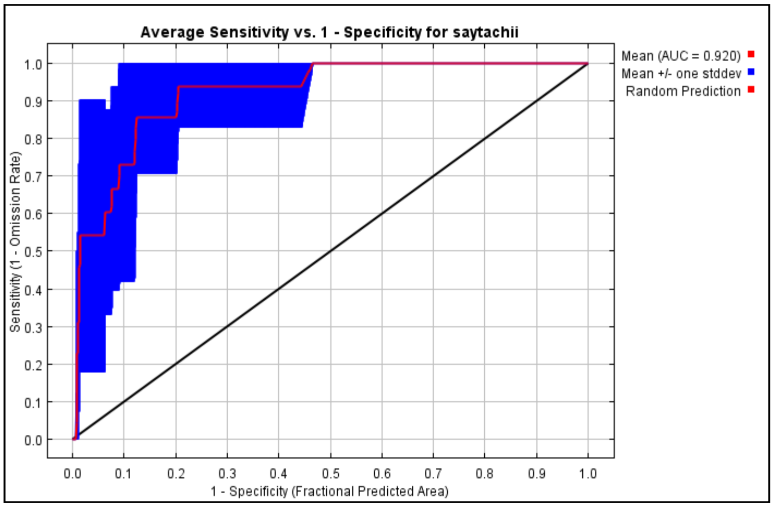


Figure 3.2-4. ROC curve averaged over the replicate runs: Red (training) line shows the "fit" of the model to the training data. Blue (testing) line indicates the fit of the model to the testing data, and is the real test of the models predictive power. Black line shows the line that you would expect if your model was no better than random. The further towards the top left of the graph the blue line is (the further it is from the black line), the better the model is at predicting the presences contained in the test sample of the data.

Table 3.2-1. Feature Contributions; values shown are averages over replicate runs.

Variable	**Percent contribution**
Isothermality (bio_3)	36.3
Annual Precipitation (bio_12)	22.5
Max Temperature of Warmest Month (bio_5)	21.6
Annual Mean Temperature (bio_1)	12.7
Slope	3.4
Mean Diurnal Range (bio_2)	3
Precipitation Seasonality (bio_15)	1

Figure 3.2-5 show the results of the jackknife test of variable importance of both training and testing gain. The environmental variable with highest gain when used in isolation is Annual Precipitation (bio_12), which therefore appears to have the most useful information by itself. On the other hand, Max Temperature of Warmest Month (bio_5) is the environmental variable that decreases the gain most when omitted, which therefore appears to have the most information that is not present in the other variables.

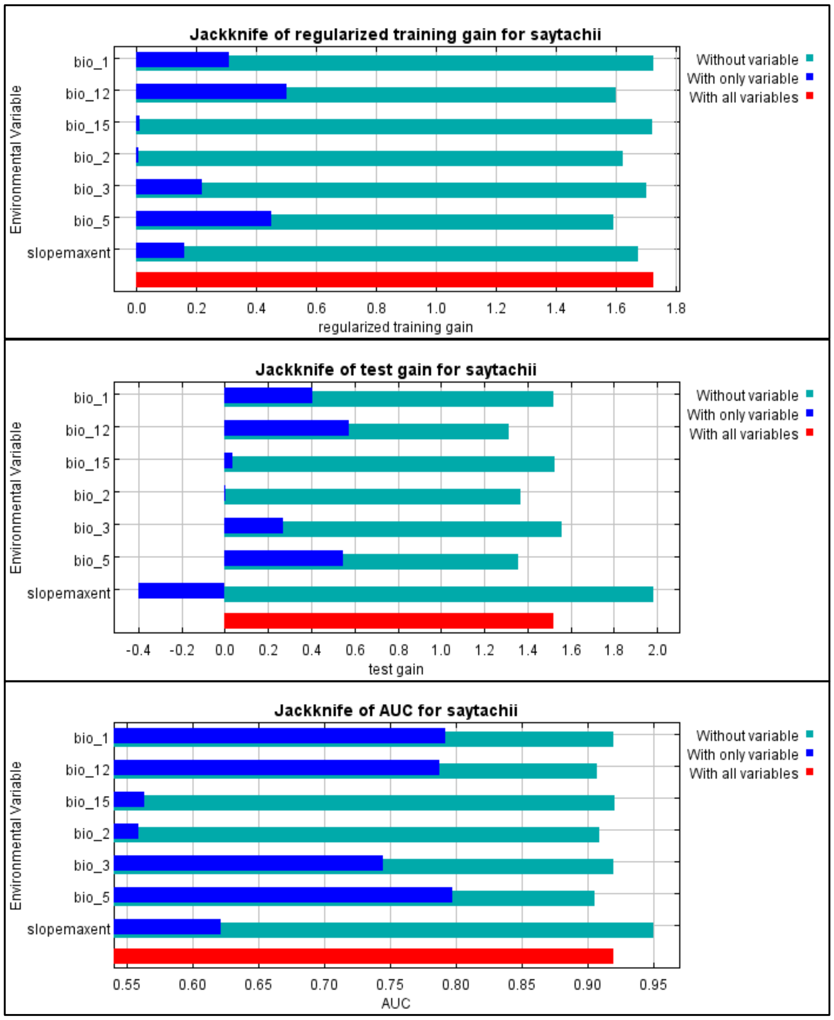


Figure 3.2-5. Jackknife test using training gain; 2. Jackknife test, using test gain; 3. Jackknife test, using AUC on test data. Values shown are averages over replicate runs.

3.2.2.1.1.3 Response Curves:

Figure 3.2-6 indicates that *S. aytachii* is distributed through areas with lower isothermality respectively.

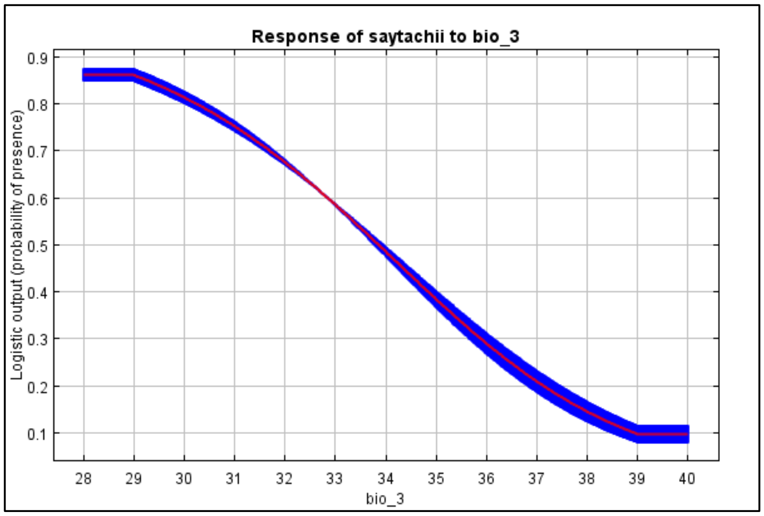


Figure 3.2-6. Response Curves: the mean response of the 4 replicate Maxent runs (red) and and the mean +/- one standard deviation (blue, two shades for categorical variables).

3.2.2.1.2 Binomial Model: Threshold Determination and Model Success

An equal training sensitivity and specificity threshold of 23.39 (cumulative) or 0.28 (logistic) is used while modelling ‘habitat’ vs. ‘non-habitat’ and making presence/absence prediction for *S. aytachii*. Bound to this threshold, distribution of the species is estimated to be 13,780 km^2, covering about 10% of the study area (Figure 3.2-7).

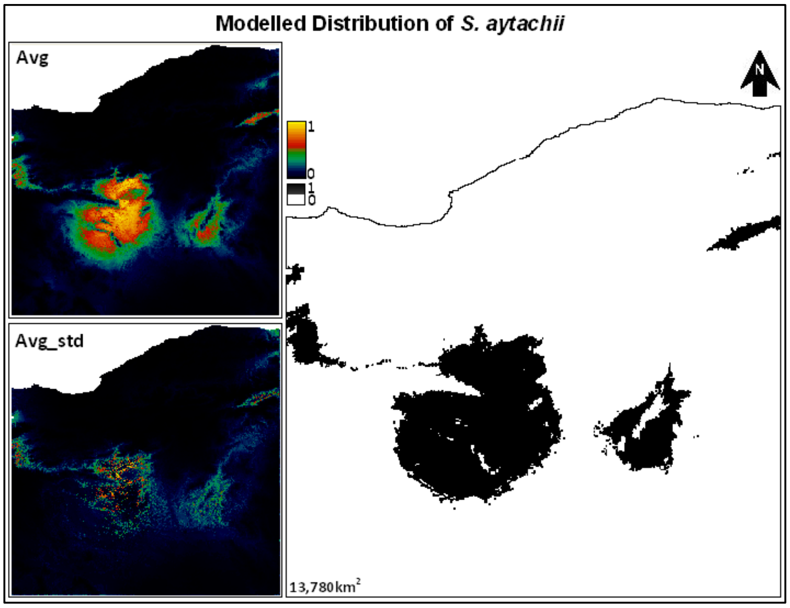


Figure 3.2-7. Modelled distribution of *S. aytachii*, including both continuous and binomial (log ths: 0.28) distribution maps.

3.2.2.1.2.1 Tests Performed by Maxent:

Binomial tests gives P values varying from one replicate to another. Only in half of the cases, results (with 2 replicates) indicated a significantly better fit than random prediction with p values lower than 0.01 (1 sided binomial test p-values: 0.3, 0.00025, 0.0009, 0.02).

3.2.2.1.2.2 Tests Performed via Confusion Matrix:

Confusion matrix constructed by evaluating the averaged model output of 4 replicate runs with the specified threshold and results of accuracy tests for this distribution map are as shown on the tables Tables 3.2-2 and 3.2-3.

In general, tests indicate that the model constructed is rather unsuccessful in predicting absences, however relatively more successful in predicting presences similar to *C. tchihatcheffii* case. However, in this case, success of the model did not improve by changing the threshold. Not only confusion matrix values but also maps indicated no better fit with any of the thresholds (Table 3.2-3, Figure 3.2-8). It is obvious that modelling strategy and efforts failed in this case. So, it would not be reliable to use this model for projecting possible future distributions.

No further analysis and modelling is carried out for this species due to the low success of the model on current distribution.

Table 3.2-2. Confusion matrix performed for binomial (ths: 0.28) map.

Confusion Matrix			
Average Model	**Recorded Presence**	**Recorded Absence**	**Sum**
Predicted Presence	4	30	**34**
Predicted Absence	1	10	**11**
Sum	**5**	**40**	**45**
Omission Rate: 0.20		**Commission Rate:** 0.75	

Table 3.2-3. Comparison of threshold dependent tests performed for two binomial (ths: 0.28 vs. 0.4 vs. 0.5) maps.

Index Value	**(Th=0.28)**	**(Th=0.4)**	**(Th=0.5)**	**Model Evaluation**
Sensitivity (Se)	0.8	0.8	0.6	Very Good
Specificity (Sp)	0.25	0.425	0.6	Poor
Positive Predictive Value (PPV)	0.118	0.148	0.158	Poor
Negative Predictive Value (NPV)	0.909	0.944	0.923	Very Good
Overall accuracy (OA)	0.311	0.467	0.6	Poor
Cohen’s Kappa (k)	0.014	0.077	0.09	Very Poor
Odds ratio	1.333	2.956	2.25	Low
F-measure	0.205	0.2	0.4	Poor

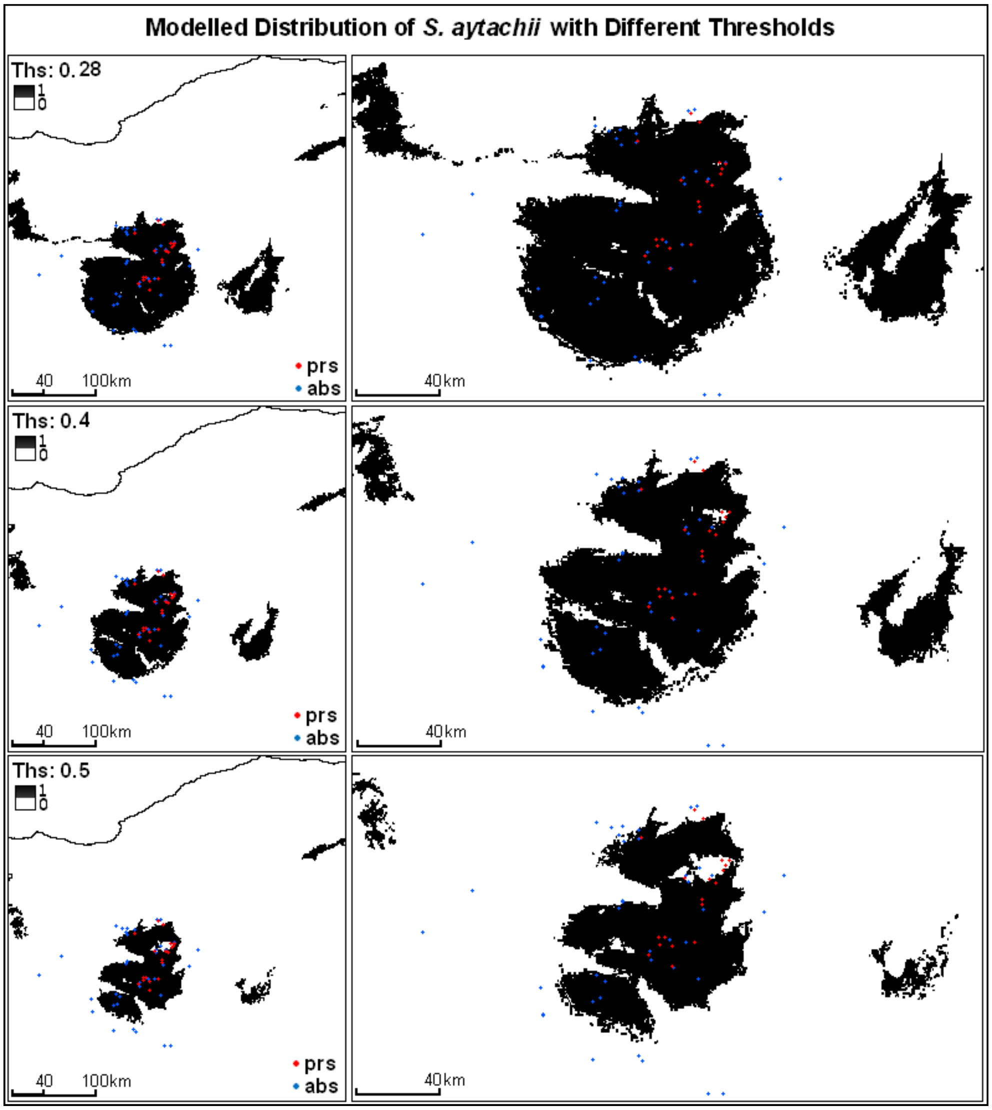


Figure 3.2-8. Presence/absences and distribution maps in respect to different thresholds determined for binomial maps of *S. aytachii*.

3.3 *Crataegus tanacetifolia*

3.3.1 Results of Fieldwork

Together with opportunistic records from unselected survey squares, totally 67 grid squares have been surveyed during August and September 2008. 65 presence and 38 absence records were obtained through these field surveys. There were 45 available herbarium records with coordinates. Altogether, they add up to 110 presence records throughout the study area. Only 61 of these remain for modelling after filtering. Yet, there was still a region within the study area where the species was known to be present but without any accurate representative presence records. Therefore, 7 most up to date herbarium records from these areas without precise coordinates, yet with high reliability have been included to the data set. Here two different aspect of this process should be underlined: Firstly, although relatively inaccurate location information is fed to the model, such records are proportionally small. Therefore, they are not expected to lead to serious bias. Secondly, representing the real distribution of the species as much as possible is very important. In this case, representativeness can only be assured by adding those records. In the end, totally 68 presence records were used during analysis (Figure 3.3-1).

3.3.2 Results of Modelling

After setting aside randomly chosen 25% percent of the presences, 51 presences were left for modelling. The remaining 17 presences and 38 absences were used during construction of a confusion matrix (Appendix H).

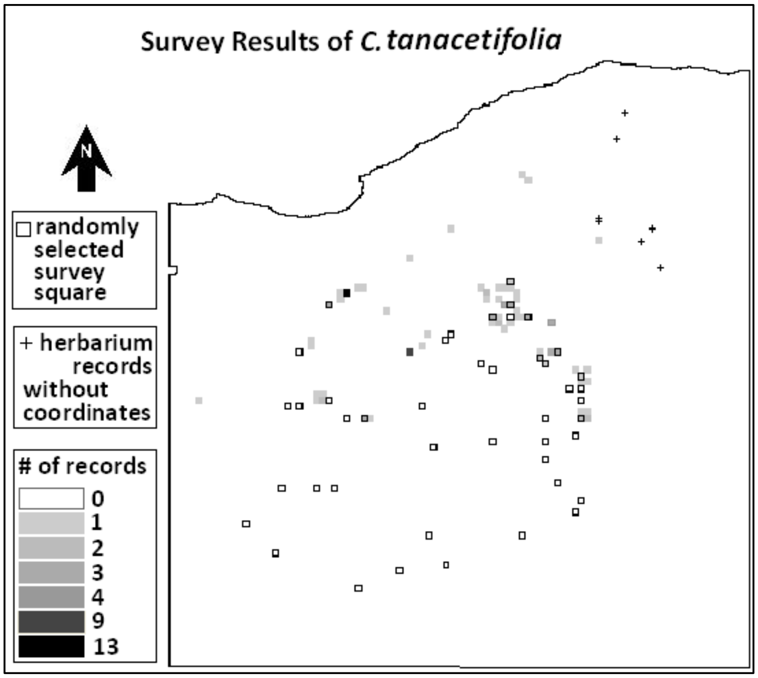


Figure 3.3-1. Survey results map of *C. tanacetifolia* represented with a density grid mesh.

3.3.2.1 Present Distribution

3.3.2.1.1 Continuous Model: Model Success, Feature Contribution and Response Curves

3.3.2.1.1.1 Model Success:

Result of the model is shown by the continuous map of presence probability (Figure 3.3-2). Figure 3.3-3 shows that the omission on test samples is a very good match to the predicted omission rate, indicating a well fit model. The ROC curve graph indicates a fit model as well (Figure 3.3-4). Average test AUC for the replicate runs obtained through this ROC curve is 0.818 indicating a successive model, with a 0.017 standard deviation.

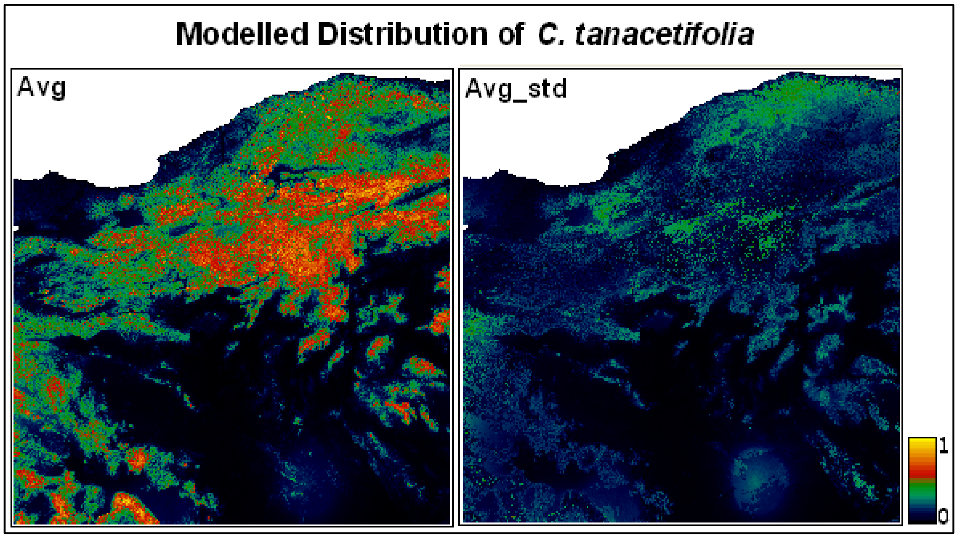


Figure 3.3-2. Modelled distribution map of *C. tanacetifolia:* Continuous probability map in logistic format.

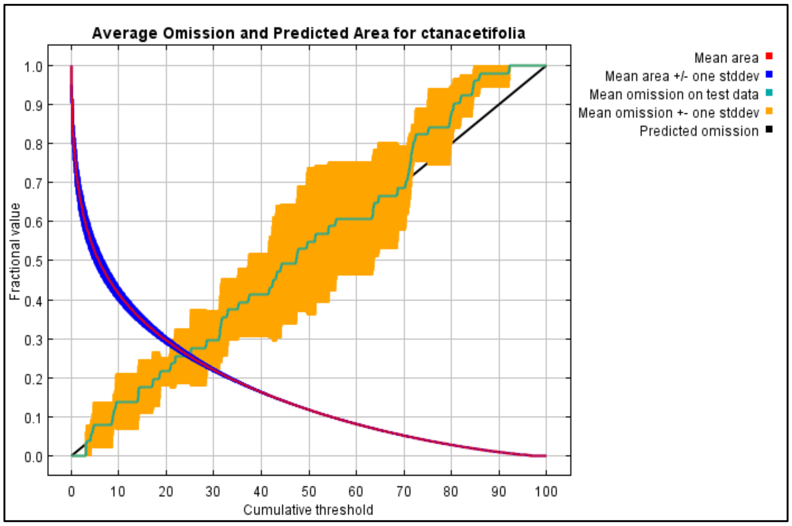


Figure 3.3-3. Graph showing how the test omission rate and predicted area vary with the choice of cumulative threshold (Averaged over 4 replicate runs). Closeness of the omission rate to the predicted omission rate (the omission rate for test data drawn from the Maxent distribution itself) gives an idea about the success of the model.

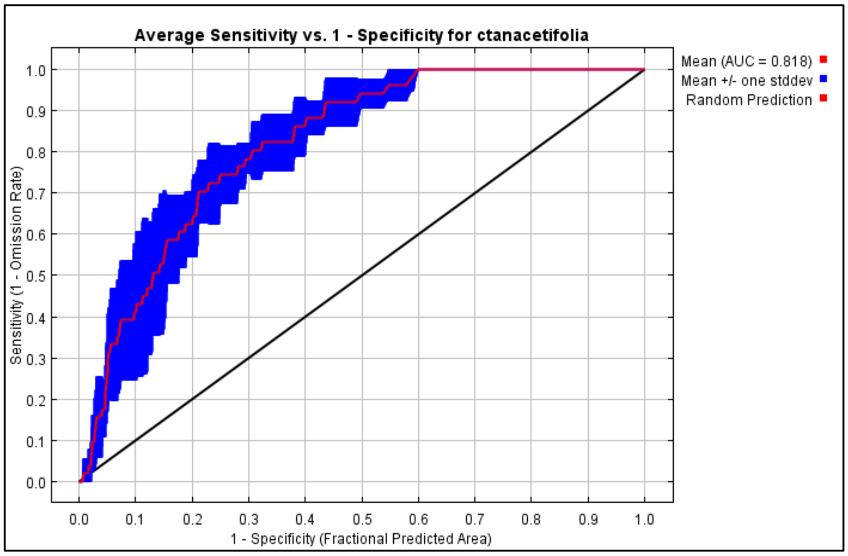


Figure 3.3-4. ROC curve averaged over the replicate runs: Red (training) line shows the "fit" of the model to the training data. Blue (testing) line indicates the fit of the model to the testing data, and is the real test of the models predictive power. Black line shows the line that you would expect if your model was no better than random. The further towards the top left of the graph the blue line is (the further it is from the black line), the better the model is at predicting the presences contained in the test sample of the data.

3.3.2.1.1.2 Feature Contributions:

Estimates of relative contributions of the environmental variables to the Maxent model indicate that Slope and Annual Precipitation (bio_12) have relatively the most important contribution on model (Table 3.3-1).

Results of the jackknife tests of variable importance show that the environmental variable with highest gain when used in isolation is Max Temperature of Warmest Month (bio_5), which therefore appears to have the most useful information by itself. On the other hand, slope is the environmental variable that decreases the gain most when omitted, which therefore appears to have the most information that isn't present in the other variables (Figure 3.3-5).

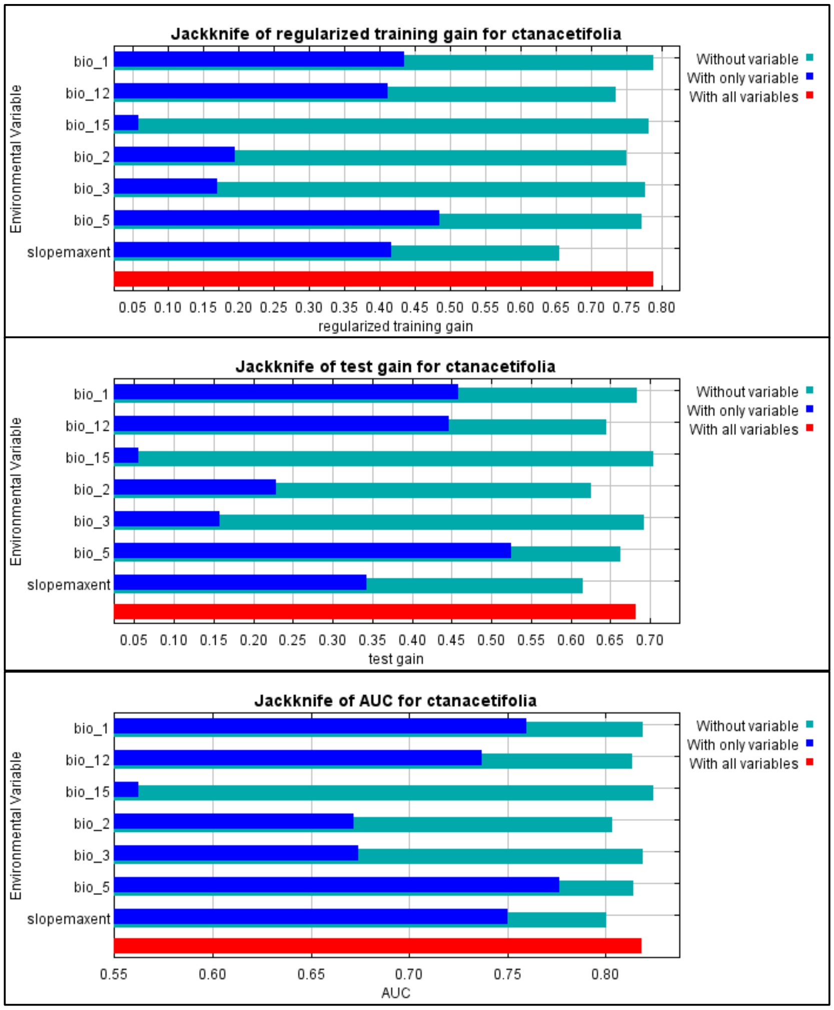


Figure 3.3-5. Jackknife test using training gain; 2. Jackknife test, using test gain; 3. Jackknife test, using AUC on test data. Values shown are averages over replicate runs.

3.3.2.1.1.3 Response Curves

Figure 3.3-6 show how each environmental variable affects the prediction. This graph indicates that *C. tanacetifolia* is distributed in areas with steep slopes throughout the study area. Species affinity to steeper areas increases gradually starting form 5 up to 35 degress (if we rank slope between 0-90 degress). This is in concordance with our observations as it seems to prefer mountainous areas.

Table 3.3-1. Feature Contributions; values shown are averages over replicate runs.

Variable	**Percent contribution**
Slope	32.9
Annual Precipitation (bio_12)	29.4
Annual Mean Temperature (bio_1)	17.7
Max Temperature of Warmest Month (bio_5)	10.7
Mean Diurnal Range (bio_2)	4.5
Precipitation Seasonality (bio_15)	3.8
Isothermality (bio_3)	0.9

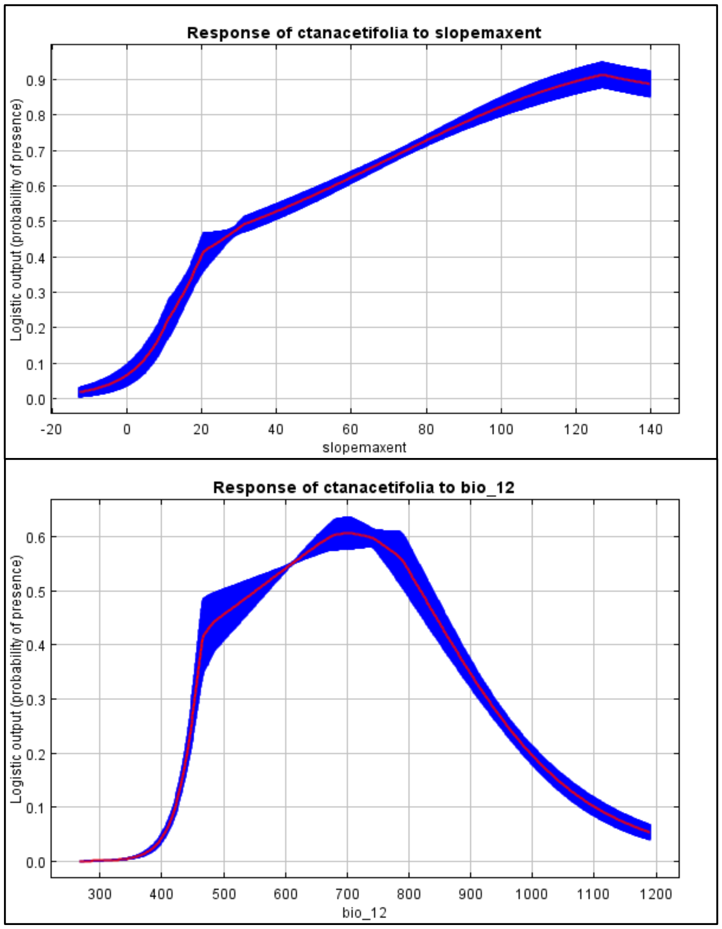


Figure 3.3-6. Response Curves of Slope and Annual Precipitation: the mean response of the 4 replicate Maxent runs (red) and and the mean +/- one standard deviation (blue, two shades for categorical variables)(slope values between 0-255).

3.3.2.1.2 Binomial Model: Map Composition and Model Success

An equal training sensitivity and specificity threshold of 30.1595 (cumulative) or 0.4145 (logistic) is used while modelling 'habitat' vs. 'non-habitat' and making the presence/absence prediction of *C. tanacetifolia*. (Figure 3.3-7). Distribution of the species is estimated to be 28,414 km^2, covering about 20% of the modelled area.

3.3.2.1.2.1 Tests Performed by Maxent

Binomial tests give P values mostly less than 0.001 (3 out of 4 cases) indicating that Maxent produced predictions that were significantly better than random predictions most of the time (1 sided binomial test p-values: 0.3, 0.00025, 0.0009, 0.02).

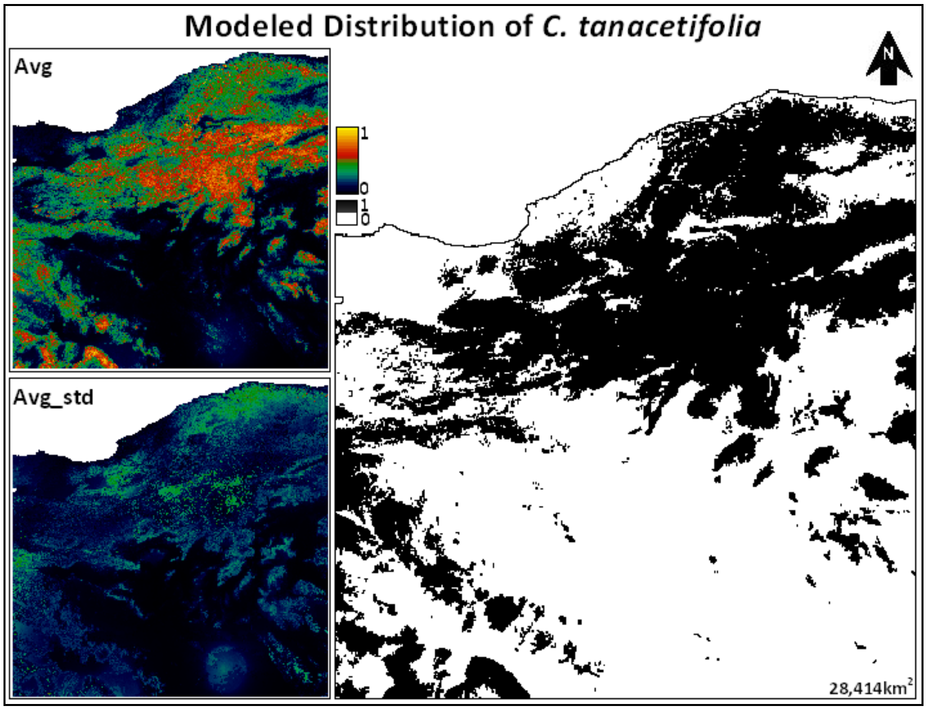


Figure 3.3-7. Modelled distribution of *C. tanacetifolia*, including both continuous and binomial (log ths: 0.41) distribution maps.

3.3.2.1.2.2 Tests Performed via Confusion Matrix

A confusion matrix was constructed by evaluating the averaged model output of 4 replicate runs with the specified threshold and results of accuracy tests for this distribution map are as shown on the Tables 3.3-2 and 3.3-3.

Table 3.3-2. Confusion matrix performed for binomial (ths: 0.41) map.

Confusion Matrix			
Average Model	**Recorded Presence**	**Recorded Absence**	**Sum**
Predicted Presence	14	7	**21**
Predicted Absence	3	31	**34**
Sum	**17**	**38**	**55**
Omission Rate: 0.1765		**Commission Rate:** 0.1842	

Table 3.3-3. Threshold dependent test performed for binomial (ths: 0.41) map.

Index	**Value**	**Model Evaluation**
Sensitivity (Se)	0.8235	Good
Specificity (Sp)	0.8158	Good
Positive Predictive Value (PPV)	0.6667	Moderate
Negative Predictive Value (NPV)	0.9118	Very Good
Overall accuracy (OA)	0.8182	Good
Cohen’s Kappa (k)	0.6003	Moderate
Odds ratio	20.667	Good
F-measure	0.7368	Good

Most of the tests indicate a good model fit (Tables 3.3-2 and 3.3-3). For example, the "odds ratio" is 20, meaning that the probability of true predictions of the model is 2000% better than false predictions. As a result, we can say that this is a good model representing the current distribution of the species well. Map showing distribution of the presence and absence records over this model gives a good visualization of this success. Yet, there have been some concerns about the model in the southwest and northeast sectors of the area. However, these concerns have been addressed through further literature search. New presence records, obtained through more up to date literature (Appendix) (Figure 3.3-8, green dots), indicating the existence of this species in those sectors showed that the fit of the model was even better than expected (Figure 3.3-8).

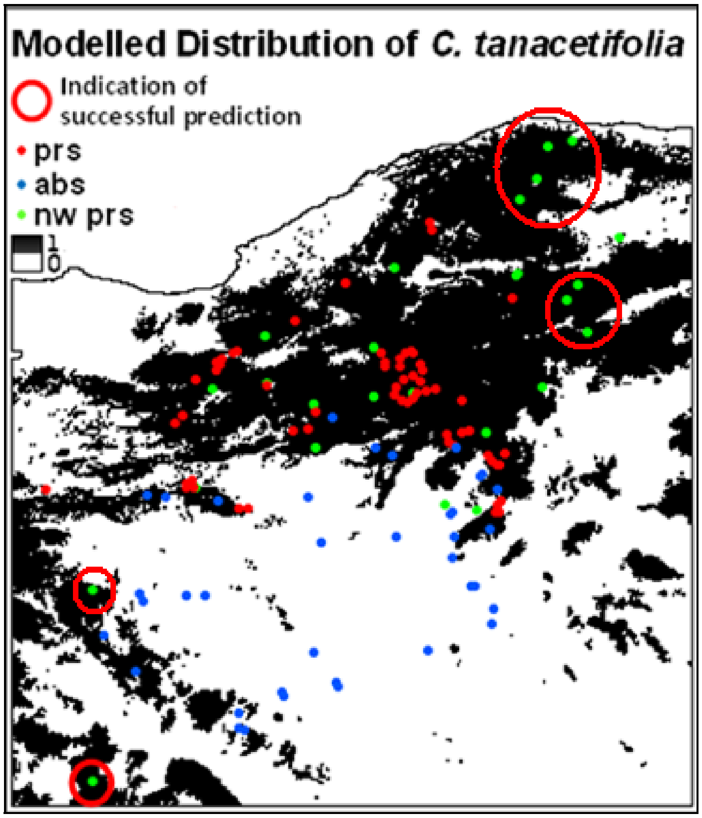


Figure 3.3-8. Illustration of binmial distribution of *C. tanacetifolia* with respect to updated available locational data.

3.3.2.2 Future Distribution Map and Expected Change

Future scenarios for 2020, 2050 and 2080 are projected under two different models. Then binomial maps are created. Characteristics of predicted distribution area are as indicated by Table 3.3-4 and shown on Figures 3.3-9 and 3.3-10.

Results indicate that on average, total area suitable for this species distribution is going to decrease gradually shrinking at least three folds smaller than its actual size till 2080 (Table 3.3-4 and Figure 3.3-9). This general scheme creates a linear trend line indicating a constant decrease in total suitable area (dashed line on Figure 3.3-9). Future predicted range of the species coincidence well with its actual range (Figure 3.3-10). In other words, suitable area for species does not shift. In fact, results indicate that this species will not need to migrate much, but will have great contraction in respect to its current distribution.

It is important to keep in mind that, modelled area does not cover overall range of *C. tanacetifolia*. Thus, computed analyses can only give ideas about its distribution through modelled area. However, modelled area is covering half of its range in a north to south transitional manner. So, it can be estimated that possible effects of climate change in the other half would be more or less similar to modelled area.

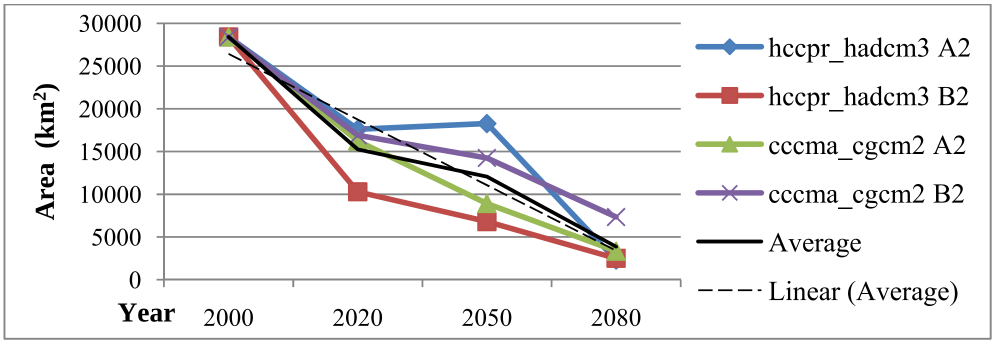


Figure 3.3-9. Change in predicted distribution area of *C. tanacetifolia* in relation to climate scenarios.

Table 3.3-4. Relative change in predicted distribution range of *C. tanacetifolia* in respect to expected climate change. (↑: increase in relative size of total suitable area compares to current range; ↓: decrease in relative size of total suitable area compares to current range)

Model	Year	Predicted Area (km^2)	% Change in Size of Total Dist. Area		Intersection		
					Area (km^2)	% of Current Distribution	% of Projected Distribution
Current	2000	28,414					
Hccpr_hadcm3 Model A2 Scenario	2020	17,608	38	↓	17,327	61	98
	2050	18,273	36	↓	17,345	61	95
	2080	2,309	92	↓	2,301	8	100
Hccpr_hadcm3 Model B2 Scenario	2020	10,292	64	↓	10,287	36	100
	2050	6,808	76	↓	6,801	24	100
	2080	2,505	91	↓	2,492	9	99
Cccma_cgcm2 Model A2 Scenario	2020	16,241	43	↓	16,227	57	100
	2050	8,918	69	↓	8,902	31	100
	2080	3,348	88	↓	3,342	12	100
Cccma_cgcm2 Model B2 Scenario	2020	16,899	41	↓	16,853	59	100
	2050	14,253	50	↓	14,243	50	100
	2080	7,334	74	↓	7,331	26	100

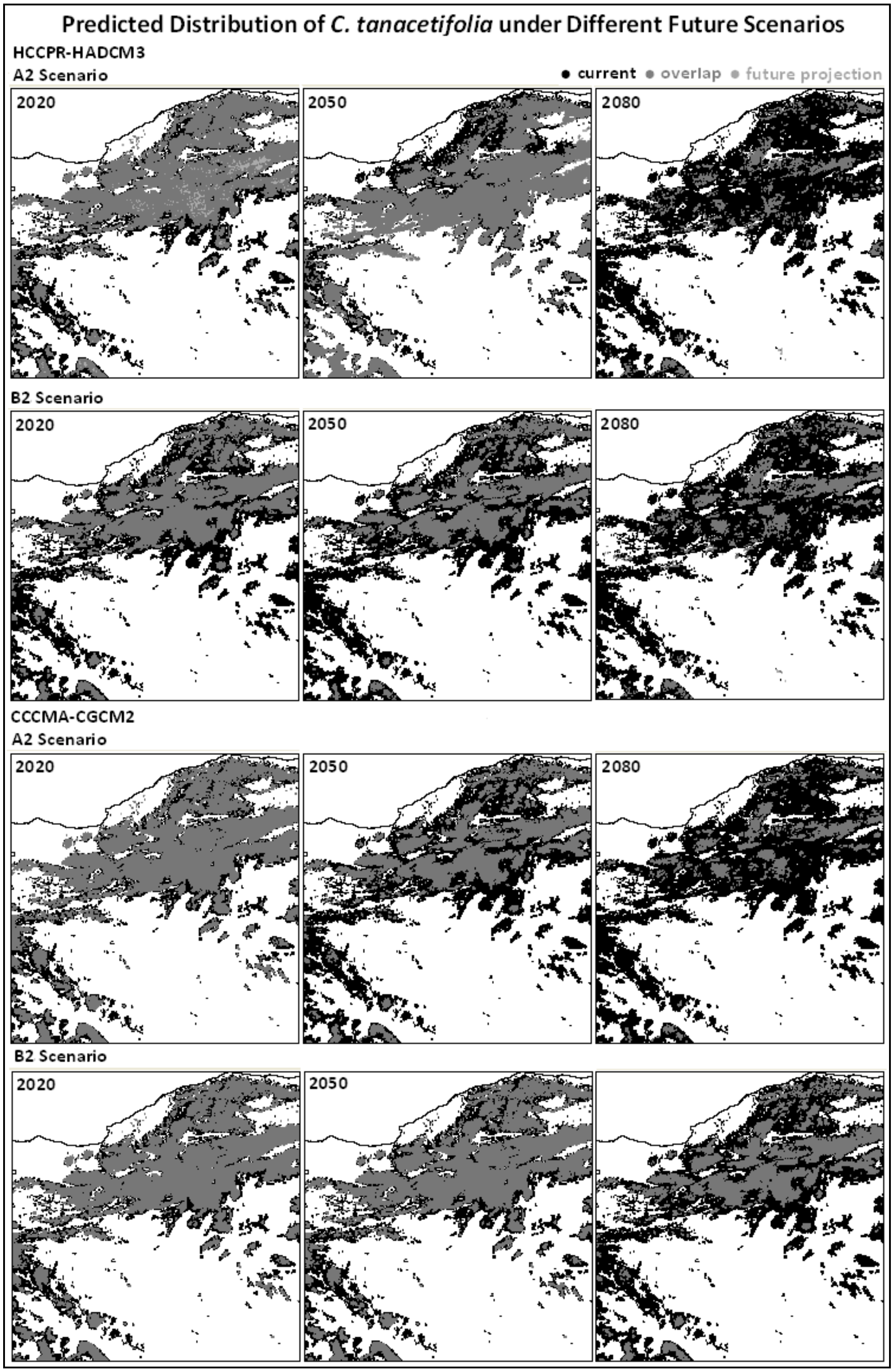


Figure 3.3-10. Illustration of change in predicted distribution range of *C. tanacetifolia* relative to expected climate change.

3.4 *Crocus ancyrensis*

3.4.1 Results of Fieldwork

Together with opportunistic records from unselected survey squares, totally 83 grid squares have been surveyed during February and March 2009. 72 presence and 60 absence records were obtained through these field surveys. There were 8 available coordinated records obtained during preliminary fieldwork. Altogether, they add up to 80 presence records through the study area. Only 51 of these presences and 39 of absences remain for modelling after filtering. Yet, there were still some part within the study area where species is known to present but left without any accurate representative presence records similar to *C. tanacetifolia* case. Therefore, 8 most up to date herbarium records from these areas without accurate coordinates but reliable accuracies have been included to the modelling procedure adding up to 59 presence records (Figure 3.4-1).

3.4.2 Results of Modelling

After setting a side randomly chosen 25% percent, only 44 presences are left for modelling. Remaining 15 presences and 39 absences are used during construction of confusion matrix (Appendix H).

3.4.2.1 Present Distribution

3.4.2.1.1 Continuous Model: Model Success, Feature Contribution and Response Curves

3.4.2.1.1.1 Model Success

Result of the model is shown in Figure 3.4-2 by the continuous map of presence probability. Figure 3.4-3 shows that the omission on test samples is a very good match to the predicted omission rate, indicating a well fitting model.

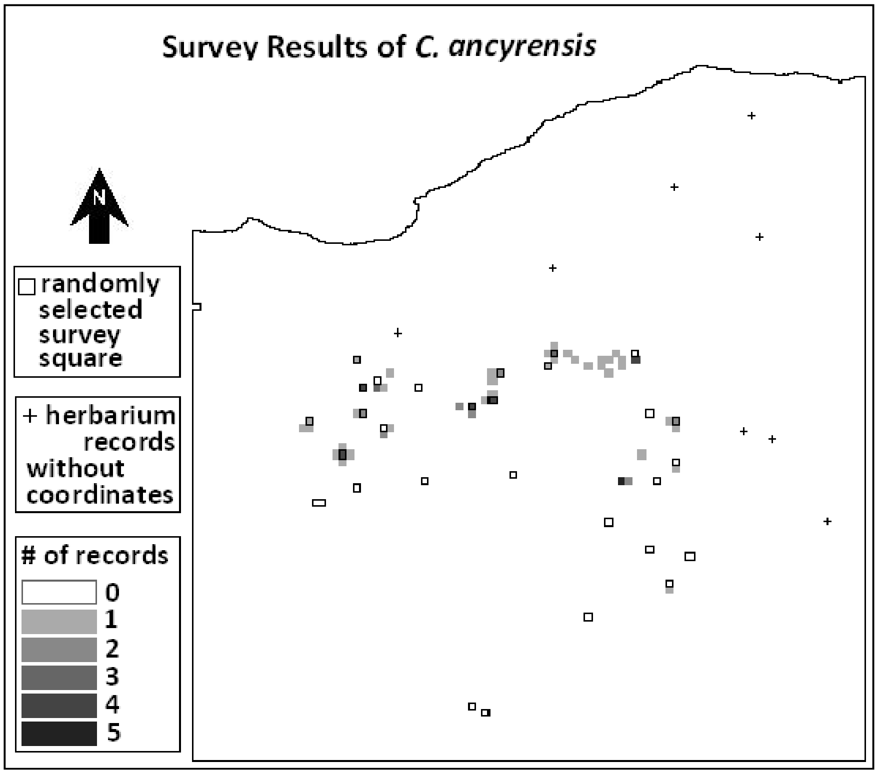


Figure 3.4-1. Survey results map of *C. ancyrensis,* represented with a density grid mesh.

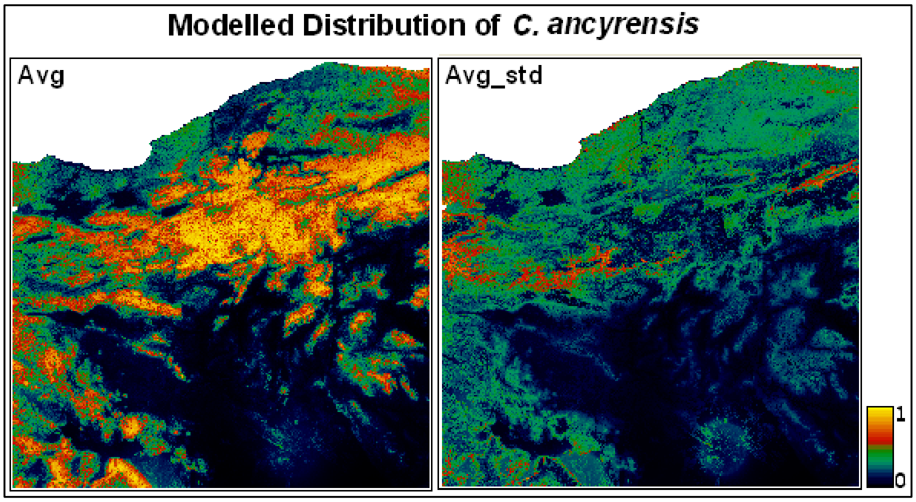


Figure 3.4-2. Modelled distribution map of C. *ancyrensis:* Continuous probability map in logistic format.

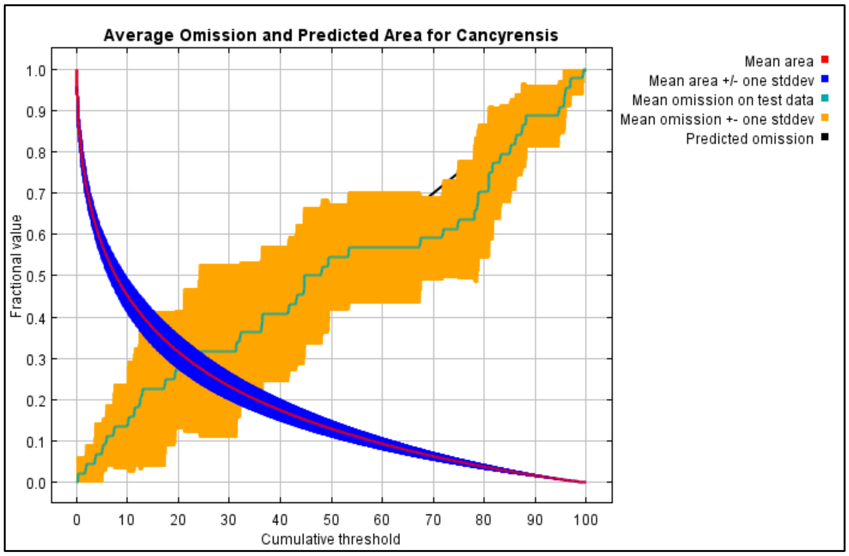


Figure 3.4-3. Graph showing how the test omission rate and predicted area vary with the choice of cumulative threshold (Averaged over 4 replicate runs). Closeness of the omission rate to the predicted omission rate (the omission rate for test data drawn from the Maxent distribution itself) gives an idea about the success of the model.

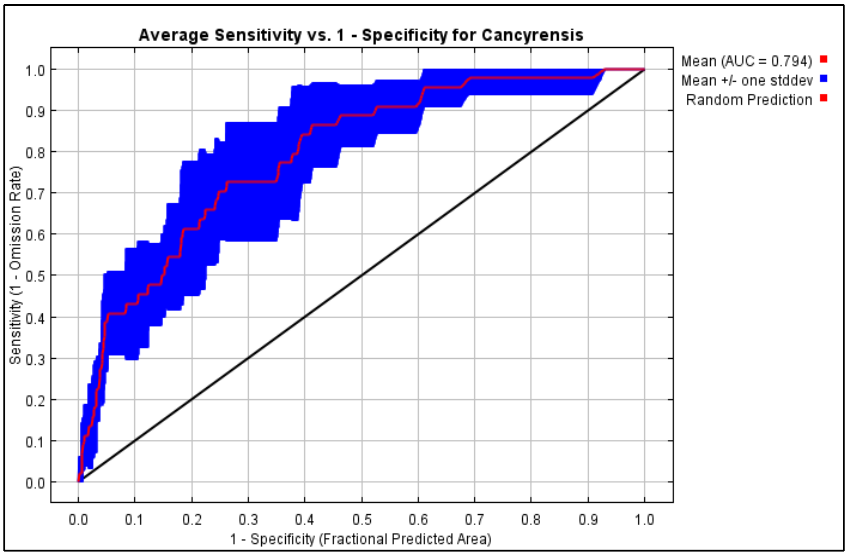


Figure 3.4-4. ROC curve averaged over the replicate runs: Red (training) line shows the "fit" of the model to the training data. Blue (testing) line indicates the fit of the model to the testing data, and is the real test of the models predictive power. Black line shows the line that you would expect if your model was no better than random. The further towards the top left of the graph the blue line is (the further it is from the black line), the better the model is at predicting the presences contained in the test sample of the data.

The ROC curve graph indicates a model with good fit as well (Figure 3.4-4). Average test AUC for the replicate runs obtained through the ROC curve is 0.794, indicating a successful model with 0.069 standard deviation.

3.4.2.1.1.2 Feature Contributions:

Table 3.4-1 gives estimates of relative contributions of the environmental variables to the Maxent model. Results of this analysis indicate that Annual Precipitation (bio_12), Slope and Max Temperature of Warmest Month (bio_5) are almost equally most important contributing features to the model. So, it is clear that interactions between these three features determine suitability of the areas for *C. ancyrensis*.

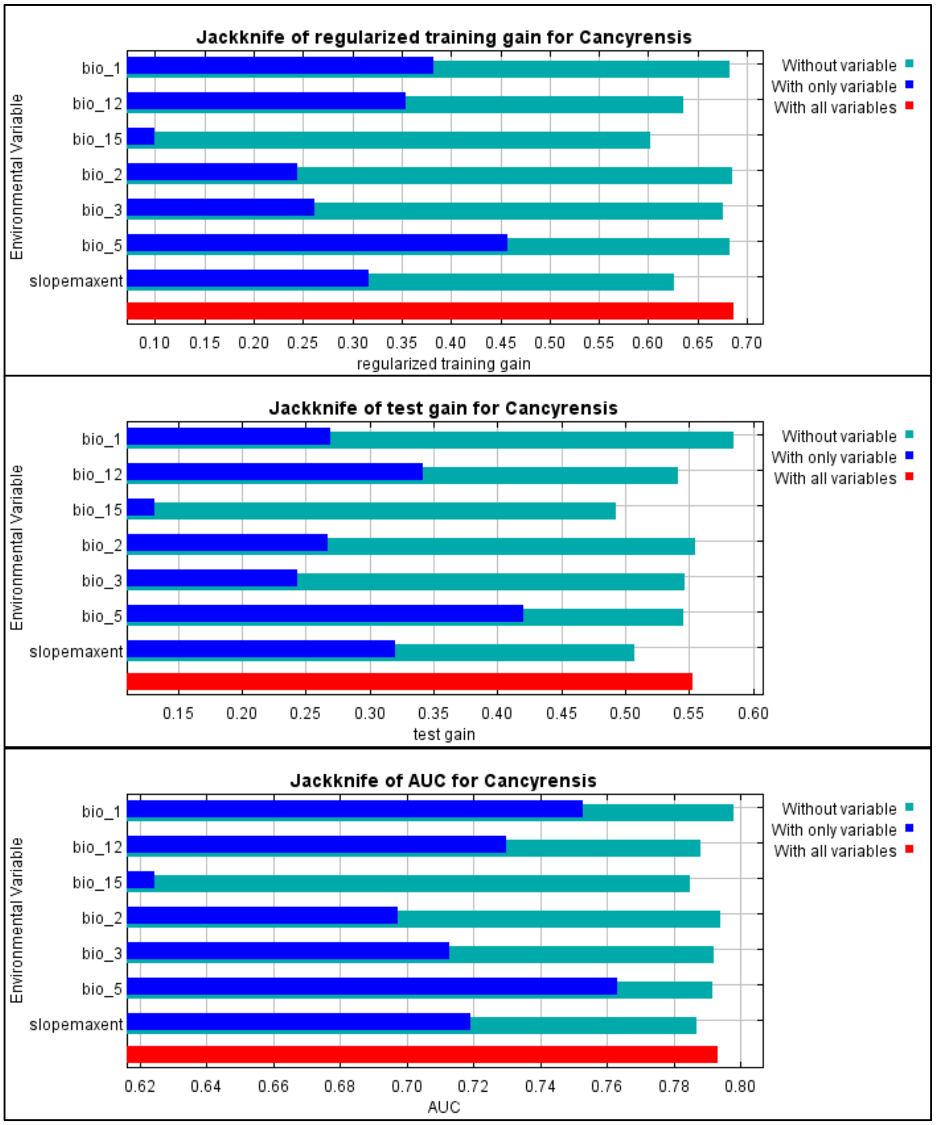


Figure 3.4-5. Jackknife test using training gain; 2. Jackknife test, using test gain; 3. Jackknife test, using AUC on test data. Values shown are averages over replicate runs.

Table 3.4-1. Feature contributions; values shown are averages over replicate runs.

Variable	Percent contribution
Annual Precipitation (bio_12)	26.5
Slope	25.3
Max Temperature of Warmest Month (bio_5)	23.3
Precipitation Seasonality (bio_15)	12.2
Isothermality (bio_3)	6.6
Annual Mean Temperature (bio_1)	6
Mean Diurnal Range (bio_2)	0.2

Results of the jackknife test of variable importance show that the environmental variable with highest gain when used in isolation is Max Temperature of Warmest Month (bio_5), which therefore appears to have the most useful information by itself. Also, Precipitation Seasonality (bio_15) is the environmental variable that decreases the gain the most when omitted, which therefore appears to have the most information that isn't present in the other variables (Figure 3.4-5).

3.4.2.1.1.3 Response Curves

These curves presented in Figure 3.4-6 show how each of the important environmental variable affects the prediction. Combination of Annual Precipitation (bio_12), Slope and Max Temperature of Warmest Month (bio_5) are almost equally important so they should be evaluated together.

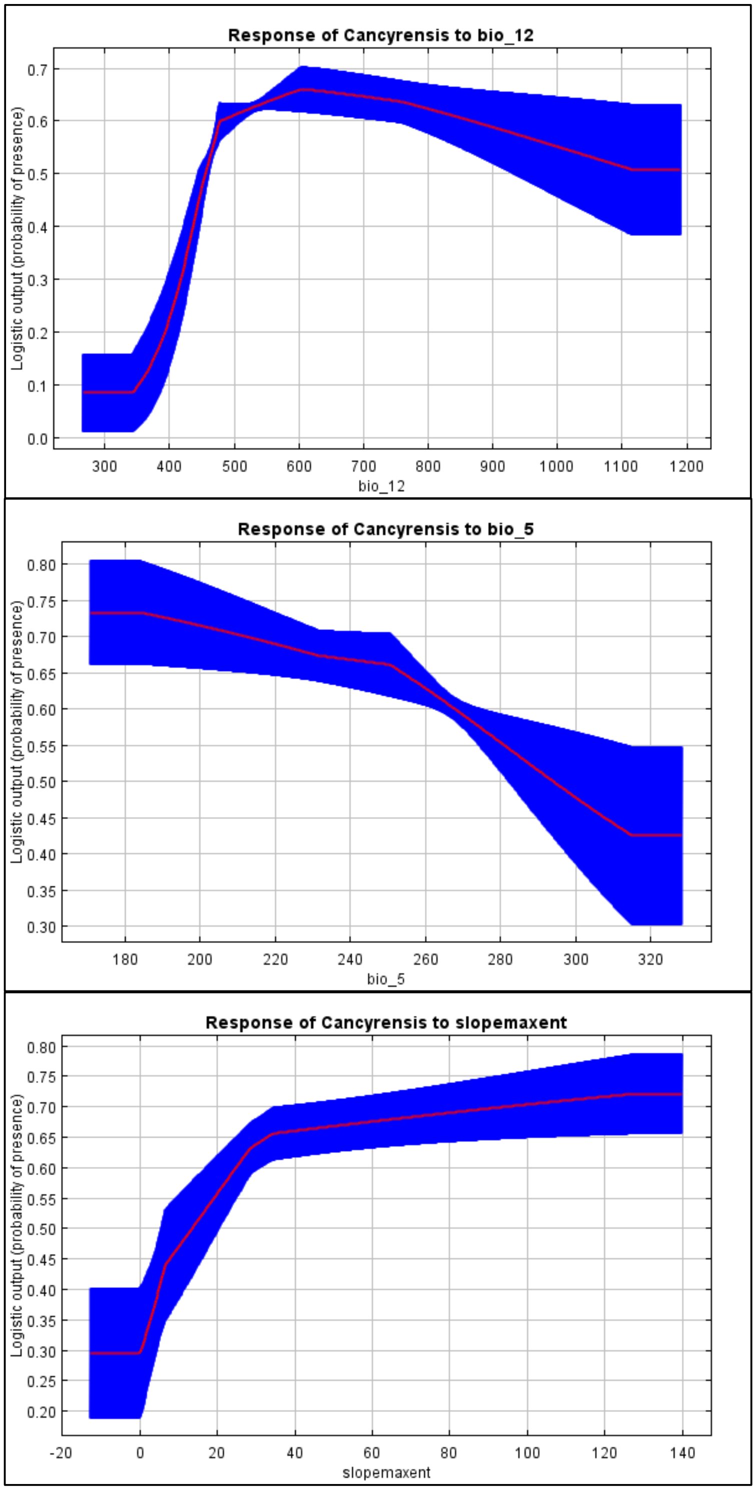


Figure 3.4-6. Response Curves: the mean response of the 4 replicate Maxent runs (red) and and the mean +/- one standard deviation (blue, two shades for categorical variables).

According to these graphs, *C. ancyrensis* is distributed through foothills (starting from 10 reaching up to 45 degrees and steeper) receiving around 500 mm and more precipitation annually with a maximum temperature of warmest month lower than 26-27 ˚C.

3.4.2.1.2 Binomial Model: Map Composition and Model Success

An equal training sensitivity and specificity threshold of 26.317 (cumulative) or 0.388 (logistic) is used while modelling 'habitat' vs. 'non-habitat' and making the presence/absence prediction of *C. ancyrensis*. (Figure 3.4-7). Distribution of the species is estimated to cover 34,185 km^2, making up about 25% of the modelled area.

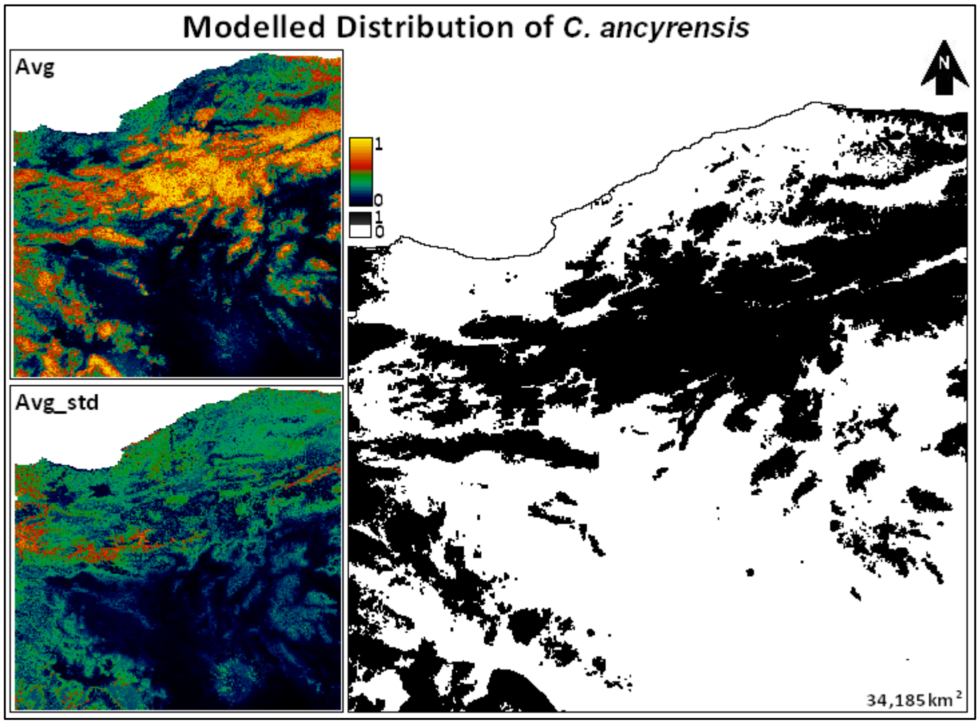


Figure 3.4-7. Modelled distribution of *C. ancyrensis*, including both continuous and binomial (ths: 0.39) distribution maps.

3.4.2.1.2.1 Tests Performed by Maxent:

Binomial tests were performed in order to evaluate the success of the model. P values of 3 replicates were less than 0.05 indicating that Maxent produced predictions that were significantly better than random predictions in 3 out of 4 replications (1 sided binomial test p-values<0.05: 0.1, 0.0003, 0,00001, 0,006).

3.4.2.1.2.2 Tests Performed via Confusion Matrix:

Confusion matrix constructed by evaluating the averaged model output of 4 replicate runs with the specified threshold and results of accuracy tests for this distribution map are as shown on the Tables 3.4-2 and 3.4-3.

Tests performed indicate a moderate model fit. In order to evaluate this fit in more detail, we performed a detailed literature review and added new distributional information (Figure 3.4-8, green dots) that have not yet been available at the very beginning of the study. Those new presence points indicated a moderate fit as well. These comparisons showed that the model is sufficient enough in predicting species' general distribution, however deficient in predicting the exact border of distribution (Figure 3.4-9). On the other hand, reconfiguration trials with different thresholds did not change the model fit much (Figure 3.4-9) so we decided to carry on the analysis with the 'equal training sensitivity and specificity' threshold. Yet, this model has been evaluated as accurate enough for giving a general idea about effects of climate change.

Table 3.4-2. Confusion matrix performed for binomial (ths: 0.39) map.

Confusion Matrix			
Average Model	**Recorded Presence**	**Recorded Absence**	**Sum**
Predicted Presence	8	18	**26**
Predicted Absence	7	21	**28**
Sum	**15**	**39**	**54**
Omission Rate: 0.4667		**Commission Rate:** 0.4615	

Table 3.4-3. Threshold dependent test performed for binomial (ths: 0.39) map.

Index	**Value**	**Model Evaluation**
Sensitivity (Se)	0.5333	Moderate
Specificity (Sp)	0.5385	Moderate
Positive Predictive Value (PPV)	0.3077	Poor
Negative Predictive Value (NPV)	0.75	Good
Overall accuracy (OA)	0.5370	Moderate
Cohen’s Kappa (k)	0.0586	Very Poor
Odds ratio	1.3333	Low
F-measure	0.3902	Moderate

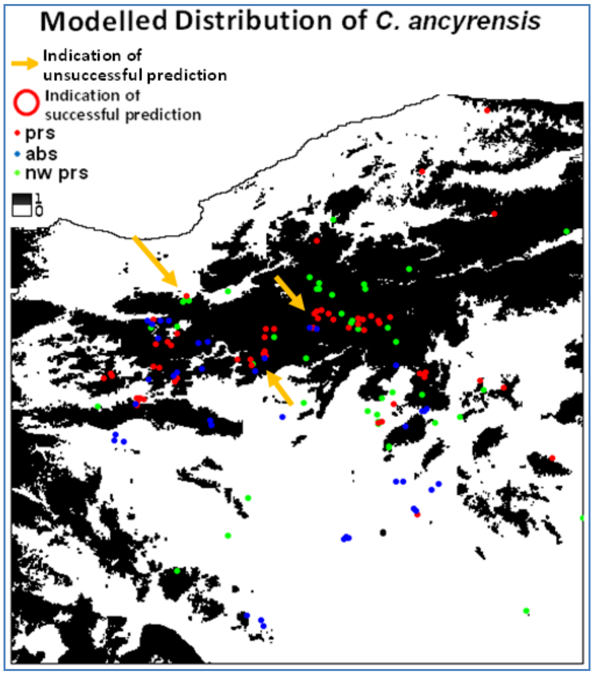


Figure 3.4-8. Illustration of binmial distribution (ths: 0.39) of *C. ancyrensis* with respect to available locational data. Orange arrows indicate places either predicted out of species current range while actually species is located there, or places that are predicted to be out of species current range where they are noted to be absent.

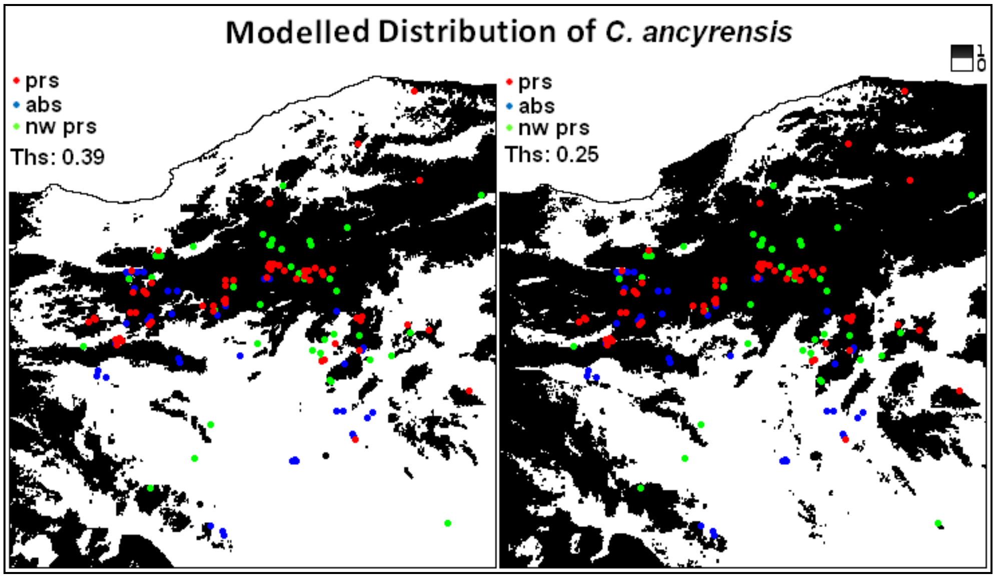


Figure 3.4-9. Illustration of binmial distributions with different thresholds (ths: 0.25 and 0.39) of *C. ancyrensis* with respect to available locational data.

3.4.2.2 Future distribution map and expected change

Future scenarios for 2020, 2050 and 2080 are projected under two different models. Then binomial maps are created. Charactheristics of the predicted distribution areas are as indicated by Table 3.4-4 and shown on Figures 3.4-10 and 3.4-11).

Results indicate that on average, total area suitable for this species distribution is going to slightly enlarge while gradually shifting towards north till 2080 (Table 3.4-10 and Figure 3.4-11). This general scheme creates a linear trend line indicating a constant increase in total suitable area (dashed line on Figure 3.4-11). In this case, predicted suitable areas for 2080 coincidence well with the actual range of the species in each case (Figure 3.4-11). In fact, results indicate that this species is not going to need to migrate much, but will need to expand northwards in respect to its current distribution. Under these circumstances, it is obvious that this species will be able to survive successfully under predicted future conditions through the modelled area.

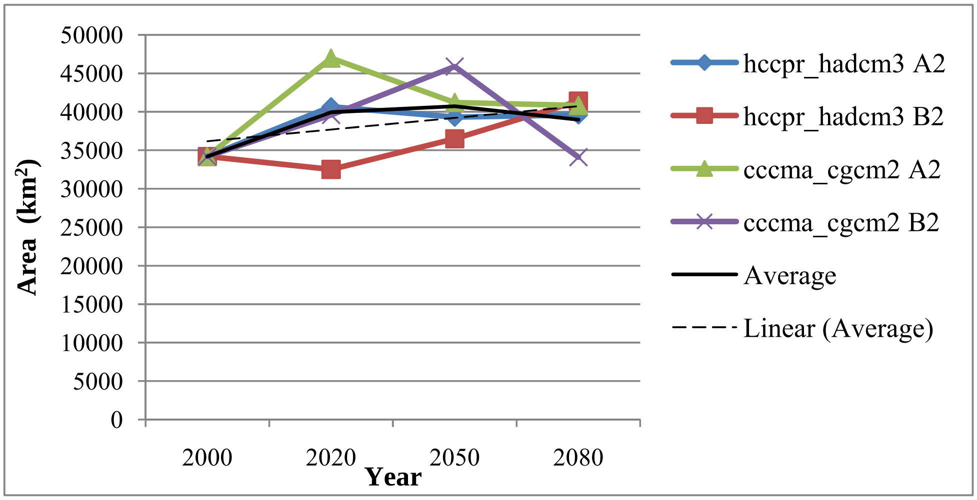


Figure 3.4-10. Change in predicted distribution area of *C. ancyrensis* in relation to climate scenarios.

Table 3.4-4. Relative change in predicted distribution range of *C. ancyrensis* in respect to expected climate change. (↑: increase in relative size of total suitable area compares to current range; ↓: decrease in relative size of total suitable area compares to current range)

Model	Year	Predicted Area (km^2)	% Change in Size of Total Dist. Area		Intersection		
					Area (km^2)	% of	
						Current	Projected
						Distribution	
Current	2000	34,185					
Hccpr_hadcm3 Model A2 Scenario	2020	40,656	119	↑	32,942	96	81
	2050	39,309	115	↑	29,586	87	75
	2080	39,603	116	↑	28,278	83	71
Hccpr_hadcm3 Model B2 Scenario	2020	32,513	5	↓	27,924	82	86
	2050	36,494	107	↑	29,321	86	80
	2080	41,392	121	↑	30,804	90	74
Cccma_cgcm2 Model A2 Scenario	2020	46,972	137	↑	32,741	96	70
	2050	41,213	121	↑	30,018	88	73
	2080	40,813	119	↑	26,277	77	64
Cccma_cgcm2 Model B2 Scenario	2020	39,593	116	↑	31,961	93	81
	2050	45,886	134	↑	33,017	97	72
	2080	34,101	100	Stable	28,143	82	83

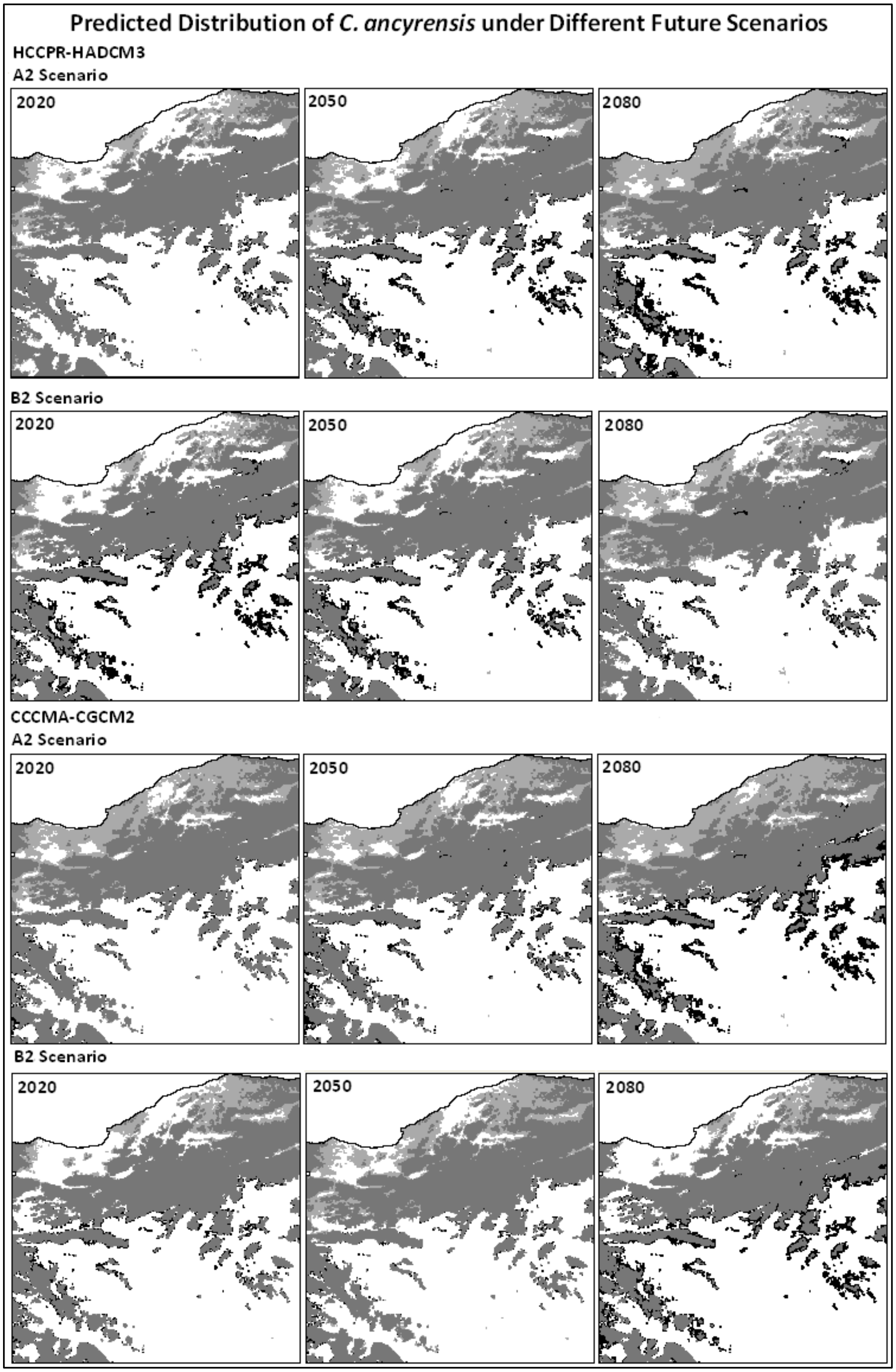


Figure 3.4-11. Illustration of change in predicted distribution range of *C. ancyrensis* relative to expected climate change.

CHAPTER 4

DISCUSSION

4.1 Analysis of fieldwork: Problems and suggestions for improvements

Successful modelling of species distributions requires a sufficient number of unbiased presence and sometimes absence records of the targeted taxon. The minimum number of records required depend upon species specific characteristics. Distribution data for endemic plant species with restricted ranges are typically lacking compared to other non-endemic and more widely distributed species. Furthermore range restricted endemic plant species are also usually recorded with a strong spatial bias. Therefore, they present a particularly difficult case for the modeller. These handicaps can be overcome through additional systematic sampling to increase sample size and/or coverage, and by filtering of available records to reduce any present bias. Conversely, in many respects plant species are simpler to model than animal species because they are not mobile and are directly influenced by climatic and other environmental factors, as they can not react as rapidly.

The extraordinary richness of the Turkish Flora and its high endemism (Vural, 2003) present many possibilities for building species distribution models. However, lack of presence records, problems on safe identification, and limitations of field logistics restrict the choices. Fieldwork for this study was initially aimed to include a long list of candidate species. Yet, information about distributions was generally very scarce and biased, as most were narrowly distributed endemics. Accordingly, it was difficult to find some target species in the field. Moreover, most of those species had overlapping flowering periods which limited efficacy of the fieldwork and potentially make identification more difficult. With this in mind, the help of expert botanists was sought to filter out problematic species. The target species were selected to represent different life history traits, such as the perennial/annual, herbaceous/woody or narrow endemic/widespread endemic dichotomies. Once study species were narrowed down to four species, minimum spatial fieldwork limits were determined for each species according to known presence locations and altitudinal range inferred from the available records. These species specific field work areas were then expanded according to species attributes. This was necessary because the limited records in herbariums are known to be generally biased towards easily accessible locations. Outcomes of fieldwork showed that this approach has been very rewarding. For example, fieldwork on *C. tchihatcheffii* has led to the discovery of a previously unknown presence location for this species (Figure 4.1-1). Also, fieldwork on the very narrowly distributed *S. aytachii* ensured coverage of its entire range, even though the species distribution is dependent on soil type rather than altitudinal range.

Among the four target species, one key environmental condition limiting *S. aytachii* within its pre-selected fieldwork area was well understood; this species is known to be restricted to gypsum-rich soils. Fieldwork supported this. However, the environmental conditions limiting other species were vaguely known or approximated by expert opinion. For example, even though there had been very detailed studies on ecology and distribution of *C. tchihatcheffii*, (Çakaroğulları, 2005) environmental factors dictating its distribution were not clearly explained. It was previously known to be very well adapted to nature-friendly (low-level/organic) agriculture, but our fieldwork revealed that it also favors wetlands or at sites that are temporarily flooded in winter. This observation triggered further fieldwork which led to the discovery of a previously unrecorded location. Such inferences are important for SDM applications, especially when evaluating model success and understanding the factors behind it.

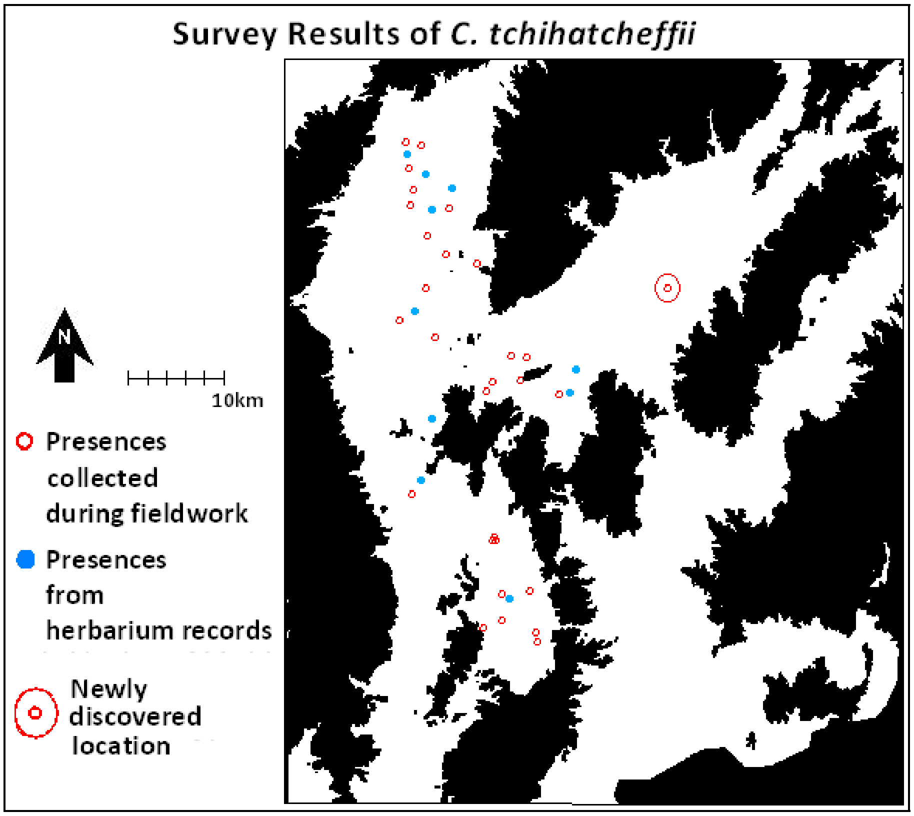


Figure 4.1-1. Survey results of *C. tchihatcheffii*, indicating the newly discovered location far from the range.

In general, observations indicate that:

- *C. tchihatcheffii* prefers wetlands that dry out in spring and summer throughout steppes and pastures of southern Ankara towards the Konya plain. Its general distribution suggests that it may be dependent on wetness for germination or survival. This might be one reason why it is adapted to agricultural lands where water availability is higher due to better soil structure than in pastures with compacted soil.

- *S. aytachii* is dependent on soil type (gypsum-rich soils) more than any other variable considered. It was observed that intensive agricultural practices are becoming more widespread within its study area, even expanding into gypsum-rich soils. Field surveys show that this species is negatively affected by such activities. Ploughing and irrigation in combination with increased competition seem to limit this species' distribution.

- *C. tanacetifolia* has never been observed inside pine forests. It rather prefers open slopes receiving sun during early spring and summer. It is common at transition zones between lowlands and mountains, disappearing where evergreen vegetation becomes dominant. It can rarely be seen also around agricultural lands, since farmers tend to keep tall *Crataegus spp.* for shade within or between their fields. However, it has not been observed in areas below 650 m, where it is replaced by other *Crataegus spp.* This distributional pattern might be due to competition or adaptation.

- Similar to *C. tanacetifolia*, *C. ancyrensis* can not survive under evergreen forests. It needs to receive sunlight during its flowering period (February–March). Yet, it can be observed in open patches within these forests. It is common throughout steppes at high elevation and can survive under deciduous trees as they do not have much leaves during the species' flowering period. It has never been recorded around agricultural fields that are common at lower parts of the study area. This absence might be due to climatic conditions or human induced activities such as agriculture, grazing and gathering. Agriculture might adversely effect its distribution. Its bulb does not go deep enough to allow it to survive ploughing. Also, grazing and collection for human consumption and use is negatively affecting its survival. It is sometimes observed together with *Crocus olivieri*, a more widespread but ecologically similar potential competitor.

As indicated in previous sections, determining absence is rather controversial and should be approached with great care. A lot of time and effort had to be spent in the quadrats where species was finally decided to be absent. Sites with signs of human activity have not been included to absence surveys in order to reduce sampling bias. For example, no absences were located in agricultural lands for *C. tchihatcheffii*, as the species is known to be adversely affected by herbicide use.

Overall, our field methods were efficient and useful for our modelling purposes. The data collected were in accordance with the independence assumption and were highly accurate. However, it would have been ideal if the field survey for each species could have been repeated through following years especially for annual species (e.g. *C. tchihatcheffii*) that have significant annual population fluctuations, or for species prone to human disturbance (*S. aytachii* and *C. ancyrensis*). However, this was not possible due to logistic and time limitations.

4.2 Present Distribution Models: How successful are they?

Two aspects of a SDM that can pose a source of bias are biological data (species distribution) and environmental data (environmental features). The former was evaluated in the previous section. The latter is a complex issue which will be further discussed here.

Four different species were selected for modelling in this study. As each of these species has different characteristics, fieldwork methods were adapted accordingly. However, the modelling procedure was kept uniform in order to obtain comparable results. The environmental layers used were either climatic variables or derived topographic variables. One particularly noteworthy omission among those layers is the soil type layer,as *S. aytachii* distribution is known to be closely related to soil type. However, high resolution soil distribution maps for Turkey (layers) were not available. Even though geological maps have been obtained from MTA, they were not informative about the distribution of gypsum soils and were at a much coarser scale than required. On the other hand, additional derived layers such as topographic wetness index and vegetation cover might have improved the model success for *C. tchihatcheffii, C. tanacetifolia* and *C. ancyrensis*; however, there are no available future predictions of vegetation cover. Instead, slope and climate layers were used here as surrogates. Although lack of such data might have caused bias, uniformity between models enabled comparison between each SDM performed.

Outcomes of the models are variable, indicating advantages and disadvantages of SDMs. These are summarized under 3 headings relative to their success rates:

1- Unsuccessful SDM: Case of *S. aytachii*

Even though AUC values (a threshold-independent method calculated by Maxent software) indicated a very successful model, other evaluation methods (threshold-dependent methods both calculated by Maxent software and via confusion matrix) suggested the opposite. Additionally, the low accuracy of the model is very obvious once one compares results of the model with actual presence/absence data. The major reason for this mismatch is the deficiency of a key known limiting environmental factor (soil type). This is simply because, in this case, available environmental features (climate and slope) were not correlated to, therefore not indirect representatives of, the absent parameter (soil type) in this scale.

Isothermality, annual precipitation and maximum temperature of the warmest month were the most important parameters for *S. aytachi*. However, this species occurs where the lowest values of annual precipitation and the highest maximum temperature of the warmest month coincides in the modelled region. Because species distribution coincides with the harsher environmental conditions in the area, these conditions are not considered to be limiting. Rather, one can only speculate that such extreme values are unsuitable for many other species (potential competitors) and *S. aytachi* may be present only because of lack of such competition.

On the other hand isothermality (which is difficult to interpret in terms of plant physiological response) is again significant (as for *C. tchihatcheffii*). It is possible that both models are highly affected by this parameter not because it imparts a highly significant influence on either species, but because it shows a pattern of change at the same scale as current ranges of such narrow-range plant species. In combination with an ecologically meaningful parameter (such as annual precipitation), it may dictate the boundaries of the study species quite well.

2- Moderately Successful SDM: Case of *C. ancyrensis*

In the case of *C. anycrensis*, annual precipitation, slope and maximum temperature of the warmest month were the most important parameters in this model. The species appeared to be restricted to cooler, more humid habitats (>450 mm annual precipitation) with moderate to steep slopes. All model evaluation methods indicate a moderately well fitting model. This is indicative of some factor(s) shaping the species' distribution, such as biotic interactions, represented in the analysis. Therefore, in general, features used were able to represent macro scale of species distribution but could not represent other interactions driven at the micro scale. Yet, this model is certainly accurate enough for further analyses. Additionally, although they might be useful, most of the time biotic interactions can not be included in a model, and it is very hard to determine actual driving forces at the micro scale.

3- Successful SDM: Case of *C. tanacetifolia* and *C. tchihatcheffii*

For *C. tchihatcheffii* fieldwork coverage was much narrower than for other species because it was assumed that this well-studied and obvious species would have almost certainly been detected if it really was present to the area west, north and south of its current known range. A particular combination of annual precipitation (350-400 mm) and isothermality (~35) appear to explain the current range of this species. However, ecologically it is doubtful that these parameters are really limiting for this species. Wider areas exist with similar climate to the west and south of current range. The rather poor prediction of absences similarly indicates a larger potential occurrence of this species that it probably could not manage to disperse due to various reasons.

For *C. tanacetifolia*, slope and annual precipitation were found to be the most influential parameters in the model. This species is largely confined to hillsides, probably because flat land has already been converted to agriculture and thus became unsuitable. Moreover, as a woody perennial, the species is expected to be present only at places where there is higher annual precipitation. This requirement apparently caused a shift (and shrinking) of potential habitat towards higher altitudes in a future drier climate (see below).

Both threshold-dependent and threshold-independent techniques validate that SDMs of *C. tanacetifolia* and *C. tchihatcheffii* are significantly accurate. Although the binomial model of *C. tanacetifolia* had quite acceptable results (even in predicting unsampled sites), that of *C. tchihatcheffii* needed reconfiguration through an increase in the threshold value.

Evaluation of *C. tchihatcheffii* binomial map indicated that the model is very successful at predicting presences, but poor at predicting absences. Yet, it has still been accounted as a successful model, because this condition is not an artefact of the model itself. This is most probably due to limited dispersal ability and evolutionary history of the species. *C. tchihatcheffii* has rather poor dispersal potential– its seeds are large (therefore not wind pollinated), do not have any animal dispersers other than (possibly) a number of ant species, and the seeds are not particularly long living (Çakaroğulları, 2005). It is also believed to be a neoendemic (a relatively recently evolved species) that did not have enough time for expansion to its climatic limits. This hypothesis emerged as a combination of different observations by expert botanists. Firstly, M. Vural (pers.comm.) carried its seeds to regions out of its natural range (such as İstanbul and Van) and yet observed that it can easily survive under these new environmental conditions. Secondly, there aren't any fossil or relict endemic relatives of this species anywhere else. Thirdly, it belongs to a diverse family with a high rate of endemism. All of these observations strengthen the possibility of this species neoendemic status. In other words, it is believed that this species is not in equilibrium with its environment yet.

Results of the SDMs confirm that model accuracy can sometimes be variable and should be interpreted with great care. Understanding general concepts and sources of errors is very important in model evaluation. There are three main causes of error for our models, as mentioned above. These are:

> <u>Scale:</u> Environmental predictors can have direct or indirect effects on a species (Austin 2002). These can be summarized under three basic topics arranged along proximal to distal drivers (Guisan and Zimmermann, 2000; Huston, 2002; Guisan and Thuiller, 2005): (i) limiting factors, especially factors controlling species eco-physiology, such as temperature, water, soil composition; (ii) both natural and anthropogenic disturbances and (iii) resources, indicating all compounds that can be used by organisms, such as energy. Interactions between species and their environments can cause different spatial patterns that can be observed at different scales (Pearson *et al.*, 2004). This issue rather complicates determination of an appropriate scale. Therefore, it is very important to understand driving forces of the observed distributional pattern of the species in combination with an underlying theory while determining the scale of a SDM. However, this is rarely possible. Scale is generally determined depending on available data. For example, during our fieldwork we managed to collect very accurate and high resolution presence/absence data that contains details about possible biotic or abiotic interactions. Yet, no data at the appropriate scale that can be input to the model in order to reflect possible interactions are available. In this case, the scale of

the available distributional data is too fine, while environmental data is at a coarse scale. This disparity prevents models from predicting lower level spatial patterns. In other words, the model fails to represent those microscale interactions, as similarly experienced by Carvalho *et al.* (2010).

Biotic Interactions: As explained before incorporating biotic interactions to SDMs is still a challenging issue. It can be done by incorporating all available data about the probable interacting species. However, detection of such cases of biotic interactions takes a lot of effort and time. In this sense, we can think of modelling only as indicative of probable interactions and try to work it out from the available species distribution data of other sister species. Accordingly, SDM results can be a way for data mining and understanding possible interactions between species. Afterwards they can be improved by further fieldwork and research.

Non-Equilibrium with Environment: One of the basic assumptions of SDMs is that the species is in equilibrium with its environment. However, in the *C. tchihatcheffii* case this assumption is probably violated. On the other hand, there are no examples through the literature on evaluating effects of such a condition. Generally, modellers do not know as much distributional information about narrow-ranged endemics as collected in this study, complicating the evaluation of such of cases (Hampe, 2004; Pearson and Dawson, 2004; Yates et al., 2010a, 2010b; Meier et al., 2011). On the other hand, further reconfiguration of the threshold produced a good model fit. The success of this reconfiguration indicates that the model is slightly over-fitted around existing presence points, which is an advantage in this case. Possible slight over-fitting of Maxent is well realized and evaluated as an advantage during extrapolations (projections of invasions or climate change).

Different independent model evaluation techniques, such as threshold-dependent techniques applied with independent data sets, are crucial in model evaluation. Researchers should be familiar with the data used for modelling and have an idea about its reliability in order to understand possible biases and evaluate results accordingly. Especially, the independency and accuracy of species distribution data is critical for computing successful models and understanding their flaws. These models can be very useful tools once they are coupled with detailed and reliable environmental features.

4.3 Future Projections: How are species viabilities affected?

Future projections are applied only to the models successful enough to give realistic predictions, i.e. models generated for *C. tcihatcheffii*, *C. tanacetifolia* and *C. ancyrensis*. These predictions estimated 3 different species viability scenarios in respect to climate change and range shifts:

4.3.1 Extinction: The *C. tchihatceffii* case

Interaction of rapid range shift from one place to another with very limited suitable habitat would probably lead to extinction of *C. tchihatcheffii*. Models predict a very fast shift from current sites to another unconnected region. Migration between these areas would be rather challenging. Even if we assume that species is very good at migration, the size of the suitable range left till 2080 is very small risking viability of species.

4.3.2 Contracting Range: The *C. tanacetifolia* case

It is predicted that *C. tanacetifolia* will survive through the changing climatic conditions; however, it will lose most of its range. This kind of a profile is very common for species preferring, for example, high altitudes. Once a species is already distributed in an area occupying the coolest parts of the region, than the only choice left in case of climate warming is a contraction of its range towards even higher ground.

4.3.3 Expanding Range: The *C. ancyrensis* case

Predictions estimate that *C. ancyrensis* will expand its range in future conditions. This might be explained by this species' relative immunity from climate changes. *C. ancyrensis* is a bulbous species that flowers for a short interval (15-30 days) in February and March, depending on the onset of spring. Afterwards, green parts may wither but the bulb survives underground protecting itself from hot weather conditions. An increase in summer temperatures and/or a decline in precipitation will not influence this species much. In the future, it is expected that the species simply will emerge and flower earlier due to increasing temperature. Therefore, predicted climate change will probably not affect its range negatively; it will rather affect it positively towards expanding its range.

4.4 Implications for plant species in face of expected climate change in North-central Turkey

Our results show that several species occuring in North-central Turkey would react differently to possible climate change scenarios. While there is considerable variability in responses, the models provide a robust relative evaluation of climate change impacts among different species.

First of all, predictions of *C. tchihatceffii* indicate that such very narrow-range endemics (especially neoendemics) will probably face a risk of extinction, basically caused by combination of limited migration capabilities and rapid range shifts in suitable habitat. There are a lot of narrowly distributed endemics all around Turkey, including north central Anatolia. About 90% of these are estimated to be neoendemics (unpublished observation, M. Vural). With regard to interaction between geology and speciation processes, predictions indicate that climate change can lead to a very high extinction rate of these species. Furthermore, some of them have different adaptations and specified needs. These kinds of species are called 'habitat specialists'. Habitat specialists, such as *S. aytachii,* require a very specific habitat type, gypsum-rich soil in this case, for all or a critical part of their life cycle. When this condition limits distribution, then such species tend to be at risk. They will face the worst case scenario as they will not be able to migrate to any other area where the condition which they are adapted to does not exist. Consequently, there are only two probable responses to climate change: They either will survive within the same range without being affected by climate change, or will become extinct. Existing results and general predictions indicate that extinction is more likely to happen for a vast majority of these species. Results of Morin *et al.* (2008) also shows similar trends for narrowly distributed species. Furthermore, many studies predict potential extinction of a huge proportion of endemic plant species in other hotspots, such as South Africa and Australia (Midgley *et al.*, 2002, 2003; Bomhard *et al.*, 2005; Broennimann *et al.*, 2006; Fitspatric *et al.*, 2008), with predictions very similar to what we observed for *C. tchihatchefii*.

On the other hand, wider ranged endemics are already spread over a larger area and thus would be able to survive by shifting their range. Consequently, they might end up having either wide or narrow ranges depending on different biotic and environmental factors. Under such conditions, species adapted to diverse environmental conditions, which can make use of different resources might not be affected negatively by climate change. Such species are called 'generalist species'. For example, *C. ancyrensis* is a bulbous species adapted to dry summers and have few requirements to survive and reproduce. They flower for a limited time interval only when climatic conditions outside is optimum for their survival. At other times of the year, they are underground protected from drought and frost. This adaptive characteristic makes them resistant to adverse effects of climate. As a result, they can make use of very different environments such as mountain tops or foothills.

Models indicate that such species might even be positively affected by climate change and expand their range accordingly making use of areas that previously used to have unsuitable climatic conditions.

In contrast, species adapted to cooler environments, such as most plant species of Euro-Siberian origin and distributed around mountains of Northern Anatolia, would be negatively affected by climate change. For example, *C. tanacetifolia* is found in cooler mountain ranges rather than hot and dry plains. Climate change projections suggest a contraction in its suitable environmental conditions in the future and also almost no available place for it to migrate. These predictions are in agreement with other studies (e.g. Crumpacker *et al.*, 2001; Berry *et al.*, 2002; Thuiller *et al.*, 2006). General evaluation of the species distribution with respect to geology of the terrain also supports these results. Supposedly, such Euro-Siberian elements are expected to lose most of their actual distributional range due to climate change in future. Climate predictions imply that most of the mountainous regions where Euro-Siberian elements abound might become dominated by a hotter, drier climate. Thus, Euro-Siberian species are predicted to become more affected by climate change than species adapted to hotter environments (Carvalho *et al.*, 2010). These effects would be exacerbated, as the north of Turkey is the most eastern part of the Euro-Siberian Phytogeographic Region and is surrounded by either costal or drier conditions, so dispersal out of it to other similar places is restricted by environmental barriers. Carvalho *et al.*, 2010 indicated that such patterns also exists through the Iberian Peninsula (Atlantic species being more vulnerable to climate change than Mediterranean species), and that it should also be found in other Mediterranean Peninsulas that span different climatic conditions. Morin *et al.* (2007) predicted a similar pattern showing that climate change could be responsible for extinction of populations at the margins of species distribution. Therefore our findings are in accordance with what these authors suggest.

Other assessments of the biotic impact of future climate change have also predicted similar plant species distribution patterns, such as extinction, range expansion, range shifts and range contractions in different places and at different scales (e.g.

Crumpacker *et al.*, 2001; Bakkenes *et al.*, 2002; Berry *et al.*, 2002; Midgley *et al.*, 2003, Thuiller *et al.*, 2006; Fitzpatric *et al.*, 2008; Morin *et al.*, 2008, Tang and Beckage, 2010; Yates *et al.*, 2010b). In general, they predict, high extinction risk for habitat specialists and range contractions for alpine or mountainous species, leading to substantial changes in species diversity through their area of interest. However, all of these researchers and more always add that responses to climate change are species-specific and related to species climate affinities (Gómez-Mendoza and Arriaga, 2007). Although, they obtain us great insights on possible future conditions, these results are also generalizations; and, unfortunately the possible effects of different factors such as population dynamics and biotic interactions are not included to the models.

4.5 Concluding remarks and suggestions for improvement

In conclusion, this preliminary assessment of species vulnerability to expected climate change in North Central Turkey has been very informative. Implemented techniques predicted statistically significant results. Detailed fieldwork, including unbiased and accurate sampling was in concordance with the main assumption that species occurrence data are unbiased, independent samples from the distribution of the species.

As there is no agreed method for model evaluation, a combination of most frequent techniques was implemented. This combination led to a better understanding of weaknesses and strengths of the models. While some models fit the data very well others did not, resulting in variety of success rates. However, most were reliable enough for further extrapolations.

Climate change extrapolations generated a variety of probable effects of climate change scenarios on species distributions. This is partly an outcome of the selection of the study species, as each of the species represents an example of different possible reaction to climate change. Therefore, these species might be used as surrogates and integrated to long-term monitoring systems for detection of effects of climate change on ground in further studies. At the same time, these species can be regarded as representatives of others with similar charactheristics. For example, as mentioned, there are 22 endemic species to Ankara. Results of this study indicates that these species might be in risk of extinction in the future due to climate change. Especially when we think of the high endemism rate of Turkey, this might be a disaster scenario for future biodiversity.

Results of these extrapolations showed the importance of identifying potential refuges for Euro-Siberian mountainous species and narrowly distributed endemics (i.e. especially at areas where the species is predicted to persist) and defining management strategies to protect these areas from threatening processes. However, there are certain limitations of these models similar to other studies implemented through the literature.

While many processes behind the building and evaluation of SDMs are improving everyday, there is a lot of ambiguity regarding certain concepts. Critics have identified several problems with SDMs and extrapolation. Some of the most challenging criticisms are predicting how environmental factors that limit distributions or biotic interactions will change in the future conditions; or, how these changes will be influenced by genetic variability, phenotypic plasticity and evolutionary changes; or, how to determine dispersal pathways (De Marco *et al.*, 2008; Dormann, 2007; Midgley *et al.*, 2006; Elith and Leathwick, 2009). Similar to other researchers' findings, our results indicated that there is a need for further development of SDM techniques in order to produce reliable predictive models with reduced errors. Such developments can only be possible by:

i. assessing equilibrium/non-equilirium state of the modelled species;

ii. exploring the degree to which biotic and environmental interactions can explain the limits of species range along environmental gradients;

How biotic interactions are likely to change and how they can be modeled is still a challenge (Elith and Leathwick, 2009). This might undermine the validity of projections, while input climate change scenarios are still too coarse to provide accurate patterns of distributional changes at the local scale (Guisan and Thuiller, 2005).

iii. developing techniques of incorporating dispersal and migration to the models;

It is very important to incorporate additional information on species dispersal abilities in order to be able to asses whether species will be able to track range shifts or not (Guisan *et al.*, 2006). In this study, we used the general knowledge on each species. Examples of this attempt includes studies that compare the extreme cases of 'all versus nothing' migration into new habitat, such as Araújo *et al.*, 2006; Thuiller *et al.*, 2006). Yet, these two different edges have a very wide range and are not very realistic. Akçakaya *et al.* (2006) indicated that possible responses of most species to climate change are still not well understood (e.g. Austin, 1992) enough to estimate extinction risk solely from SDM extrapolations. Adding more realism about dispersal or species' migration to SDMs is needed to improve predictions about climate impacts on species distributions and persistence (Thuiller *et al.*, 2008). Incorporation of these factors into SDM techniques is continuously undergoing improvement (for example, Midgley *et al.*, 2006; Schurr *et al.*, 2007; Iverson *et al.*, 2009).

iv. inclusion of landscape dynamics, population dynamics and environmental relationships to SDMs (creating process based models);

Only by linking species–environment relationships, landscape dynamics and population dynamics in a multi-modelling framework models can make realistic predictions on combined impacts of climate change and land cover dynamics on species. This is only possible by understanding the life history parameters and habitat requirements of the species. Modellers recently started to use multiscale environmental variables, such as combination of broad-scale climatic factors limiting species ranges together with finer scale factors related to distribution of required resources, barriers to dispersal, and risk or history of disturbance (reviewed in Franklin, 2010a-b). Moreover, some modellers began to link SDMs to more dynamic models of dispersal and species migration, landscape dynamics (disturbance) and population dynamics (Franklin, 2010b).

v. inclusion of evolutionary change in models (Hoffmann and Kellermann, 2006).

vi. assessing how different scales may be considered in SDMs, depending upon species behaviour, dispersal ability, extent of the study area, and the very nature of the data;

vii. reducing differences between models by consensus (Pearson *et al.*, 2006), used for discovering why predictions differ (Elith and Graham, 2009), or quantified to inform risk analyses and decision making;

Thuiller (2004) indicated that uncertainty introduced by the combination of different analyses, scales, modelling techniques and evaluation methods is more than the variability of using different climate change scenarios. This observation shows that different analyses using different models and resolutions are not comparable. He binds this to variation models construction methods and overpredictions or overparameterization which strongly influences the model outputs (Thuiller *et al.*, 2004; Thuiller, 2004). Because of these, researchers are trying to find a way of combining different algorithms within a common framework and exploring the central tendency of model projections (Thuiller, 2004; Araújo *et al.,* 2005b; Gelfand *et al.*, 2005).

viii. developing assessment techniques for understanding errors and uncertainties in SDMs;

Uncertainty in SDMs can result both from data deficiencies (e.g., missing covariates, and samples of species occurrences that are small, biased, or lacking absences) and from errors in specification of the model (Barry and Elith, 2006). Some researchers considered taxonomies of uncertainty as a basis for assessing errors, and suggested general treatments; for example, Heikkinen *et al.* (2006), Hortal *et al.* (2008) and Burgman *et al.* (2005). Fewer pointed out uncertainty and its effects on the model, predictions in SDMs. Such studies concentrated on data errors assess influence of errors and biases in species records, and in predictors such as DEMs. However, modellers can try to reduce error and uncertainty, by characterizing it and exploring its effects on decision making (Elith and Leathwick, 2009).

ix. quantifying differences between the sampled and extrapolation spaces (for example, Williams *et al.*, 2007);

x. understanding the generation of climate scenarios and their impact on projections of SDMs;

Both simulations derived from alternate climate models and simulations produced by the same climate model with different scenarios show differences (e.g. Dai *et al.*, 2001). Studies that have compared uncertainty in projected species ranges that results from various SDMs vs. different climate scenarios and models (e.g. Thuiller, 2004; Araújo *et al.*, 2006; Beaumont *et al.*, 2007) showed that limiting SDM projections to single climate models could misrepresent the vulnerability of species to climate change. For example, modelled broad-scale climate surfaces are generally downscaled to finer-scale maps, which contribute to the uncertainty in future scenarios (Schmidli *et al.*, 2007). However, the extent of these procedures' influence on model results is not known (Beaumont *et al.*, 2008).

xi. realistic selection of emissions scenarios

Recent studies showed that fossil fuel CO_2 emissions since 2000 have increased at a rate higher than estimated by conservative emission scenarios such as B1 and B2 (Canadell *et al.*, 2007; Raupach *et al.*, 2007). Therefore, Beaumont *et al.* (2008) suggests that the use of the more conservative scenarios should be replaced by the more extreme scenarios closer to A1 and A2.

In brief, better SDMs and reliable projections can only be possible by combining ecological theories, detailed information about species characteristics (both biological and environmental interactions including demographic characteristics etc.) and reliable climate data with robust SDMs coupled with better documentation of the uncertainties. Elith and Leathwick (2009) indicate that further advances in SDMs will basically come from integration of theory, concepts, and practice rather than method improvements. This can only be achieved by collaboration between spatial modellers, biogeographers, ecologists (from very diverse sections such as community ecologists, theoretical and functional ecologists), population biologists, statisticians and ecophysiologists.

Finally, it is very critical and important to realize that it is necessary to update SDMs. Any kind of new information such as improved SDMs, climate scenarios or increased understanding of species ecology should be used to upgrade models. Once new information is available prior assumptions should be revisited and new SDMs and projections should be generated (Beaumont *et al.*, 2008).

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APPENDIX A

Table. A-1. 13 Candidate Species with their Charactheristics

Family	Apiaceae	Asteraceae	Brassicaceae	Caryophyllaceae
Species	*Prangos denticulata* FISCH. et MEY.	*Centaurea tchihatcheffii* FISCH. et MEY.	*Aethionema dumanii* M. VURAL et ADIGUZEL	*Dianthus ancyrensis* HAUSSKN. et BORNM.
Life	Perennial	Annual	Perennial	Perennial
Stem Length	50-150 cm	up to 20 cm	10-20cm	3/5-15cm
Body Form	Erect	Erect-ascending	Erect-ascending	Slender
Flowering Period	5 to 6	4 to 6	5 to 7	7 to 8
Life Form	Herb		Herb	Herb
Habitat	Only around Hüseyin Gazi	Steppe, around waterbeds and irrigated fields	Marl and gypsaceous slopes	Steppe, stony places
Altitude	500-1000m	900-1000 m	840-1400m	1700-1800m

Table. A–1. Continued.

Family	**Chenopodiaceae**	**Dipsacaceae**	**Fabaceae**	
Species	*Salsola grandis* FREITAG *et al.*	*Scabiosa pseudograminifolia* HUB.-MOR.	*Astragalus coodei* CHAMB. et MATTHEWS	*Astragalus panduratus* BUNGE
Life	Annual	Perennial	Perennial	Perennial
Stem Length	10-100cm	10-30cm	20-25cm	Tall
Body Form	Erect	Erect	Erect- (or) - ascending	Erect
Flowering Period	6 to 7	7 to 8	6 to 7	6 to 7
Life Form	Herb	Wooden herb	Herb	Herb
Habitat	Xerohalophytic colonizer of raw marl substrates	Chalk hills	Rocky slopes under Pinus	Step, around fields
Altitude	450-550m	1500-1700m	1300-1600m	1200-1600m

Table. A–1. Continued.

Family	**Iridaceae**	**Lamiaceae**	**Rosaceae**	**Scrophulariaceae**	
Species	*Crocus ancyrensis* (HERBERT) MAW	*Salvia aytachii* VURAL et ADIGUZEL	*Crataegus tanacetifolia* (POIR.) PERS.	*Verbascum ancyritanum* BORNM.	*Verbascum heterobarbatum* HUB.-MOR.
Life	Perennial	Perennial	Perennial	Biennial	Biennial
Stem Length	~5cm	20-50cm	8-10m	35-80cm	80-110cm
Body Form	Erect	Erect- (or) -ascending	Deciduous tree/shrub with throns	Longitudinally straight	Robust, terete (cylindrical)
Flowering Period	2 to 4/6	5 to 7	5 to 6	6 to 6	6 to 7
Life Form	Bulbous	Herb	Shrub or small tree	Herb	Herb
Habitat	Open rocky places, in scrub and in Pinus woods	Steppe, marl places and gypsum soils	Rocky limestone slopes in Pinus or Quercus forest, steppe	Dry slopes, fields	Roadsides, steppe, fallow fields, serpentine slopes
Altitude	500(1000)-1600m	600-875m	800-1800	900-1000m	870-1020m

APPENDIX B

Table. B-1. Coordinates of *C. tchihatcheffii* available in the literature (Baytok, 2008) in latitude longitude (dd mm ss)(Datum WGS 84) format. (LR: Literature Record, also names of the locations given by the researcher is also mentioned in brackets)

Literature Record	Latitude (N)	Longitude (E)	Altitude (m)
LR 1 (Pop)	39 46 45	32 45 32	1002
LR 2 (Süleyman Demirel I.)	39 44 43	32 46 19	983
LR 3 (İnta Vericisi).	39 42 32	32 45 24	991
LR 4 (Örencik)	39 43 31	32 48 34	1016
LR 5 (Yavrucak)	39 40 48	32 46 44	983
LR 6 (Yamaç Paraşütü S.)	39 39 10	32 50 24	1082
LR 7 (Karagedik)	39 34 58	32 47 13	1023
LR 8 (Mahmatlı)	39 33 49	32 53 59	1047
LR 9 (Pop1)	39 20 11	32 52 12	1057
LR 10 (Pop2)	39 18 17	32 50 48	1090

APPENDIX C

Table. C-1. Coordinates of *S. aytachii* available in the literature and collected during preliminary fieldwork in latitude longitude (dd mm ss) (Datum WGS 84) format. All records are collected from dry steppe lands and valleys with gypsum soils. (Lat: Latitude, Long: Longitude, Alt: Altitude (values in bracket are vague estimates of recorders while actual values are obtained by google earth or gps), LR: Literature Record, (c): with coordinates, PlFwR: Preliminary Fieldwork Record, GUH: Gazi University Herbarium, HU-GAH: Hacettepe University, Assoc. Prof. Galip Apaydın Personal Herbarium, Davis-1988: Flora of Turkey and East Aegean Islands Book, PlFw: Preliminary Fieldwork)

Table. C–1. Coordinates of *S.aytachii* available in the literature and collected during preliminary fieldwork

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-1 (c)	40 09 32	32 00 11	669	06/01/05		Ankara: Kirmir Valley	Ministry of Environment, 2008
LR-2	40 07 45	32 00 02	554 (600)	26/05/02	gypsum valley	Ankara: Ayaş, Acısu junction	HU-GAH
LR-3	40 09 50	31 51 58	750 (750)	05/08/94	side of the road	Ankara: 5km west of Beypazarı	GUH
LR-4	40 06 41	31 46 53	606 (600)	26/05/97	gypsum hills	Ankara: Beypazarı-Nallıhan Road, 15km from Beypazarı	GUH
LR-5	40 08 43	31 52 57	650 (650)		gypsum soils	Ankara: Beypazari-Nallihan, 5km from Beypazar	
LR-6				06/04/05	gypsum soils	Ankara: around Çayırhan Bird Paradise	HU-GAH
PlFwR-1	40 08 12	31 59 10	612	20/05/07	gypsum soils	Ankara: Ayaş-Beypazarı, 10km to Beypazarı	PlFw (also, Davis-1988)
PlFwR-2	40 08 13	31 59 10	618	20/05/07	gypsum soils	Ankara: Ayaş-Beypazarı, 10km to Beypazarı	PlFw (also, Davis-1988)
PlFwR-3	40 09 04	31 59 52	609	25/05/07	gypsum plain	Ankara: Ayaş-Beypazarı, 5km from Beypazarı	PlFw (also, GUH and Davis-1988)
PlFwR-4	39 34 39	31 56 02	727	06/01/07	gypsum soil	Ankara: Polatlı-Sivrihisar Road, 18 km from Polatlı, Gordion	PlFw (also, GUH and Davis-1988)
PlFwR-5	39 33 48	31 48 17	875	06/01/07		Eskişehir: Polatlı-Sivrihisar, 25km from Polatlı	PlFw (also, GUH and Davis-1988)

APPENDIX D

Table. D-1. Coordinates of *C. tanacetifolia* available in the literature and collected during preliminary fieldwork in latitude longitude (dd mm ss) (Datum WGS 84) format. (Lat: Latitude, Long: Longitude, Alt: Altitude (values in bracket are vague estimates of recorders while actual values are obtained by google earth or gps), LR: Literature Record, (c): with coordinates, PlFwR: Preliminary Fieldwork Record, AUH: Ankara University Herbarium, HUH: Hacettepe University Herbarium, HU-ADH: Hacettepe University, Prof. Dr. Ali Dönmez Personal Herbarium, Davis-1988: Flora of Turkey and East Aegean Islands Book, PlFw: Preliminary Fieldwork by Damla Beton)

Table. D–1. Coordinates of *C. tanacetifolia* available in the literature and collected during preliminary fieldwork

Records	**Lat (N)**	**Long (E)**	**Alt (m)**	**Date**	**Habitat**	**Location**	**Source of Information**
LR-1	38 27 34	30 25 48	1410	96-01		Afyon-Karahisar: Kumalar Mountain	Akçiçek and Vural, 2007
LR-2	40 49 13	35 52 32	1900 (1900)	16/07/1889	Alpinik-subalpinik parts of mountain	Amasya: Akdağ	HU-ADH
LR-3	40 21 15	31 55 44	1430	25/8/01	Mixed deciduous forest	Ankara: Beypazarı, Karagöl, Gölet çevresi	HU-ADH
LR-4	40 16 07	31 53 05	1050-1300	01/06/01	Under *Pinus nigra*	Ankara: Beypazarı Kıbrıscık arası, Yiğitler Köyü çevresi	HU-ADH
LR-5	40 10 00	31 56 00	778	08/09/71	steppe	Ankara: Beypazarı	AUH
LR-6	40 08 04	33 12 42	1350	09/09/01	steppe	Ankara: from Akyurt 1.5km to Tepe Beli Passage	HU-ADH
LR-7	39 52 42	32 48 21	1050 (1050)	27/05/95	*Pinus sylvestris* mixed forest	Ankara: Balgat, Çiğdem Region	HU-ADH
LR-8	40 14 32	33 04 56	1050 (1050)	27/09/92	*Quercus* bush	Ankara: from Çubuk 5km to Şabanözü	HU-ADH
LR-9	40 08 09	33 12 38	1350 (1350)	26/09/92		Ankara: between Akyurt to Kaleceik	HU-ADH
LR-10	40 26 47	32 35 31	1606 (1600)	22/09/92	Alpinik-subalpinik parts of mountain	Ankara: Kızılcahamam National Park	HU-ADH
LR-11	39 50 50	33 01 13	1300	23/10/05	Mixed deciduous forest	Ankara: Kıbrısköyü Valley, around Rock of Durhasan	Aslan and Vural, 2009
LR-12	39 57 22	30 06 44	1080	05/05/01	*Quercus* bush	Bilecik: from Günyarık Village 1km to Söğüt	HU-ADH
LR-13	40 49 20	31 47 43	680	02/06/01	Mixed deciduous forest opening	Bolu: 1km south of Taşcılar Village	HU-ADH

Table. D–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-14	40 29 35	31 36 16	1440	25/08/01	*Pinus nigra* - *P. sylvestris* mixed forest	Bolu: from Seben 12.7km to Bolu	HU-ADH
LR-15	40 41 06	32 19 26	1243 (1150)	16/08/76	*Pinus nigra* opening	Bolu: Gerede, Aktaş Külfet Köyü	AUH
LR-16	40 44 31	31 35 30	750 (750)	08/09/57	Pine forest small tree up to (3m)	Bolu: Bolu Çevresi	HU-ADH
LR-17	40 23 12	31 55 23	1199 (1100)	01/06/01	*Pinus nigra* forestry area	Bolu: Kıbrıscık Köseler Village	HU-ADH
LR-18	40 28 12	31 13 53	1300 (1300)	09/06/62	*Quercus* bush	Bolu: North of Mudurnu	HU-ADH
LR-19	40 40 59	32 19 26	1250 (1250)	19/10/76	Mixed deciduous forest opening	Bolu: Gerede, Aktaş Forest	AUH
LR-20	40 55 56	33 15 48	1360	10/09/01	*Pinus nigra* - *P. sylvestris* mixed forest	Çankırı: from Bayramören-Boyalı crossroad 2.6km Kurşunluya	HU-ADH
LR-21	40 28 37	33 28 01	1400 (1100-1650)		*Pinus nigra* opening	Çankırı: Eldivan Mountain	HUH
LR-22	40 25 30	32 19 23	1000 (1000)	05/05/01	Pine forest small tree up to (3m)	Çankırı: Şabanözü, Mart Village Eldivan Mountain	HUH
LR-23	41 00 13	33 42 51	1450 (1450)	10/10/92	*Pinus nigra* opening	Çankırı: Ilgaz Passage, around Kazancı	HU-ADH
LR-24	40 45 33	33 46 39	1222	26/09/92	*Quercus-Carpinus* mixed forest	Çankırı: north of Yapraklı	HU-ADH
LR-25	39 57 20	38 42 03	1500 (1500)	24/07/34	Forestry area	Erzincan: Suşehri to Refahiye	HU-ADH
LR-26	39 57 20	38 42 03	2070 (1800)	27/5/98	*Quercus-Carpinus* mixed forest	Erzincan: around Kolçekmez Mountain ge	HU-ADH

Table. D–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-27	39 58 08	31 07 08	1721	16/06/92	*Quercus* bush, calcareous	Eskişehir: Sarıcakaya, Sündiken mountains	GUH
LR-28	39 26 16	30 25 45	1300 (1300)	07/10/76	calcareous slopes	Eskişehir: Türkmendağı, Belören uplands	AUH
LR-29	41 16 57	32 42 51	1020-1010	05/06/01 10/09/01	Degraded areas	Karabük: around Aşağıdana Village picnic area	HU-ADH
LR-30	41 19 24	32 42 02	992	05/06/01	*Pinus nigra* opening	Karabük: Safranbolu, around Yukarıdana Village, crossroad	HU-ADH
LR-31	41 05 35	32 27 38	1700 (1700)	03/08/62	*Quercus-Pinus* mixed forest	Karabük: Keltepe, north of Karabük	HU-ADH (also, Davis-1988)
LR-32	41 32 48	33 25 49	1150 (1150)	24/07/89	Forestry area	Kastamonu: 52.9km from Kastamonu on Azdavay road	GUH
LR-33	40 55 32	33 37 52	906 (800)	22/09/81	*Quercus-Carpinus* mixed forest	Kastamonu: Ilgaz Mountain, around Ilgaz Province	AUH
LR-34	41 42 40	33 30 23	1000 (1000)	08/10/80		Kastamonu: Küre Mountain, Ağlı ilçesi ile Hasan Köyü arası	AUH
LR-35	41 14 23	33 59 34	1370 (1370)	18/08/65		Kastamonu: Lakes Region, Akkaya	HU-ADH
LR-36	41 03 52	33 17 46	1100 (1100)	5 /6 /2001		Kastamonu: Araç-Çankırı border, around Susuzköy	HU-ADH
LR-37	41 02 45	33 17 30	700 (700)	05/06/01		Kastamonu: from Sıragömü Village 5km to Boyalı	HU-ADH
LR-38	41 26 29	33 18 48	1078 (1000-1200)	30/07/62		Kastamonu: from Daday 15km to Eflani	HU-ADH
LR-39	41 44 13	33 40 17	1150 (1100-1200)	30/06/62	*Quercus-Carpinus-Pinus sylvestris* forest	Kastamonu: between Ecevit, Seydiler-Küre	HU-ADH

Table. D–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-40	39 00 53	36 20	1800 (1800)	16/09/81		Kayseri: Hınzır Mountain, over Pınarbaşı Kavak Village,	AUH
LR-41	39 02 37	36 20 09	1850 (1850)	20/06/80		Kayseri: Hınzır Mountain, over Pınarbaşı Malak Village	HUH
LR-42	39 21 03	29 13 30	700 (700)			Kütahya: Emet, Eğrigöz Mountain, Yeniköy entrance	HU-ADH
LR-43	39 01 57	37 45 00	1450	08/10/80		Malatya: Kangal to Hekimhan	Davis-1988
LR-44	41 01 35	35 54 03	801	18/08/65		Samsun: Karadag	Davis-1988
LR-45	40 55 07	35 53 55	910	10/09/65		Samsun: Ladik, Station, Karadağ	HU-ADH
LR-46	41 08 31	35 03 47	1330	07/06/95	slopes with *Pinus sylvestris-Daphne sp*	Samsun: Vezirköprü, Kunduz Mountain	Özen and Kılıç, 2002
LR-47	41 38 20	34 51 11	1305	24/07/62		Sinop: between Boyabat-Sinop	HU-ADH
LR-48	41 42 57	34 40 11	1330 (1330)	11/08/45		Sinop: Ayancık Çamgal Mountain	AUH
LR-49	39 58 53	37 55 05	1801	07/07/86		Sivas: Zara, around Deredam Village	GUH
LR-50	40 07 09	38 14 57	950	06/10/01		Sivas: Susehri to Refahiye	Davis-1988
LR-51	40 08 12	37 48 46	1810	06/10/01		Sivas: Suşehri'nden Şerefiye'ye 29. km, Karabayır Geçidi	HU-ADH
LR-52	40 02 35	37 43 46	1730	24/06/01	marl soils	Sivas: from Şerefiye to 15km Zara, over Arapça Village	HU-ADH
LR-53	40 09 57	37 51 56	1810 (1810)	06/09/94		Sivas: from Şerefiye to Suşehri, around Karabayır Passage	HU-ADH

Table. D–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-54	39 15 35	37 57 32	1550 (1750)	27/06/02		Sivas: Divriği, Karasar upland, around Karasar Village, eastern slopes	HU-ADH
LR-55	39 16 30	37 57 53	1750 (1750)	10/09/65	slopes with *Pinus sylvestris-Daphne sp.*	Sivas: Divriği, Karasar Passage	HU-ADH
LR-56	39 16 42	37 57 42	1850 (1850)	18/06/95	on rock	Sivas: around Divriği, Karasar Passage	HU-ADH
LR-57	39 16 51	38 00 30	1415	10/07/01	slopes of steppe	Sivas: Over Divriği, Kayapınar Village, 13.5km to Divriği	HU-ADH
LR-58	39 15 58	38 10 20	1300	11/07/01	*Quercus pubescens* bush	Sivas: from Divriği 15km to Arapgir, between İkizbacak-Derimli Villages	HU-ADH
LR-59	39 26 56	36 07 09	1800	26/08/94	*Quercus* forest opening	Sivas: Sarkışla, Karababa mountain, Örenyuva Village	HU-ADH
LR-60	39 48 48	36 07 03	1260	08/04/02 15/09/01	next to a garden	Sivas: from Yıldızeli Çukursaray Village 1km to Yozgat	HU-ADH
LR-61	39 58 08	37 44 09	1650	24/06/01	*Pinus sylvestris* forest	Sivas: from Zara 10-12km to Şerefiye	HU-ADH
LR-62	39 29 71	38 07 13	1370	13/09/01	Mixed forest opening	Sivas: from Divriği 11km to Maltepe Village	HU-ADH
LR-63	39 31 36	36 07 09	1450 (1450)	18/08/95	on rock	Sivas: Divriği, Karyağan Village, around Acıgöz	HU-ADH
LR-64	40 07 01	36 18 21	1100 (1172)	01/10/79	bozkır yamaçları	Tokat: Artova, 3km to Silisözü	AUH
LR-65	40 04 28	35 30 40	1000 (1250-1300)	21/06/80	*Quercus pubescens* bush	Yozgat: Çekerek, Kabak Hill	AUH
LR-66	39 48 25	34 48 42	1500 (1500)	07/06/79	*Quercus* forest opening	Yozgat: Yozgat National Park	AUH

Table. D–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-67	39 32 30	36 00 46	2100 (2000-2200)	05/07/79		Yozgat: Akdağmadeni Nalbant Mountain	AUH
LR-68	39 48 32	36 04 01	1350 (1350)	24/07/93		Yozgat: from Akdagmadeni 27km to Sivas	HU-ADH
LR-69	39 32 48	36 00 51	2167	23/06/01	serpentine, gypsum fields, mountain meadows	Yozgat: Akdağmadeni, Kızılcaova, around Nalbant Hill	HU-ADH
LR-70	39 13 12	35 40 14	1720 (1720)	25/08/94	*Quercus* opening	Yozgat: Çayıralan, between Elçi-Büyüktoraman Villages	HU-ADH
LR-71	39 42 03	35 35 50	1295	15/09/01	steppe, field margins	Yozgat: Akdağmadeni, Abdurrahmanlı Village	HU-ADH
PlFwR-1	40 24 47	32 54 49	1521	26/07/07	*Pinus sylvestris* opening	Ankara: Çubuk, Karagöl Picnic Area	PlFw
PlFwR-2	40 24 38	32 54 59	1511	26/07/07	*Pinus sylvestris* opening	Ankara: Çubuk, Karagöl Picnic Area	PlFw
PlFwR-3	40 24 53	32 54 56	1551	26/07/07	*Pinus sylvestris* opening	Ankara: Çubuk, Karagöl, Yaşmağın Hill	PlFw
PlFwR-4	40 24 59	32 54 58	1552	26/07/07	*Pinus sylvestris* opening	Ankara: Çubuk, Karagöl, Yaşmağın Hill	PlFw
PlFwR-5	40 35 50	32 24 25	1628	28/07/07		Ankara	PlFw
PlFwR-6	40 35 07	32 24 30	1484	28/07/07		Ankara	PlFw
PlFwR-7	40 35 36	32 38 57	1096	28/07/07		Ankara: Seyhhamamı road	PlFw
PlFwR-8	40 34 00	32 39 10	1090	28/07/07		Ankara: Işık Mountain road	PlFw
PlFwR-9	40 30 19	32 38 29	983	28/07/07		Ankara: Kızılcahamam to Işık Mountain	PlFw

Table. D–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
PlFwR-10	40 34 58	32 30 13	1365	28/07/07		Ankara: Mountain house around Çamkoru	PlFw
PlFwR-11	40 15 08	31 46 49	1654	04/10/07	scarce *Pinus sylvestris*, *Quercus*-*Crataegus* mix	Ankara: around Beypazarı Keltepe	PlFw
PlFwR-12	40 15 08	31 46 44	1633	04/10/07	scarce *Pinus sylvestris*, *Quercus*-*Crataegus* mix	Ankara: around Beypazarı Keltepe	PlFw
PlFwR-13	40 15 09	31 46 50	1630	04/10/07	scarce *Pinus sylvestris*, *Quercus*-*Crataegus* mix	Ankara: around Beypazarı Keltepe	PlFw
PlFwR-14	40 15 12	31 46 55	1638	04/10/07	scarce *Pinus sylvestris*, *Quercus*-*Crataegus* mix	Ankara: around Beypazarı Keltepe	PlFw
PlFwR-15	40 15 14	31 46 59	1645	04/10/07	scarce *Pinus sylvestris*, *Quercus*-*Crataegus* mix	Ankara: around Beypazarı Keltepe	PlFw
PlFwR-16	40 15 13	31 47 01	1649	04/10/07	scarce *Pinus sylvestris*, *Quercus*-*Crataegus* mix	Ankara: around Beypazarı Keltepe	PlFw
PlFwR-17	40 15 26	31 47 22	1640	04/10/07	scarce *Pinus sylvestris*, *Quercus*-*Crataegus* mix	Ankara: around Beypazarı Keltepe	PlFw
PlFwR-18	40 15 27	31 47 24	1660	04/10/07	scarce *Pinus sylvestris*, *Quercus*-*Crataegus* mix	Ankara: around Beypazarı Keltepe	PlFw
PlFwR-19	40 15 45	31 48 14	1634	04/10/07	scarce *Pinus sylvestris*, *Quercus*-*Crataegus* mix	Ankara: around Beypazarı Keltepe	PlFw
PlFwR-20	40 36 29	31 16 04	1365	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-21	40 36 30	31 16 06	1377	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-22	40 36 30	31 16 03	1365	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw

Table. D–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
PlFwR-23	40 36 20	31 15 42	1363	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-24	40 36 19	31 15 39	1379	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-25	40 36 27	31 16 15	1337	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-26	40 35 36	31 16 41	1411	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-27	40 35 36	31 17 47	1514	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-28	40 35 53	31 16 50	1336	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-29	40 36 23.7	31 17 40.4	1348	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-30	40 36 36.6	31 17 31.2	1329	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-31	40 37 12.4	31 17 45.7	1230	28/07/07	*Pinus sylvestris* opening around lake	Bolu: around Abant Lake	PlFw
PlFwR-32	40 38 59.0	31 22 24.3	970	28/07/07		Bolu: Dereören Village	PlFw
PlFwR-33	40 39 33.6	31 24 15.8	916	28/07/07		Bolu: DereörenVillage	PlFw
PlFwR-34	40 39 01.8	32 22 23.8	1401	28/07/07		Bolu: Gerede Ankara main road	PlFw
PlFwR-35	40 36 01.2	32 24 16.4	1642	28/07/07		Bolu: Gerede, Yukarı Ovacık Village	PlFw
PlFwR-36	41 00 32.1	32 08 12.8	1166	28/07/07		Bolu: Yenice Mountain	PlFw

APPENDIX E

Table. E-1. Coordinates of *C. ancyrensis* available in the literature and collected during preliminary fieldwork in latitude longitude (dd mm ss) (Datum WGS 84) format. (Lat: Latitude, Long: Longitude, Alt: Altitude (values in bracket are vague estimates of recorders while actual values are obtained by google earth or gps), LR: Literature Record, (c): with coordinates, PlFwR: Preliminary Fieldwork Record, AUH: Ankara University Herbarium, HUH: Hacettepe University Herbarium, HU-GAH: Hacettepe University, Assoc. Prof. Galip Apaydın Personal Herbarium, Davis-1988: Flora of Turkey and East Aegean Islands Book, PlFw: Preliminary Fieldwork by Damla Beton)

Table. E–1. Coordinates of *C. ancyrensis* available in the literature and collected during preliminary fieldwork

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Location	Source of Information
LR-1	40 45 41	35 52 50	1400			Amasya: Akdağ, Değirmendere Hills	Davis-1988
LR-2	40 26 40	32 37 05	1400 (1400)	18.3.1990	around *Pinus nigra*	Ankara: Kızılcahamam, Soğuksu National Park	GUH
LR-3	40 27 12	32 37 20	1200 (1200)	28.2.1990	around *Pinus nigra*	Ankara: Kızılcahamam, Soğuksu National Park	GUH
LR-4	40 24 29	32 40 23	1140 (1100)	19.3.1974	*Quercus pubescens* bush	Ankara: Kızılcahamam, Kargasekmez	AUH
LR-5	40 29 59	32 32 09	1396	3.4.1955	*Pinus silvestris* opening	Ankara: Kızılcahamam, Çamkoru	AUH
LR-6	40 39 20	32 43 56	1500	2.5.1976		Ankara: Kızılcahamam, Işık Mountain	HUH
LR-7	40 00 46	32 56 39	1012 (1100)	16.3.1988	Meadows, wet soils	Ankara: Çubuk II Dam	GUH
LR-8	40 19 29.	32 58 16	1341 (1200)	28.3.1992	Meadows north of lake	Ankara: Çubuk, Ovacık-Saraycık Village	GUH
LR-9	40 24 47	32 54 45	1511 (1500)	21.3.1974	around *Pinus nigra*	Ankara: Çubuk Karagöl Bölük Mountain	HUH
LR-10	40 11 11	31 49 11	1050-1240	10.4.1998		Ankara: between Beypazarı-Sekli Villages	GUH
LR-11	40 21 23	31 59 50	1500 (1500)	2.5.1971	around *Pinus nigra*	Ankara: Beypazarı, Belen Plain	AUH
LR-12	39 49 31	33 17 23	813	21/03/71	Serpentine	Ankara: Elmadağ, Hisarköy Civarı, Ba	AUH
LR-13	39 40 48	32 54 55	1400	20/03/69	open rocky areas	Ankara: Beynam Ormanı	AUH
LR-14	39 40 22	32 55 02	1450 (1450)	24/03/71	Steppe	Ankara: Beynam Ormanı	AUH

Table. E–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-15	39 56 57	32 13 47	1297	22/03/75		Ankara: Ayaş Dağları	AUH
LR-16	39 58 38	32 52	900	15/03/56	Steppe	Ankara: Keçiören, Kalaba Köyü	AUH
LR-17	39 52 20	32 49 20	1100 (1100)	26/05/94	Calcareous rocks	Ankara: Dikmen Turtaş Blokları çevre	HU-GAH
LR-18	39 53 35	32 44 40	900 (900)	05/07/76	Agglomerate rocks	Ankara: Beytepe, DSİ yakınları	HUH
LR-19	40 00 00	33 11 00	1200 (1500)	06/03/02	*Pinus sylvestris* opening	Ankara: Hasanoğlan, Çed deresi yukar	HUH
LR-20	40 13 18	32 14 49	680 (680)	06/03/02	*Quercus* foorest	Ankara: Güdül ilçesi Kirmir Çayı vad	HUH
LR-21	40 37 14	32 27 32	1470	09/04/05	Serpentine	Ankara: Akyarma, Gerede'ye kadar kes	GUH
LR-22	38 39 30	34 01 09	1600	19/04/98	open rocky areas	Aksaray: Pınarbaşı Köyü	HUH
LR-23	40 41 19	32 21 30	1500 (1500)	23/04/76	*Pinus sylvestris* opening	Bolu: Gerede-Aktaş Mountain, Dikmen Hill	AUH
LR-24	40 39 02	32 21 15	1500 (1500)	23/04/76	*Pinus sylvestris* opening	Bolu: Gerede-Aktaş mountain, Dikmen Hill	AUH
LR-25	40 39 22	32 20 05	1350			Bolu: Gerede to Kizilcahamam	Davis-1988
LR-26	40 34 47	31 16 13	1100 (1100)		calcareous, *Quercus* and *Juniperus* opening	Bolu: 2km from Abant to Mudurnu	Davis-1988
LR-27	40 34 47	31 17 87	1500 (1500)	06/03/02	meadows	Bolu: from Abant Lake 3km to Mudurnu	HUH
LR-28	40 36 37	31 17 31	1329 (1400)	06/03/02	around *Pinus nigra*	Bolu: around Abant Lake	HUH

Table. E–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-29	40 25 10	31 13 02	1400	07/03/78	below the summit, *Abies*, and *Pinus* opening	Bolu: Mudurnu	AUH
LR-30	40 40 47	32 43 12	1510 (1500)	05/04/02	Steppe	Çankırı: Işık Mountain, from Çerkeş to Kızılcahamam	HUH
LR-31	40 46 36	33 04 43	1250 (1200)	29/03/92		Çankırı: Atkaracalar, Dumalı mountain, Hoşislamlar District	GUH
LR-32	41 00 44	34 20 29	1496 (1450)	17/04/76		Çorum: Kargı, Kösdağı Region, Abdullah Upland	AUH
LR-33	40 15 49	34 38 09	1044			Çorum: 26.5km northeast of Sungurlu	Davis-1988
LR-34	40 24 42	31 00 30	1162 (1250)	22/03/72		Eskişehir: Sündiken Mountain, around Çatacık	AUH
LR-35	39 21 36	31 46 53	1014 (1000-1500)	17/03/01	meadows towards east	Eskişehir: Sivrihisar Mountains, passing Günyüzü Bridge	HUH
LR-36	37 38 38	36 56 35	1588 (1400-1500)	22/05/92	close to snow	Kahramanmaraş: Ahır mountain, Karagöl District, İncebel Ridges	GUH
LR-37	40 57 07	32 20 29	1000 (1000)	29/03/85		Karabük: Eğriova Region	AUH
LR-38	41 22 49	33 10 51	1250 (1250)	10/04/80	Degraded *Quercus* bush	Kastamonu: Sakardağı Göktepe	AUH
LR-39	41 45 34	33 42 25	1056 (1000)	21/03/79	Rocky slopes	Kastamonu: between Seydiler and Küre	AUH
LR-40	41 07 04	33 45 51	1500 (1500)	08/04/82	Rocky areas	Kastamonu: Ilgaz Mountain, Baldıran River	AUH
LR-41	38 41 54	35 57 37	1488 (1400-1450)	08/03/01	Rocky slopes	Kayseri: Korumaz Mountain, Arşılık Hill	GUH
LR-42	38 40 45	35 52 09	1650 (1600-1650)	29/03/01		Kayseri: Korumaz Mountain, Kazlar Hill	GUH

Table. E–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-43	39 03 29	36 20 41	1750 (1750)	23/04/80	meadows towards east	Kayseri: over Pınarbaşı Ortaköy, Hızır Mountain	AUH
LR-44	38 34 36	35 25 50	2200		close to snow	Kayseri: Erciyes Mountain	Davis-1988
LR-45	39 03 01	36 20 05	1800 (1800)	23/04/80	kayalık yamaçlar	Kayseri: Pınarbaşı, north of Malak Village	HUH
LR-46	40 05 03	33 39	1090 (1000)	13/03/90	ağaçlandırma alanı	Kırıkkale: Deredüzü Village	HUH
LR-47	40 02 25	33 50 29	1096 (1000)	25/03/89	Vitis-Quercus açıklığı	Kırıkkale: around Aşağı Karaksık Village	HUH
LR-48	39 51 26	33 29 38	790 (1100)	23/03/93		Kırıkkale: Kocababa Province, Bağlarbaşı District	HUH
LR-49	40 01 37	33 40 33	1171 (1200)	18/03/90	kalker	Kırıkkale: Hıdırşeyh Köyü, eastern slopes	HUH
LR-50	39 36 12	34 13 49	1550 (1550)	09/05/93	Alpinik step	Kırşehir: Çiçek Mountain, Halaçlı Village, Alman-derebaşı District	HU-GAH
LR-51	37 37 42	36 56 55	1300 (1300)		jipsli toprak	Kahramanmaraş: Akher Monutain	AUH
LR-52	38 00 07	34 26 57	1763 (1750-1950)	11/03/01	kayalık yamaçlar	Niğde: from Tepe Village 1km to Aksaraya Melendiz Mountain	HUH
LR-53	39 03 01	36 20 05	2200 (22009	08/05/74	ağaçlandırma alanı	Niğde: Aksaray, Hasan Aa., Karagücü Oğlu Cisterns	AUH
LR-54	40 58 50	35 31 19	1100 (1000-1200)		Vitis-Quercus açıklığı	Samsun: Tavsan Mountain, near Merzifon	Davis-1988
LR-55	39 55 09	37 23 04	1360 (1360)	08/05/92		Sivas: Hafik, Koşutdere Village	GUH
LR-56	39 11 44	38 09 31	1400			Sivas: near Sivas	Davis-1988

Table. E–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Region: Location	Source of Information
LR-57	39 11 44	38 09 31	2125			Sivas: Divringi, Demirdağ	Davis-1988
LR-58	39 48 20.	34 48 33	1500 (1500)	10/03/80	Forestry area	Yozgat: Yozgat National Park	AUH
LR-59	39 16 39	35 39 30	1550 (1500-1550)	28/03/80	Under *Quercus*	Yozgat: Çayıralan, 5km	AUH
LR-60	40 04 49	35 27 28	1104 (1500)	25/03/80		Yozgat: Çekerek, Dondurmanın Başı Hill	AUH
LR-61	41 04 52	32 28 04	1800 (1800)			Zonguldak: Kel Hill	Davis, 1988
LR-62	40 44 12	35 11 51	1150			Amasya: Gümüshacıköy, Ovabası-Akpınar-Güllüce ve Köseler Villages	Cansaran *et al*., 2007
LR-63	40 39 17	35 56 32	1050	2004-2006		Amasya: Yassıçal	Cansaran and Kaya, 2010
LR-64	40 38 16	35 52 00	1100	2004-2006		Amasya: Vermiş	Cansaran and Kaya, 2010
LR-65	40 41 05	35 46 19	750	2004-2006		Amasya: Bağlarüstü	Cansaran and Kaya, 2010
LR-66	40 54 58	35 06 21	1100	2005-2008		Amasya: Gümüşhacıköy, İnegöl Mountain	Yıldırım and Kılıç, 2010
LR-67	40 40 26	35 50 17	500 (450-550)	12/01/03	roadsides, steppe and scrubes	Amasya: lower Tersakan Valley, surroundings Göllü Bağları	Celep *et al*., 2006
LR-68	38 54 34	31 12 45	1750	1999-2000	foothills, steppe	Afyon: Emirdağ, Boztepe	Köse and Ocak, 2004
LR-69	39 55 32	30 34 51	1185	22/03/02	Limestone rocky places	Eskişehir: Eskişehir Drivers Fountain, *Pinus nigra* forest around	Yücel, 2002
LR-70	39 07 30	31 37 26	884 (840)	2008	steppe	Eskişehir: Sivrihisar, Göktepe Village, around Düden	Koyuncu *et al*., 2008

Table. E–1. Continued.

Records	Lat (N)	Long (E)	Alt (m)	Date	Habitat	Location	Source of Information
LR-71	39 13 54	34 28 41	1120	1992	together with *Verbascum sp.*, opened places of Pinus brutia	Kırşehir :around Seyfe Lake	Ministry of Environment, 2008
LR-72	37 37 45	36 57 54	1350 (1200-1500)	20/03/04	together with *Verbascum sp.*, stony slopes	Kahramanmaraş: Ahir Dağ, Ulucak Hill, Bakacak Ridge	Aytaç and Duman, 2005
LR-73	40 34 24	31 15 46	1048	09/04/05	under and opened places of *Pinus brutia* and *Pinus sylvestris*	Bolu: Abant Lake-road of Mudurnu, around Çepni Village	Şık and Candan, 2009
LR-74	40 43 44	32 17	1190	09/04/05	under *Pirus elaeagnifolia*	Bolu: 13km to Gerede from Bolu, around Kayıkiraz Village,	Şık and Candan, 2009
LR-75	40 38 25	31 37 09	1485	29/03/07	under *Pirus elaeagnifolia*	Bolu: Kıbrısçık- road of Bolu, 10km to Bolu	Şık and Candan, 2009
PlFw-1	39 49 17	32 49 50	980	29/03/07	under *Pirus elaeagnifolia*	Ankara: around Eymir Lake	PlFw
PlFw-2	39 49 40	32 50 13	978	29/03/07	under *Pirus elaeagnifolia*	Ankara: around Eymir Lake	PlFw
PlFw-3	39 49 08	32 49 52	1000	29/03/07	under *Pirus elaeagnifolia*	Ankara: around Eymir Lake	PlFw
PlFw-4	39 49 03	32 50 00	999	29/03/07	under *Pirus elaeagnifolia*	Ankara: around Eymir Lake	PlFw
PlFw-5	39 56 36	32 57 26	1341	07/04/07	Open rocky slopes	Ankara: Hüseyin Gazi	PlFw
PlFw-6	39 49 17	32 49 50	978	15/03/08	under *Pirus elaeagnifolia*	Ankara: around Eymir Lake	PlFw
PlFw-7	39 49 32	32 50 43	977	15/03/08	Open slopes	Ankara: around Eymir Lake	PlFw
PlFw-8	39 49 59	32 51 35	959	15/03/08	Open slopes	Ankara: around Eymir Lake	PlFw

APPENDIX F

Table. F-1. Correlation Matrix; showing correlations between bioclimatic variables through the modelled area (as bioclimatic variables are derived from the annual temperature , annual minimum temperature, annual maximum temperature and annual precipitation in combination with altitude (DEM) correlations between these were higher. So they are not represented here)

Table. F–1. Correlation matrix of bioclimatic variable

Mtx	**bio1**	**bio2**	**bio3**	**bio4**	**bio5**	**bio6**	**bio7**	**bio8**	**bio9**	**bio10**	**bio11**	**bio12**	**bio13**	**bio14**	**bio15**	**bio16**	**bio17**	**bio18**	**bio19**
bio1	1.0	0.2	0.5	-0.2	0.7	0.9	0.0	0.2	0.9	0.9	0.9	-0.1	-0.1	0.0	0.0	-0.1	0.0	-0.1	-0.1
bio2	0.2	1.0	0.7	0.8	0.8	-0.3	0.9	0.1	0.5	0.5	-0.1	-0.8	-0.7	-0.8	0.7	-0.7	-0.8	-0.8	-0.6
bio3	0.5	0.7	1.0	0.1	0.6	0.3	0.4	0.0	0.5	0.6	0.4	-0.3	-0.2	-0.2	0.3	-0.2	-0.2	-0.4	-0.1
bio4	-0.2	0.8	0.1	1.0	0.5	-0.6	0.9	0.1	0.3	0.2	-0.5	-0.9	-0.8	-0.9	0.7	-0.8	-0.9	-0.8	-0.8
bio5	0.7	0.8	0.6	0.5	1.0	0.3	0.6	0.3	0.9	0.9	0.5	-0.7	-0.6	-0.6	0.4	-0.6	-0.6	-0.7	-0.6
bio6	0.9	-0.3	0.3	-0.6	0.3	1.0	-0.5	0.1	0.5	0.6	1.0	0.3	0.3	0.5	-0.4	0.3	0.5	0.3	0.2
bio7	0.0	0.9	0.4	0.9	0.6	-0.5	1.0	0.1	0.4	0.3	-0.4	-0.9	-0.8	-0.9	0.7	-0.8	-0.9	-0.9	-0.8
bio8	0.2	0.1	0.0	0.1	0.3	0.1	0.1	1.0	0.3	0.3	0.2	-0.3	-0.3	-0.1	-0.2	-0.3	-0.1	0.0	-0.5
bio9	0.9	0.5	0.5	0.3	0.9	0.5	0.4	0.3	1.0	1.0	0.6	-0.5	-0.5	-0.4	0.2	-0.5	-0.4	-0.5	-0.5
bio10	0.9	0.5	0.6	0.2	0.9	0.6	0.3	0.3	1.0	1.0	0.8	-0.4	-0.4	-0.3	0.2	-0.4	-0.3	-0.4	-0.4
bio11	0.9	-0.1	0.4	-0.5	0.5	1.0	-0.4	0.2	0.6	0.8	1.0	0.2	0.2	0.3	-0.3	0.2	0.3	0.2	0.1
bio12	-0.1	-0.8	-0.3	-0.9	-0.7	0.3	-0.9	-0.3	-0.5	-0.4	0.2	1.0	1.0	0.9	-0.5	1.0	0.9	0.9	0.9
bio13	-0.1	-0.7	-0.2	-0.8	-0.6	0.3	-0.8	-0.3	-0.5	-0.4	0.2	1.0	1.0	0.8	-0.4	1.0	0.8	0.8	1.0
bio14	0.0	-0.8	-0.2	-0.9	-0.6	0.5	-0.9	-0.1	-0.4	-0.3	0.3	0.9	0.8	1.0	-0.8	0.8	1.0	1.0	0.8
bio15	0.0	0.7	0.3	0.7	0.4	-0.4	0.7	-0.2	0.2	0.2	-0.3	-0.5	-0.4	-0.8	1.0	-0.4	-0.8	-0.8	-0.3
bio16	-0.1	-0.7	-0.2	-0.8	-0.6	0.3	-0.8	-0.3	-0.5	-0.4	0.2	1.0	1.0	0.8	-0.4	1.0	0.8	0.8	1.0
bio17	0.0	-0.8	-0.2	-0.9	-0.6	0.5	-0.9	-0.1	-0.4	-0.3	0.3	0.9	0.8	1.0	-0.8	0.8	1.0	1.0	0.8
bio18	-0.1	-0.8	-0.4	-0.8	-0.7	0.3	-0.9	0.0	-0.5	-0.4	0.2	0.9	0.8	1.0	-0.8	0.8	1.0	1.0	0.7
bio19	-0.1	-0.6	-0.1	-0.8	-0.6	0.2	-0.8	-0.5	-0.5	-0.4	0.1	0.9	1.0	0.8	-0.3	1.0	0.8	0.7	1.0

APPENDIX G

Table. G-1. Correlation Matrix; showing correlations between topolographical variables through the modelled area (as both topographical and bioclimatic variables are derived from DEM, it is not included to the analysis, and as can be seen here slope represents the least correlated topographical variable respectively)

Mtx	Dem	Slope	Aspect	Shading
Dem	1.0	0.077	-0.004	-0.019
Slope	0.077	1.0	0.041	-0.219
Aspect	-0.004	0.041	1.0	-0.398
Shading	-0.019	-0.219	-0.398	1.0

APPENDIX H

Table. H-1. Locations (dd) of *C.tchihatcheffii* collected via fieldwork

Presence Data				Absence Data	
for modelling		for confusion matrix		for confusion matrix	
Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
39.58278	32.78694	39.72528	32.80944	39.76583	32.73583
39.56361	32.89972	39.73833	32.77556	39.76556	32.71139
39.33639	32.87	39.7575	32.75361	39.71833	32.77889
39.30472	32.84667	39.70417	32.78417	39.66861	32.80083
39.65278	32.84	39.60778	32.76333	39.63778	32.84028
39.68	32.77889	39.52944	32.95417	39.54278	32.8325
39.70861	32.75806	39.55167	32.96111	39.58167	32.87333
39.72361	32.76083	39.445	32.77139	39.65111	33.08639
39.76972	32.75222	39.33222	32.87972	39.6625	33.08306
39.76583	32.77028	39.50444	32.78472	39.62028	33.05833
39.74472	32.75528			39.62861	33.09722
39.70639	32.80556			39.79083	32.79194
39.66139	32.80111			39.74222	33.11639
39.59917	32.74444			39.73694	33.12722
39.63028	32.77639			39.745	33.14806
39.54028	32.85778			39.37944	32.82194
39.53167	32.84972			39.43833	32.78667
39.54167	32.89194			39.34889	32.99944
39.56528	32.88083			39.34889	32.99944
39.62889	33.07389			39.30944	33.00139
39.52833	32.93972			39.30944	33.0925
39.39139	32.85917			39.78306	32.78306
39.38778	32.86278			39.19444	32.97861
39.38806	32.8575			39.17389	32.98139
39.43306	32.75972			39.21861	33.12333
39.34	32.90333			39.23167	33.07694
39.31167	32.87			39.77528	32.7225
39.29944	32.91167			39.76306	32.68222
39.29083	32.91278				

Table. H-2. Locations (dd) of *S. aytachii* collected via fieldwork

Presence Data				Absence Data			
for modelling		for confusion matrix		for confusion matrix			
Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
40.13667	31.98611	39.90328	32.10947	39.71444	32.35472	39.30972	31.32389
39.5775	31.93389	39.87083	31.87322	40.08417	31.60056	39.32917	31.36833
39.56333	31.80472	39.52486	31.65747	40.04528	31.60222	40.195	31.95278
40.05281	31.61228	40.17525	31.93336	39.95167	32.14361	39.88028	32.03583
39.94939	32.14078	39.84908	32.06147	39.91417	31.96333	40.18556	31.91528
39.92336	32.12319			39.88194	31.88611	39.72583	31.98611
39.95122	32.10167			39.85333	31.89472	39.40472	31.40278
39.60219	31.75678			39.57667	31.88194	39.43194	31.35111
39.60133	31.71983			39.58778	31.78333	39.37472	31.01111
39.57025	31.72878			39.87917	32.47278	39.25028	31.02639
39.46839	31.80089			39.54139	31.66722	39.25278	31.03167
39.86533	32.02825			39.50056	31.67333	39.62694	30.31083
39.75208	31.98208			39.46694	31.80972	39.81111	30.60611
39.77175	31.97819			39.41167	31.95417	40.03139	31.50861
				38.89611	32.10417	39.73333	31.48444
				38.89583	32.015	39.75889	31.50361
				40.06167	31.48222	39.76778	31.50639
				39.04472	31.62194	40.11972	31.35111
				39.06639	31.59722	40.09833	31.4375
				39.05	31.32361	40.10028	31.50472

Table. H-3. Locations (dd) of *C. tanacetifolia* collected via fieldwork

Presence Data						Absence Data	
for modelling				for confusion matrix		for confusion matrix	
Latitude	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
40.41047	32.91644	40.10233	33.12500	40.25369	31.78372	39.46333	33.00500
40.58539	32.40819	39.89294	33.19044	40.62011	31.29603	40.32583	32.04194
40.59339	32.64917	39.87878	33.16656	40.65933	31.40439	39.70833	32.47472
40.56669	32.65283	39.83522	33.14431	40.26864	31.88475	39.67917	31.97111
40.50528	32.64139	40.25858	32.96822	39.96553	31.06475	39.91306	31.88250
40.58281	32.50364	40.24486	32.92589	39.85600	31.41411	39.41389	31.18722
40.60467	31.26072	40.23647	32.82528	40.13311	33.09747	39.92833	30.79000
40.59819	31.28056	40.19969	32.83811	39.83519	33.17242	39.91389	30.91472
40.64972	31.37342	40.18269	32.87750	40.52153	32.53153	39.38611	30.76833
40.65050	32.37328	40.46239	32.68633	40.44331	32.46917	39.42194	30.74750
40.60033	32.40456	40.47319	32.74014	40.41228	32.51256	39.12194	31.92556
41.00892	32.13689	40.53656	32.59153	40.40256	32.55486	39.26611	33.12000
40.35417	31.92900	40.47483	32.47550	40.65564	32.59317	38.96472	32.06722
40.13447	33.21164	40.44886	32.61394	40.51975	31.12197	38.94306	32.08250
39.95611	30.11194	40.42269	32.59303	40.33667	31.02786	38.89722	31.71361
40.82222	31.79533	40.62806	32.49786	40.29528	30.98747	38.91694	31.70028
40.49297	31.60439	40.65483	32.53972	41.04572	33.29151	38.72333	31.45500
40.93231	33.26339	40.66714	32.58572			38.73333	31.40722
41.28242	32.71417	40.57014	31.25747			38.81278	31.41389
41.32333	32.70042	41.00358	33.71411			39.20806	30.50194
39.98314	31.05858	40.75919	33.77737			39.01944	30.72083
39.99969	31.09600	41.54656	33.43013			39.34611	33.14333
39.96181	31.10956	40.92547	33.63098			40.16500	32.88806
39.85536	31.47806	41.71097	33.50638			40.13278	32.45111
40.08161	33.16769	41.06433	33.29623			40.16917	32.34083
40.07828	33.17758					40.32278	32.05333
						39.40750	31.05472
						39.61000	32.85972
						39.71028	32.86833
						39.84111	32.86250
						39.82750	32.84889
						40.03444	33.06444
						39.74861	33.11750
						39.95833	33.16250
						40.02583	33.05333
						39.13056	32.69583
						39.46139	32.98139
						39.89250	31.27361

Table. H-4. Locations (dd) of *C. ancyrensis* collected via fieldwork

Presence Data						Absence Data	
for modelling				For confusion matrix		For confusion matrix	
Latitude	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
40.61017	31.29200	40.41369	32.59650	41.38040	33.18094	40.08972	30.98417
40.95204	32.34127	40.46386	32.47386	40.04021	33.84127	40.13528	31.20972
41.75955	33.70702	40.50375	32.43097	39.82131	32.83050	40.11444	31.18583
41.11774	33.76418	40.52058	32.37478	39.83311	32.85978	40.345	31.06083
40.08426	33.65028	40.51631	32.33600	39.89314	33.19033	40.45472	31.145
39.60324	34.23024	40.50164	32.32189	40.10347	30.62717	40.45417	31.08306
39.94336	32.95708	40.47400	32.34825	40.07731	31.19906	40.43583	31.00972
40.13011	33.16753	40.41583	32.31172	40.32508	31.14228	40.45833	30.97667
40.10728	33.20217	40.23586	31.92558	39.25583	33.14858	40.31889	31.38111
40.13622	33.21267	40.25461	31.90750	40.46714	32.70883	40.32333	31.46333
40.11714	30.68650	40.26656	31.92167	40.25672	31.91461	39.27639	33.14028
40.13186	30.67883	40.35725	31.92194	39.96097	30.89725	39.29278	33.12028
40.16767	31.07378	40.40308	31.92506	39.97903	30.91544	39.1	32.55889
40.17036	31.02183	40.40400	31.99633	40.47683	32.93181	39.10611	32.5925
40.09928	31.21833	40.21936	31.70125	40.45869	32.83208	39.11528	32.57306
40.30700	31.16792	40.21967	31.80714			38.63194	31.77944
40.31300	31.04072	40.18244	31.80931			38.565	31.91333
40.46519	31.02783	39.93450	30.89122			38.59778	31.88972
40.37706	31.21819	39.97286	30.88692			40.40889	32.33472
40.43292	32.67422	39.96875	30.94611			40.41444	32.28278
40.48344	32.77458	40.40147	32.71892			40.22083	31.915
40.46919	32.66783	40.43933	32.84317			40.15972	31.41333
						40.14694	31.84472
						39.86083	32.0575
						39.83556	31.47944
						39.81083	31.48694
						39.70694	30.78917
						39.71389	30.70972
						39.74778	30.72222
						39.94028	30.88222
						40.18222	32.97417
						39.91417	33.22361
						39.89417	33.20833
						39.46167	33.035
						39.46	32.97222
						39.89639	33.18667
						39.80306	33.05194
						39.4075	33.26222
						39.44778	33.31972

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name:	Beton, Damla
Nationality:	Turkish Cypriot
Date and Place of Birth:	May 14, 1980; Nicosia, Cyprus
Phone / Fax:	+90 542 881 37 50 / +90 392 223 16 49
E-mail:	damlabeton@gmail.com
Foreign Languages:	English (Advanced)

EDUCATION

Degree	**Institution**	**Graduation**
Ph.D.	METU Biological Sciences Dept.	2011
M.Sc.	METU Biological Sciences Dept.	2004
B.Sc.	Hacettepe Biology Dept.	2001
High School	Nicosia Türk Maarif College Nicosia, Cyprus	1996

PROFESSIONAL EXPERIENCE

Year	**Role**
2010-still	Scientific officer in the project entitled “Important Bird Areas in Cyprus” (Kuskor and BirdlifeCyprus funded by European Union)
2008- 2009	Flora expert in the project entitled “Technical assistance for management and protection of potential Natura 2000 sites in the northern part of Cyprus” (NIRAS-NEPCon-GOPA-Oikon (EU Project))

2007-2008	Ecology expert in the project entitled “Assessing the Current Status of the RAMSAR Areas in Turkey” (WWF-World Wildlife Foundation- Turkey)
2006	Fauna expert in the project entitled “Preparation of a Baseline Study on the Environmental Conditions of the Karpaz Peninsula in the Northern Part of Cyprus” (The Nature Conservation Centre)
2005	Biologist in the project entitled “Determination of Ecologically Important Wetlands of T.R.N.C. Project” (Ministry of Economy and Tourism, Nature Conservation Department)
2003	Volunteer biologist in the project entitled “Great Bustard Conservation Workshop and writing Great Bustard National Action Plan” (Doğa Derneği (Nature Association))
1998-2003	Volunteer field assistant in the project entitled “North Cyprus Marine Turtle Conservation Project” (Marine Turtle Research Group and North Cyprus Marine Turtle Conservation Project)

ACADEMIC ACTIVITIES

Academic Publications

M. Vural, U. Zeydanlı, **D. Beton** and M. K. Meraklı (2010) “Determining Core Areas of Floral Species Richness in the Karpaz Peninsula (Cyprus)” TOP Biodiversity 2010 - Threats, Opportunities and Paces for Biodiversity Conference, 3 - 4 June 2010- Larnaca, Cyprus (Oral Presentation and Conference Paper)

Academic Research Projects

Technical Reports

Presentations

D. Beton (2010). “Process of Determining Important Birds Area in Cyprus” XII. Turkey Bird Conference (Türkiye Kuş Konferasnı), 15-17 September- Adana (Turkey).

D. Beton and C.C.Bilgin (2010) “Modelling the Potential Effects of Climate Change on the distribution of endemic *Crataegus tanacetifolia* (Lam.) Pers. and *Crocus ancyrensis* (Herbert) Maw. Species” 20. National Biology Congress, 21-25 June 2010- Denizli (Turkey). (Poster Presentation)

M. Vural, U. Zeydanlı, **D. Beton** and M. K. Meraklı (2010) "Determining Core Areas of Floral Species Richness in the Karpaz Peninsula (Cyprus)" TOP Biodiversity 2010 - Threats, Opportunities and Paces for Biodiversity Conference, 3 - 4 June 2010- Larnaca, Cyprus (Oral Presentation and Conference Paper)

D.Beton, A. Dönmez and C.C.Bilgin (2009) "Modelling the Potential Effects of Climate Change on the distribution of endemic *Crataegus tanacetifolia* (LAM.) Species" IX National Ecology and Environment Congress, 07-10 November 2009- Nevsehir (Turkey). (Oral Presentation)

D.Beton and C.C.Bilgin (2009) "Change in accuracy of distributional range modelling for restricted-range plants with different sample sizes", 2nd European Congress of Conservation Biology, 01-05 September 2009 – Prague (Czech republic). (Oral Presentation)

D.Beton and A.Kence (2004) "Genetic and Morphometric Differentiation Between the *Bombus terrestris* Populations in Ankara and North Cyprus", XVIIth National Biology Conference, 21-24 June 2004, Adana (Turkey). (Oral Presentation)

D.Beton and A.Kence (2004) "Genetic and Morphometric Differentiation Between the *Bombus terrestris* Populations in Ankara and North Cyprus", First EurBee Conference of Apidology, September 2004, Udine (Italy). (Poster Presentation)

Organized Workshops and Symposiums

"Symposium on Evolution" by Evolution Working Group in Hacettepe University, May 04, 2006 and in Cultural Convention Center in Middle East Technical University, May 08, 2006, Ankara, Turkey.

Workshops and Conferences Attended

April, 2008	"Patterns and Dynamics of Species Occurrence Workshop" Workshop and Training Course CNRS: Centre d'Ecologie Fonctionnelle and Evolutive (France)
September, 2006	"Systematic conservation planning: concepts & techniques, applications & challenges" Training Course 1st European Congress of Conservation Biology

2006	“Systematic conservation planning: concepts & techniques, applications & challenges” Summer school for PhD students ISOBIS/GBIF/NordForsk: Denmark

Experimental Skills

Fieldwork Skils	Distance Sampling Bird and Plant Identification limited experience in Bird Ringing and Camera Trapping
Computer Based	GIS softwares: ArcGis, Idrisi, TNTmips MicroImages Modeling Software: Maxent Statistics programs: Minitab GPS data handling softwares: Mapsource, TrackMaker, etc... Data bases to import global data and use them for the models Spatial Data Analysis software: CrimeStat in combination with others such as ArcGis