Spatial Modeling of Endemic Plants Hotpots

A case of in Manjella National Park in Italy

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by

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Abstract

Due to increase of human impact on the world scale, there is an urgent need to identify the sectors of greatest biodiversity that are also most endangered. Better understanding of the patterns of endemic plant occurrence and underlying factors will allow predicting areas with high probability of these plants and help in conservation strategies. The study overall objective is to identify and map endemic plant hotspots in the mountainous region of Majella national parl and determine the factors causing this pattern. A combination of Kennel density estimation and modeling were used for the study. The ArcGIS Kennel density tool was used to determine the endemic hot spot areas. The MaxEnt modeling tool was used to predict the occurrence of the occurrence of the endemic plant taxon. The environmental variations used in the models are solar rations, aspect, slope, vegetation cover type and elevation. The study shows the hot spots for endemic plant taxon in Majella national park are found on highlands. In conclusion, two environmental variables – elevation and vegetation cover type were enough to predict the occurrence of the endemic plant taxon.

Dedicated to
Joseph, Justine
and
Family

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1. Introduction

1.1. Background

In recent years, assessing and understanding the distribution of biological diversity have shifted from being topics of largely theoretical interest to occupying centre-stage in conservation biology (Rosenzweig, 1995). Biodiversity loss has been a major concern to mankind especially since the last quarter of the twentieth century. This concern culminated in the biodiversity convention that was opened for signature at the United Nations conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, June 1992. Since then different international fora have echoed the problems of continuing environmental degradation. In spite of significant efforts to curb the menaces, the loss of biodiversity worldwide is continuing at an unprecedented rate. A reverse in the ongoing decline should urgently be realized (Hens and Nath, 2003).

Biodiversity became popularized as a term to mean ‘life on earth’ as a consequence of a National Forum on Biodiversity that met in Washington D.C. in September 1986. Biological diversity" means the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Species richness, often simply defined as “biodiversity” is the immediate and most utilized indicator to evaluate species or taxonomic diversity in an area. Despite its wide use, biodiversity still lacks a universally agreed upon definition and is often redefined depending on the context and the author’s purpose. For instance as many as eighty – five different definitions of biodiversity have been reviewed by (DeLong Jr, 1996).

Due to increase of human impact on the world scale, there is an urgent need to identify the sectors of greatest biodiversity that are also most endangered. Examination of biodiversity of five regions with in the Mediterranean climate (SW Australia, the cape region of South Africa, California Mediterranean Chile and Mediterranean basin.) clearly demonstrates their key role in the world context. A number of criteria are available for identification of conservation areas and generally priority areas are identified basing on biological aspects taking into account species richness, level of endemism and exposure to threat (Myers et al., 2000). The degree of endemism is a reliable criterion for identifying hotspots (Orme et al., 2005). Ten plant diversity regional hotspots have been proposed within the Mediterranean basin (Medail and Quezel, 1997), due to their high species richness and endemism. The 10 red alert areas or hotspots situated in the Mediterranean basin and Macaronesia identified include, Canary islands and Madeira ,the High and middle Atlas mountains, Baetic-Rifan complex, the Maritime and Liguria Alps, the Tyrrhenian islands, Southern and Central Greece, Crete, Anatolia and Cyprus, the Syria- Lebanon- Israel area, and the Cyrenaica Mediterranean. There are two main centres of biodiversity in the Mediterranean region, one in the west that includes the Iberian Peninsula and Morocco and one in the East that includes Turkey and Greece (Medail and Quezel, 1997).

The great biodiversity of the Mediterranean basin is due primarily to particular climatic conditions, habitat heterogeneity as a result of pale geographical and historical factors, and varying origins of flora itself (Quézel, 1985; Quézel, 1995). The major patterns observed in the Mediterranean Basin, endemic plants are mainly stress- tolerant species that are adapted perfectly to harsh habitats (rock-crevices, cliffs, screes) and act as refuges little affected by natural or human disturbances (Medail and Quezel, 1997). Rocky slopes, screes and alpine grasslands are typical habitats of the Alpine landscape above the tree line (Ellenberg, 1988) and the high number of endemic species in these habitats is in accordance with the general distributional pattern of endemic plant species at high altitudes in Eurasia mountains(Casazza et al., 2005; Dhar, 2002; Tribsch and Nswetter, 2003). A higher occurrence of endemic species in extreme habitats such as rocky slopes and screes reflects the low competitive ability of rupicolous species compared to congeneric wide spread species (Lawler et al., 2003; Médail and Verlaque, 1997). Thus insular, mountain or isolated edaphic systems generally appear to be major endemic center (Quézel, 1985; Stevanovi et al., 2003).

The term 'biodiversity hotspot' was coined by (Myers, 1988; Myers, 1990). In his two papers that identified 18 geographical regions as conservation priorities because they contained large numbers of endemic species found in relatively small areas that were facing significant threats of habitat loss (Figure 1-1). It was reasoned that protecting hotspots, defined in this manner, should prevent the extinction of a larger number of species than would protecting areas of a similar size elsewhere.

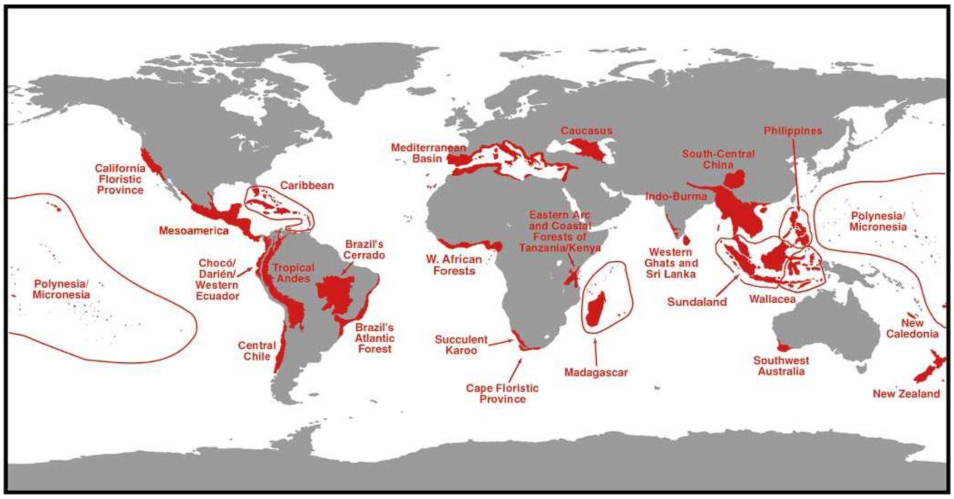


Figure 1-1: Global 25 Hotspots of Endemics (Myers et al., 2000)

Areas with high species richness may also have a high number of endemic species, but not necessarily in a coherent pattern (Huston, 1994; Whittaker et al., 2001). The most characteristic centres of endemism are generally thought to be isolated oceanic islands, for example Canary islands (Hobohm, 2000). Massive topographic relief can, potentially, provide a similar barrier that inhibits gene flow and facilitates speciation (Brown, 2001). However the hot-spot of endemic plants are found both in rather flat areas for example Texas and Northern Florida, and in areas with high topographic relief e.g. Andes,(Gentry, 1986). In mountainous areas the maximum number of endemic species is expected to occur at high elevation due to isolation mechanism,(Shrestha and Joshi, 1996).

Both latitudinal and altitudinal gradients in vascular plant diversity have long been recognized. Theories to explain these gradients are manifold, but are based mainly on area, available energy, habitat heterogeneity and substrate fertility (Givnish, 1999; Rohde, 1992) generally, species richness is lower at more pole wards latitudes and at higher altitudes. However, these trends are not universal e.g. exceptions have been reported with tropical epiphytes in south America (Ibisch et al., 1996), woody vegetation in South Africa, (O'Brien, 1998) and rock out crop communities in West Africa (Porembski et al., 1995). It appears that these gradients in diversity may differ between plant groups. For example, for woody and tree species (Leathwick et al., 1998) and (Ogden, 1995) have shown that species richness decreases with increasing altitude in New Zealand forests, whereas for total species richness in the forest (Wilson and Allen, 1990) showed the opposite trend.

Altitude is a main factor that determines the floristic diversity of mountainous area. It is known that towards high altitudes occurs a decrease in mean annual temperatures and an increase in precipitation (Ozenda and Borel, 1995), this directly influences the diversity of the flora. The decrease in species number along the elevation gradient studied support the hypothesis that species richness decreases with altitude (Woodward, 1987).

1.2. Problem statement and justification

Understanding geographical patterns of species richness and predicting suitable habitats of high biological diversity, i.e., hotspots (Reid, 1998) are central to ecology and biogeography. A hotspot is a sector with an exceptional concentration of species and high rate of endemism (Myers et al., 2000). The hotspot boundaries were determined by biological commonalities, each of the areas features a separate biota. The Mediterranean Basin ranks third out of the 25 endemic hotspots on a global scale with 25,000 native plant species that include 13,000 endemics and many plants of potential medicinal use as in Myers et al. (2000) next to Sundaland which is second and Tropical Andes which ranks first. The Mediterranean basin covers portions of three continents, Europe, Asia and Africa .Europe lies to the north and the three and large peninsulas, Italy and Balkan Peninsula and Iberian Peninsula, extend into the Mediterranean climatic zone.

Given that endemism (the number of species endemic or confined to an area) and extinction are closely coupled, actions to minimize global extinction need to focus on patterns in endemism and range- restricted species (Myers et al., 2000; Pimm and Brooks, 2000; Pimm et al., 1995). Most species are not scientifically described (MAY, 2000), and consequently nothing is known about their ecology or geographical distribution (Pimm and Brooks, 2000). However, present knowledge of species and their geographical distribution must be used to elucidate the causes of patterns in endemism. The number of taxa endemic to an area increases with its size and isolation (Anderson, 1994).

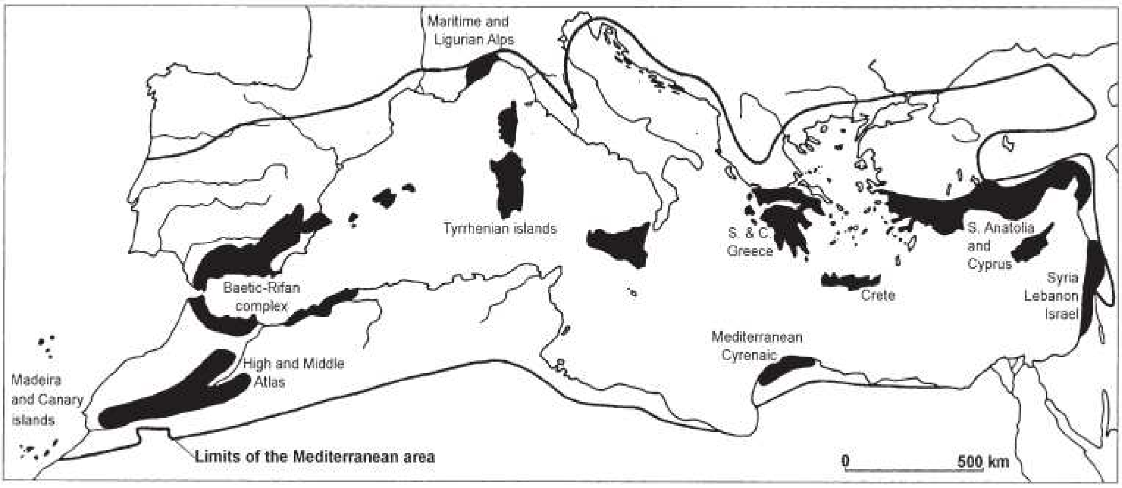


Figure 1-2: The 10 Mediterranean Basin Hotspots based on plant endemism and richness (Medail and Quezel, 1997)

Majella national park, in central Apennine is lacking as a hotspot on a regional scale as in (Medail and Quezel, 1997) shown in (Figure 1-22) and yet Majella qualifies as an intra-Mediterranean endemic plant hotspot due to the fact that it has 143 endemic plant taxa which is relatively an equal number compared to other hotspots of the Mediterranean basin as is the case with in the Maritime and Ligurian Alps where there are, one hundred and fifteen endemic taxa sensu lato (Casazza et al., 2005).

Endemism of plant taxa in the context of this research was of different scales, ranging from Majella in central Apennines, the Abruzzo region and to a large extent Italy (Conti, 1998). This research aims to detect the endemic taxa hotspots using the ArcGIS/ Kernel density tool and MaxEnt to identify causative and controlling factors associated with distribution of the endemic plant taxa on a local scale in Majella National Park. In the context of this research a hotspot has been defined as an area with high density of endemic taxa. Better understanding of the patterns of endemic plant occurrence and underlying factors will allow predicting areas with high probability of these plants and help in conservation strategies.

1.3. Research objectives

1.3.1. Main objective

The overall objective is to identify and map endemic plant hotspots in the mountainous region of Majella N.P and determine the factors causing this pattern.

1.3.2. Specific objectives

1. To establish the location of endemic plant taxa hotspots in Majella National Park.

2. To determine the effect of altitude, aspect, slope solar radiation, and vegetation cover on the occurrence of endemic plant taxa of the Majella National Park.

1.4. Research questions

1. Can endemic plant taxa hotspots be indentified in the Majella National park?

2. Is Majella National .Park an intra- Mediterranean endemic plant taxa hotspot?

3. Can the occurrence of endemic plant taxa hotspots be explained using environmental variables?

1.5. Hypothesis

1. Ho: Occurrence of endemic plant species is significantly affected by any combination of altitude, aspect, slope, solar radiation, vegetation cover type.

2. H1: Occurrence of endemic plant species is not significantly affected by any combination of altitude, aspect, .slope, solar radiation, and vegetation cover type.

2. Materials and Methods

2.1. Study area

The study area is the Majella national park (Figure 2-1), Italy (latitude 41051'N to 42015'N, longitude 13050' 21, 209'E to 140 14'46.21''E.). The study area is assumed to be one of the most important intra- Mediterranean endemic hotspot of the Mediterranean basin because of the number of endemic species that it has which is one hundred forty two. Endemics referred to here are for the Abruzzo region. In terms of altitudinal gradient basing on the DEM 30 m resolution and vegetation cover map of Majella N.P. 1999, the main five vegetation belts described were, the Mediterranean; stone oak, evergreen forest, Quercus pubescens, forest patches, farmland, at < 900 m a.s.l. Sub Mediterranean; Downy oak, deciduous thermophilic forest ,Quercus pubescens. Forest patches, farmland, at < 900 m a.s.l. Temperate montane ;European beech deciduous mesophilic forest, Fagus sylvatica, contiguous forest, at 900-1700 m a.s.l. Subalpine/Dwarf juniper, coniferous shrubland, Pinus mugo/pinus nana, Majella massif, at 1700-2200 m a.s.l. Alpine , without trees or shrubs, grassland, open herbaceous and dwarf shrub vegetation or bare at >2200 m a.s.l.

In terms of climate the park can be divided into three zones, the Mediterranean climate which is characterised by relatively mild temperatures and a period of summer drought. Annual mean temperature is mostly in the range of 14o to 180 C, and none of the mean monthly temperature is below the freezing point. Rainfall can have a wide range of variation and is sometimes relatively low (350-400mm) but in general between 600-750mm. Under particular moisture conditions the yearly rainfall can reach 1000mm and more. As a matter of fact, the yearly average of rainfall is not very indicative for Mediterranean conditions but the more important factor is the distribution of rain during the year. Precipitations are concentrated mainly in spring and autumn, sometimes in winter, or there is a more or less continuums rainy season during the cold period of the year, nevertheless there is always a dry period during the warmer months (Aschmann, 1973). This is only in the North West of the Majella Park with annual drought in July to August, confirmed from Popoli meteostation at 260 m a.s.l. with high values of maximum temperature 30.260 and 30.390 centigrade and very low precipitation records of 27.72 mm and 29.12mm for the months of July and August respectively as in Mameteopdf.

The humid climate is on the Majella massive and the rest of the park area is sub humid. The Majella national park is in the Abruzzo region, the mountain ranges that comprise Majella form part of the Italian Appennines. Endemic taxa were found in mainly two belts namely alpine and sub alpine which cover relatively wide areas of the Majella massif. Because of the difficulty of reaching the high altitude zones, comprehensive studies of these environments have not been carried out. This is especially the case as regards the central and eastern sectors of the massif, which are characterised by extensive plateaus, such as Piano Amaro and Selma di Grotta Canosa (Di Pietro et al., 2008).

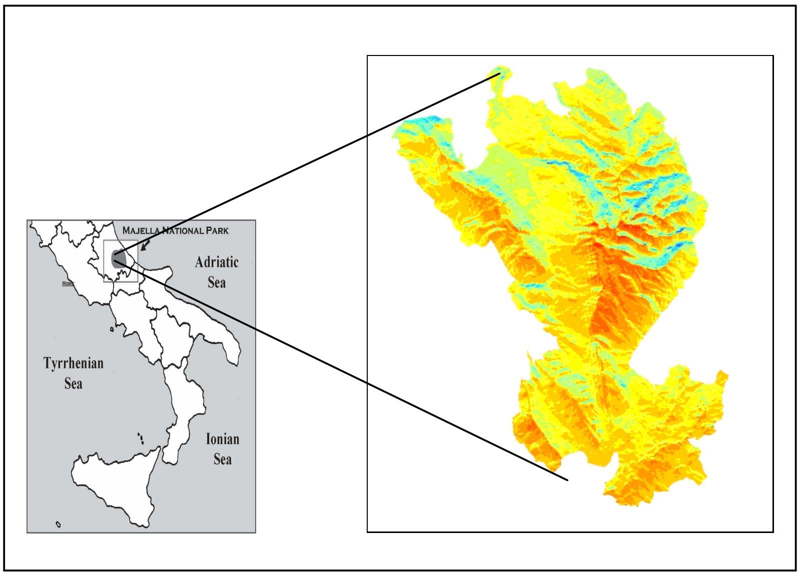


Figure 2-1: Location of Majella National Park

2.2. Materials

Table 2-1 is the list of the materials used for the study.

Table 2-1: List of material used for the study

Material	Source	Format	Data type
Endemic taxa locations data set	Botan geodatabase	Excel table	Point
Topographic map (Carta turnistica parco-nazionale della Majella) Scale 1; 50,000.	Majella national park	Raster	Categorical
Vegetation cover 1999.	Majella national park	Vector	Categorical
Digital Elevation Model (DEM) 30m resolution	Aster image (27 May 08)	Raster	Continuous

2.3. Methods

2.3.1. Data collection

Field work was conducted from 7th-September to 1st- October 2009. Location point data of endemic plants of Majella national park was obtained from secondary sources. This was the digital geodatabase named Data Base Della Flora Vascolare Del Parco Nazionalle Della Majella (Conti et al.,

2002) at the Centro di Ricerche Floristiche dell'Appennino (Apennine Flora Research Centre) Barisciano. The centre consisted of a herbarium and Botanical Gardens.

The data base is referred to as CRFA in this study. CRFA is a large dataset consisting of all the plants of the Abruzzo region. During the fieldwork, only the dataset for Majella national park was extracted for use. For purposes of this study the extracted data base was named BOTAN. The data types in BOTAN are of two categories; Bibliographic reference data and Herbarium data set. Herbariun data set comprised of data with actual records from the field. That data was again grouped into three according to source including:

1. Data from the internal herbarium called Appenninicum named APP found at the Research Center;
2. Data from the external herbarium coming from two sources namely: Magellense named PNM and Neopolitanum named as NAP

The herbarium data from the internal source was 460 records while that from the external sources from both the PNM and NAP was 183 records. The bibliographic reference data in the BOTAN was all from one source and it comprised of 1902 records.

In order to familiarise with the habitats of endemic plant species, field survey was done at Grotta del Cavallone near Taranta Peligna and the location of these plants reflected the common patterns observed in the Mediterranean Basin, where endemic plants are mainly stress –tolerant species that are adapted perfectly to harsh habitats (rock- crevices, cliffs, screes) and that act as refuges little affected by natural or human disturbances (Médail and Verlaque, 1997). Plants occurring on rocks and screes are light requiring species which would not be able to compete for resources under a dense growth (Ellenberg, 1988; Vogiatzakis et al., 2003).

2.3.2. Data cleaning

Data quality was improved through a cleaning process to make it consistent. Part of it was done using ArcGIS tools. Data from the internal herbarium had both geographical and projected coordinate systems. There was lack of consistence in format in the geographical coordinates with respect to degrees, minutes or seconds because three formats had been used. The geographical coordinates used for the Herbarium data were excluded from being used for analysis in this research because not all endemic taxa had been assigned coordinates this was complete only for data from APP and also on grounds that there was lack of consistence. The proper projection used ED50 zone 33N (European Datum 1950) used for the projected coordinates had to be clearly defined. This was further transformed to another Projection; Universal Transverse Mercator, ellipsoid; WGS 84, zone 33 North. To reference to the DEM and other data sets used for this study. There was no information on exact altitudinal range for all the endemic taxa, that available was only for eighty - endemic taxa so it was excluded from analysis. The coordinate records for the endemic taxa in both the Bibliographic and Herbarium data sets were repeated a number of times for different taxa, one location could be recorded many times for the same endemic taxa by different Authors for different years, hence after combining the two data sets Bibliographic reference and Herbarium and removing duplicates the number reduced to 1246 records, and was not equal what would be obtained if you added the two data sets i.e Bibliographic references 1902, plus both the herbarium data sets of 450 internal and 183 external source respectively as it was the case before the cleaning operation. The database is shown in Appendix A.

2.3.3. Data processing

A geodatabase was extracted from BOTAN to produce yet another geodata base named MYLA, geodatabase. The BOTAN geodatabase comprised of two data sets, one from the herbarium and another from Bibliographic references. The Botan geodatabase consisted of all plant taxa for the Abruzzo region, but only a portion of it was extracted for use in this research. Additional records were added on the MYLA data base and these included family and life form names. Both BOTAN and MYLA geodatabases consist of only point data (for locations of endemic plant taxa.

BOTAN geodatabase, bibliographic reference data comprised 1902 records with the checklist code, which was used to identify the taxa from a range of 591 to 8270 for only endemic plant taxa.

- *Name*: This was the most recently accepted name together with the author.
- *Sub*: This was the original name found in publication hence one taxa could have several names depending on the author;
- *Localities*: these included names of places were the taxa had been observed.
- *Year*: This was the period in which the taxa was observed and ranged from 1830 to 2008.

For some of the taxa the period was not specified but instead a range was given as for the period between 1831 to 1842 and 1833 to 1854.

- *Author*: This was the name of the person in the reference. References, this included the publication. However some taxa did not have documentation for references. The data base had attribute for age when the occurrence of the taxa was observed, that observed before 1950 was assigned 2 while that observed after this period was assigned 1.
- *Source*: This was 0 for herbarium data source and 1 for reference data source.
- *Accuracy*: The spatial accuracy was of four 4 levels, 1 for Geographical position system (GPS), location data 2 for a known buffer region in this case it was < 3km buffer region. 3, for an administrative boundary this included all the thirty eight municipalities with in the park. 4 represented a geographical region. The X coordinate data and Y coordinate data both in European Datum 1950 (ED50). The last attribute for this data base is file /id, which is the file identity for each taxon.

BOTAN geodatabase, Herbarium data,

The second data set was from the herbarium. Some of the attributes were similar to those of the Bibliographic reference data set .The first one was the checklist code, used to identify the taxa from a range of 591 to 8270 for only endemic plant taxa.

- *Name*: this was the most recently accepted name together with the author;
- *Sub*: this was the original name found in publication one, hence one taxa could have several names depending on the source.
- *Localities*: These included names of places were the taxa was observed. Date, this was the period when the endemic taxa was observed, but it was recorded from 1824 to 2008. In several ways, for majority of the taxa the date, month and year were recorded, for some only month and year were recorded, others only the year was recorded and for 15 of the taxa no records of period of observation were recorded.
- *Author*: This was the name of the person in the reference.

- Herbarium name, the herbarium data set was from three sources two external herbariums and one internal located at the Research center. The internal herbarium with 460 records and external herbarium with 183 records. The three herbarium sources were Appenninicum one found at the research center as well as Magellense and Neapolitanum both of which are located externally. Each of these had an Acronym which was APP for Appenninicum, PNM for Magellense and NAP for Neapolitanum. The data base had attribute for age when the occurrence of the taxa was observed, that observed before 1950 was assigned 2 while that observed after this period was assigned 1.Source in this case was zero assigned because all sources were herbarium. Accuracy the spatial accuracy was of four 4 levels, 1 for Geographical position system (GPS), location data 2 for a known buffer region in this case it was < 3km buffer region. 3, for an administrative boundary this included all the thirty eight municipalities with in the park.4 represented a geographical region. The data set had both geographical and projected coordinate systems being used. Data from the internal herbarium had both geographical and projected coordinate systems. While data from the external herbarium had only projected coordinate system. Universal Transverse Mercator, ellipsoid; WGS84, zone 33 North for geographical and ED50, zone 33 North for the projected one. Not all taxa in the herbarium data had geographical coordinate records. The last attribute for this data base is file /id which is the file identity for each taxa.

The MYLA geodatabase

In order to obtain a list of endemic taxa of the Majella national park, the list of extracted from the Botan geodatabase was the used as a fundamental source. The geodatabase consisted of 142 endemic plant taxa three of which are endemic only to Majella N.P., these included *Centaurea scannensis, Pinguicula fiorii* and *Soldanella minima samnitica*. This geodatabase had only 1246 endemic taxa after the cleaning were been completed. This consisted of seven columns in the following order, X_ED which represented the projected y coordinate. Y_ED which represented the y coordinates both in the European datum of 1950 projection which is specific to Italy.

- ACCURACY; the spatial accuracy was of four levels, 1 for Geographical position system (GPS),location data 2 for a known buffer region in this case it was < 3km buffer region. 3, for an administrative boundary this included all the thirty eight municipalities with in the park.4 represented a geographical region.
- NUMBER, this referred to the identity of the taxa.
- END_TAXON this referred to the endemic taxon of each of them accompanied with author.
- FAMILY: This referred to the respective families in the geodatabase. In all there were 31 families.
- LIFE_FORM referred to the respective life forms ,this consists of 6 six categories as follows, phanerophytes, nanophanerophytes chamaephytes, hemicryptophytes, geophytes and therophytes The taxa were identified according to the following life form categories by Raunkiaer (1934). Appendix B shows the detail of the MYLA database.

2.3.4. Computation of Kernel densities

The Kernel Density Estimator (from ArcGIS) tool was used to generate kernels densities of endemic plant hotspots of the Majella national park using variable distances which ranged from one to several kilometres. For this research map two hotspot maps were produced one for a distance of 1.5 kilometres and the other for 2 kilometres. This was done at a contour range of 200 meters. The search radius of distance in kilometres ranged from one 1 , two 2, three 3 , four 4 and five 5. The best results from the kernel out puts were used for analysis in this research.

When using the kernel density the following are considered: the in put features used to calculate density; the population field, which is the count or quantity to be spread across the landscape to create a continuous surface; the output cell size at which the output will be created; the search radius with in which to calculate density; and area units of the output density values.

Kernel Density calculates the density of point features around each raster cell, conceptually, a smooth curved surface is fitted over each point, zero at the search radius distance from the point. Only a circular neighbourhood is possible. The volume under the surface equals the population field value of all the kernels equals the population field value for the point, or one if NONE is specified. The density at each raster cell is calculated by adding the values of all kernel surfaces where they overlay the raster cell centre. The kernel function is based on the quadratic kernel function described in (Silverman, 1986). If a population setting other than NONE is used, each items' value determines the number of times to count the point.

Increasing the radius will not greatly change the calculated density values. Although more points will fall inside the larger neighbourhood, this number will be divided by a larger number of points, which can be further from the cell. This results in smoother output raster.

The species (END_TAXON) and location (X_ED, Y_ED) data from the MYLA geodatabase were used to produce maps of endemic hotspots. The study sites were selected on the basis of data completeness, accuracy ranging from 1 to 3, and reliability i.e. with reasonable number of at least 17 and above location points.

2.3.5. Preparation for the modeling

The raster layers for only the continuous variables which were to be used in the MaxEnt model were subjected to the Pearson correlation test, using statistical software SPSS. The variables include solar radiation, aspect, elevation and slope. A pair wise comparison was done for each of the variables. All environmental layers were checked for spatial referencing, pixel size, rows and column among others. This was done for both the continuous and the categorical layers.

2.3.6. Derivation of predictor variables

As said earlier, the explanatory variables were either continuous or categorical as in (Table 2-2). The variables were continuous and vegetation cover type which was categorical. All the four continuous variables were estimated from the 30m DEM. The same procedure was used to estimate slope, aspect and elevation. For solar radiation a different procedure was used.

2.3.7. Estimation of solar radiation

Solar radiation provides information on how much of the sun's energy strikes the surface at the place on the earth during a certain time period. The potential direct solar radiation of the growing season was calculated following the method developed by (Kumar et al., 1997). The values were calculated in ArcGIS using the DEM for a period of 5months, which is the growing season of summer starting from May to September. The growing season corresponds only roughly to the snow free period of the year. The values were calculated for every 15 minutes and summed up for the growing season. Table 2-2 shows the environmental variable, the units in which it is measured, the source and pixel size.

Table 2-2: Environmental variables

Variable	unit	source	Pixel{m)
Elevation	m.a.s.l	DEM	30m
Slope	percentage	DEM	30m
Aspect	degrees	DEM	30m
Solar radiation	Kj/m^2	DEM	30m
Vegetation cover	categorical	1999 N.P.	30m

The variables tested as predictor of endemic taxa distribution (Table 2) were elevation as proxy for rainfall and temperature (Hijmans et al., 2005); slope, aspect and solar radiation as proxy for topo – climate, vegetation as habitat disturbance measure. The DEM derivatives (elevation. slope aspect and solar radiation) were calculated. The layers of environmental predictors were georeferenced to the same coordinate system in ArcGIS 9.3.

The criteria for selecting which species to model was to ensure that the four major representative life forms of the MYLA geodatabase of endemic taxa, have been selected. These included *Saxifraga* from chamaephytes, *Stipa dasyvaginata* from hemicrytophytes, *Bunium* from geophytes, *Melampyrum italicum* from therophytes and *Campanula fragilis* from chamaephytes.

2.3.8. Modeling of endemic plant species occurrence using MaxEnt

For this research, MaxEnt (maximum entropy) model (Phillips et al., 2006) was selected for modeling species occurrence because the endemic taxa locations represented presence data. Analysis was performed on the occurrence data of 1246 location records of endemic plant taxa of the Majella national park. Five endemic plant taxa from four representative life forms were selected from the MYLA geodatabase. Two of the endemic plants chamaephyte, represented the dwarf shrub one hemicryptophyte represented the perennial herbs, one therophyte represented the annuals and one geophyte represented the orchids. In order to be selected each of the endemic taxa. With a reasonable number of location points, and for this study it ranged between ten and twenty. The endemic plant taxa selected included *Saxifraga italica*, *Melampyrum, italicum*, *Campaula fragilis* ,*Bunium petraeum* and *Stipa dasyvaginata*.

To run of the model two files are needed one containing presence localities referred to as the sample and another containing the environmental variables in the directory layers. The directory layer contains a number of Ascii raster grids each of which describes an environmental variable. These should have the same geographic bounds and cell size. It should also be clear to the program which variables are categorical or continuous.

The maximum entropy model (MaxEnt 3.2.0) predicts probabilities of species distribution from records of species occurrences and from data layers representing environmental variables without assumption on the statistical distribution underlying the species or the variables. MaxEnt starts assuming a uniform probability distribution and iteratively updates an algorithm predicting the species distribution based on computed weights of the variables. The gain indicates how closely the model is concentrated around the presence samples. Figure 2-2 shows the interface of the MaxEnt.

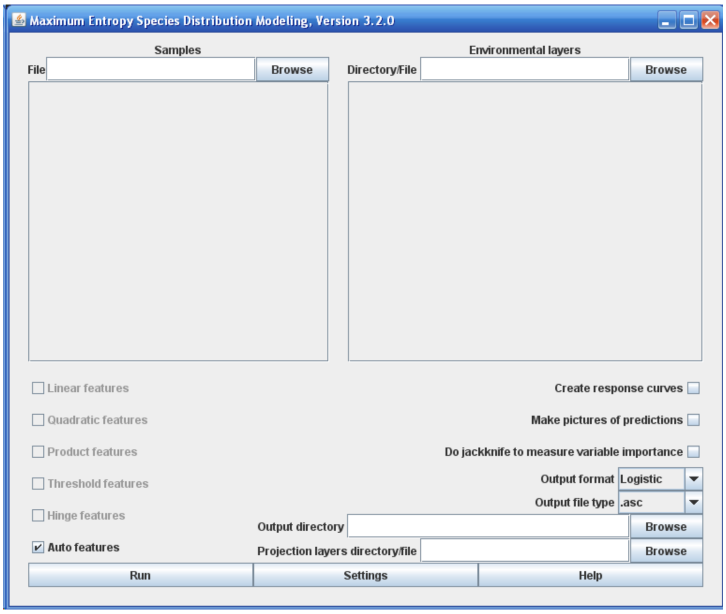


Figure 2-2: Interface of Max Ent

2.4. Analysis

To estimate which environmental variable contributes most to the model prediction, various analysis were done using response curves, percentage tables and Jackknife charts. A model was created using each variable in isolation. The results appeared in three charts results for training gain, test gain and AUC. The relative contribution of each predictor variable to the MaxEnt output has been calculated with its Jackknife module. Model performance was assessed with the receiver operating characteristics (ROC) and area under ROC curve (AUC).

The MaxEnt model parameters were set as follows; regularization multiplier =1; maximum number of iterations =1000; convergence threshold $=10^5$; maximum number of background pixels=10,000. Model predictions per pixel are presented as cumulative probabilities of all layers multiplied by 100 to arrive at a percentage (Phillips et al., 2006). The MaxEnt output was exported to ArcGIS 9.3 for good visualization.

2.5. Validation

The accuracy of MaxEnt in the prediction of distribution of *Saxifraga italica* was validated statistically using results from the plots of the area under Receiver operating curve ROC (AUC). The data had been split into two partitions one for training 75% and another for testing 25%. The red (training line) shows the "fit" of the model to the training data. The blue (testing line) indicates the fit of the model to the testing data, and is the real test of the models' predictive power. The further towards the top left of the graph that the blue line is, the better the model at predicting the presences contained in the test sample of the data.

Figure 2-3 below shows the summary of the methodological process.

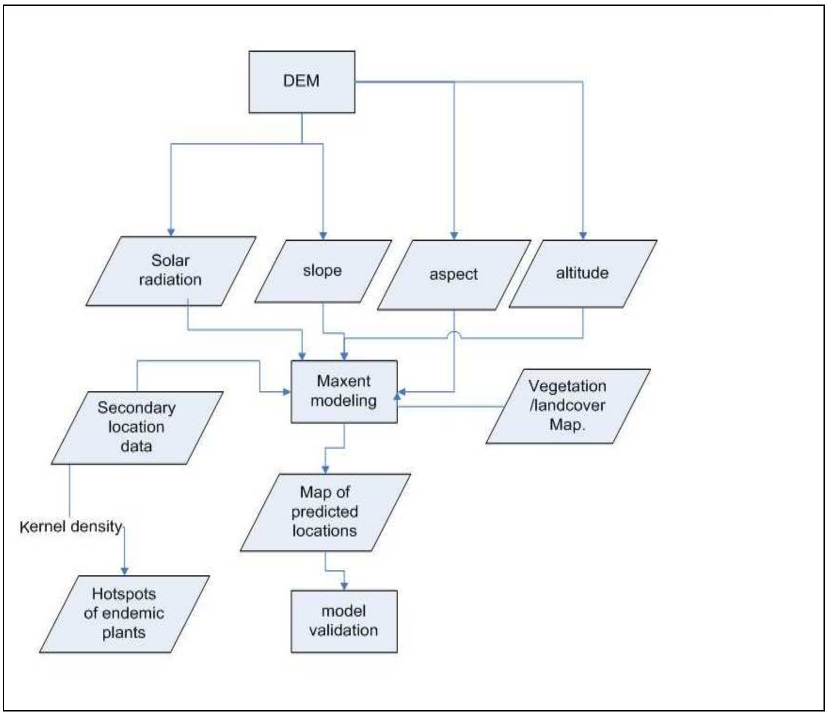


Figure 2-3: Summary of methodology

3. Results and Analysis

3.1. DEM environmental variables

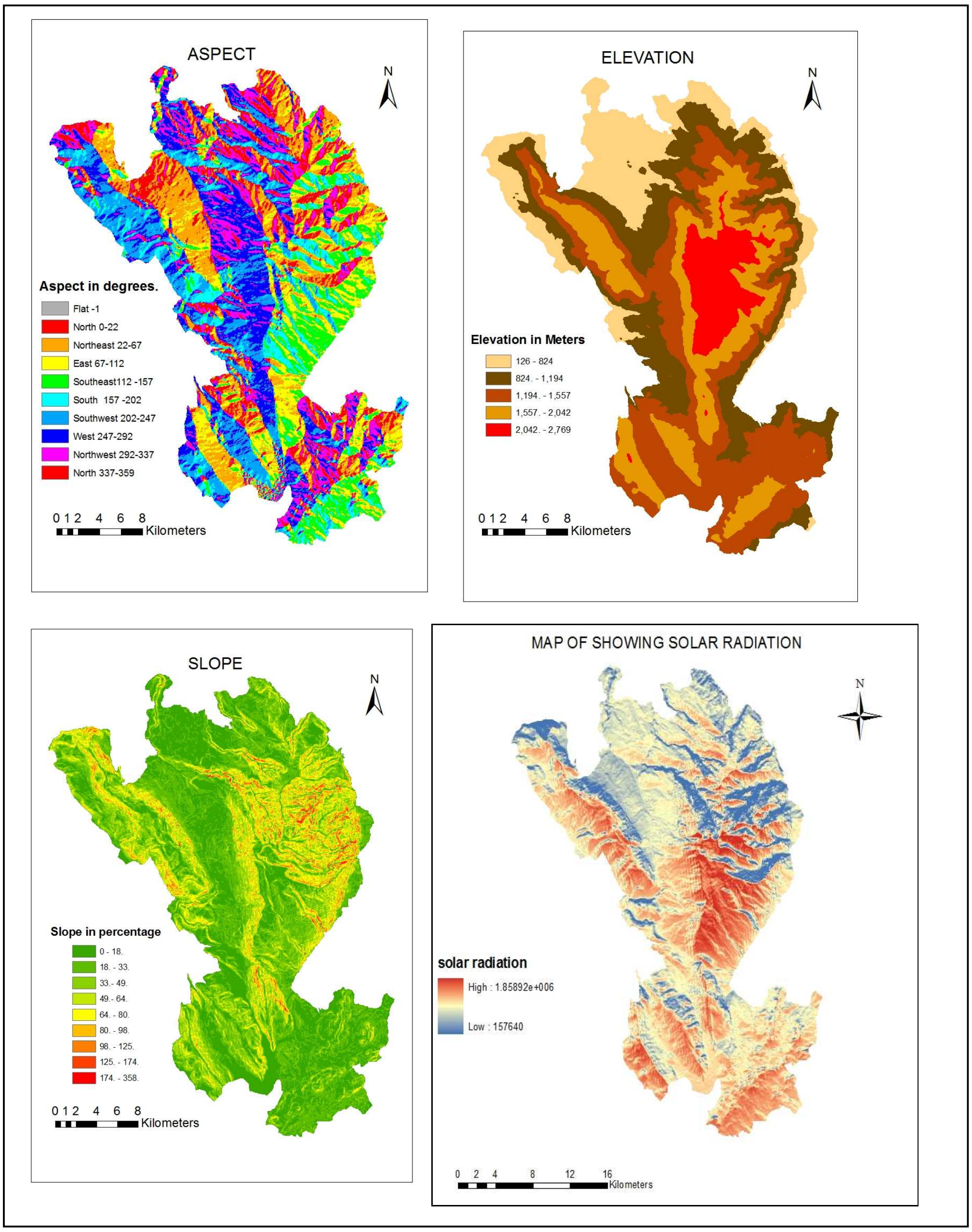


Figure 3-1: DEM Environmental variables

Figure 3-1 shows the DEM environmental variables shown as aspect, elevation, slope and solar radiation. The Pearson correlation values are shown in Table 3-1.

Table 3-1: Pearson correlation among continuous environmental variables

	Solar radiation	aspect	elevation	slope
Solar radiation	1.000	.109	.392	-.335
aspect		1.000	-.064	-.086
elevation			1.000	.214
slope				1.000

The table shows that none of the variables was highly correlation with one another. Hence all layers could be useful for modeling. The correlations are all significant at the 0.001 level.

3.2. The distribution pattern of families of the endemic taxa of Majella

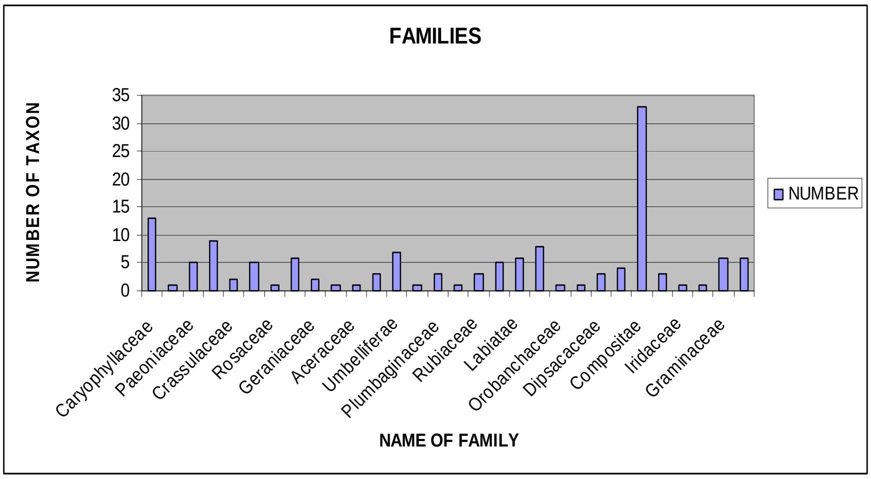


Figure 3-2: Distribution of families' within the Endemic plant taxon

Figure 3-2 indicates that most represented family among the endemic plant taxa of Majella National Park is the composite with the largest number of 33 endemic taxa. Many taxa within this family are observed to be perennial herbs hemicryptophytes and chamaephytes. This higher number may be attributed to the fact that such plants are better adapted to harsh environment habitats where most of these plants occur. The results imply that it is possible that the rate of speciation within the family is high compared to that of extinction relative to other families.

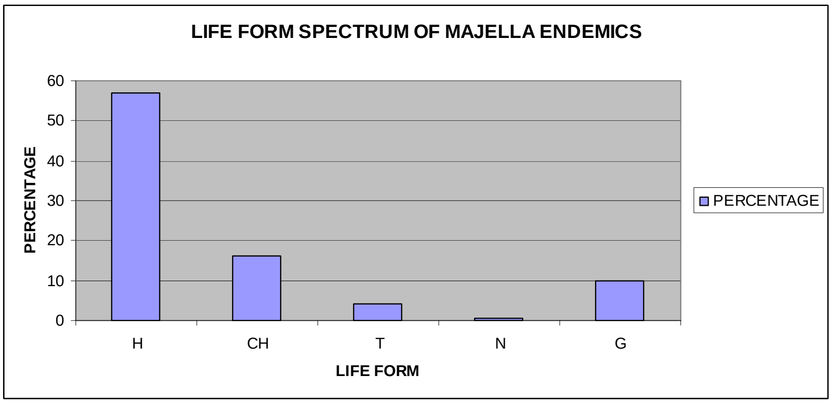


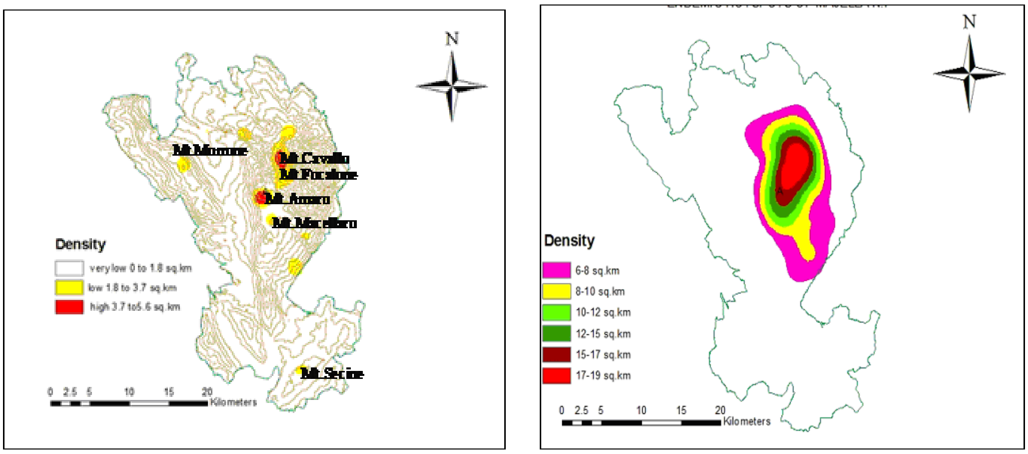
Figure 3-3: Life form spectrum of Majella endemics plants

N= nanophanerophytes Ch = chamaephytes H = hemicryptophytes G = geophytes T = therophytes

Figure 3-3 showing the life form spectrum for the Majella endemics indicates Hemicryptophytes with the highest 57% and chamaephytes, with 16% and Geophytes with 10%. The rest each had relatively small percentage that some could not be indicated on the bar chart.

3.3. Mapping of endemic plant hotspots using Kernel density tool

Figure 3-4 shows the results of the hotspots maps of Endermic plant taxa. Figure 3a and 3b shows the maps produced at a distance of 2 kilometres and 1kilometer respectively. According to the procedures when distance was set at 2 kilometres, there were 9 main areas, in the Majella with hotspots of endemism that were used to explain the distribution pattern of endemic taxa with in Majella national park.



a) 2 kilometres distance b) 1.5 kilometres

Figure 3-4: Endemic plant hotspots

From Figure 3-4, hotspots of endemics showed that, there is a high density of endemic plant taxa mainly on the highlands. Such areas included the two major hotspots (mountain Cavallo and mountain Amaro) out of the total of nine (9). The rest of the hotspots had a lower density of endemic plant taxa, namely mountain Morrone in the North West Park and mountain Secine in the south, mountain Macellaro near Amaro and Focalone near Covallo, together with the slopes of Orfonto canyon and on the eastern slopes of the Majella massif of Taranta. These hotspots are identified with the eastern slopes of the Majella massif. These results could be explained in term of less competition among species at high elevation. It could also be explained with tolerance to harsh environmental conditions which is the case as elevation increases.

3.4. MaxEnt modeling

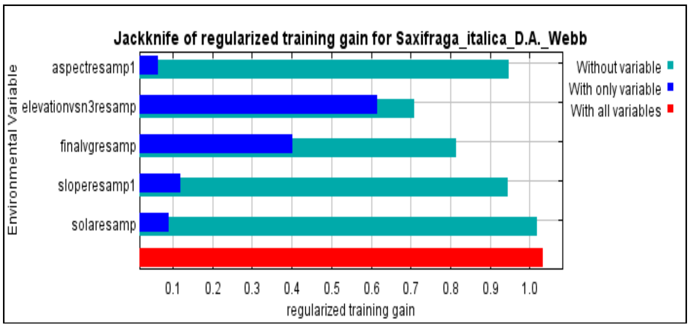
Table 3.2 shows an explanation of the codes for environmental variable used in the modeling.

Table 3-2: Explanation of codes of environmental variable

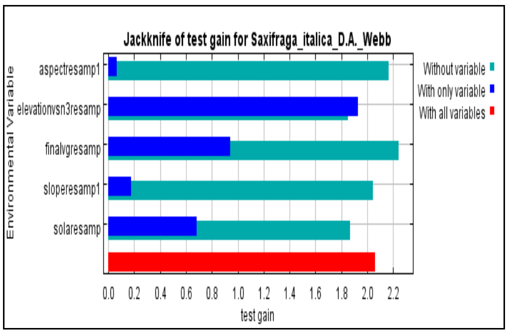
Code for environmental variable	meaning
aspectresamp1	aspect
elevationvsn3resamp	elevation
finalvgresamp	vegetation cover type
Sloperesamp1	slope
solaresamp	Solar radiation.

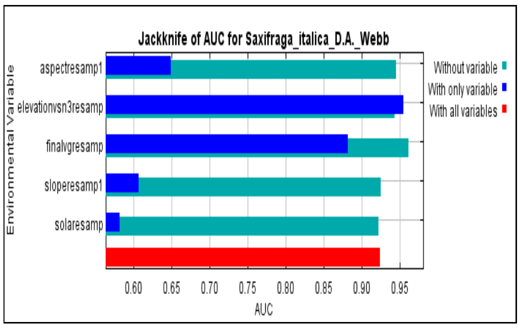
3.4.1. Saxifraga_italica

Jackknife test



a)





b) **c)**

Figure 3-5: Jacknife test for Saxifraga_italica

a) Regularised training gain b) test gain c) AUC

Figure 3-5 shows the Jacknife of training gain for Saxifraga_italica, illustrating environmental variables against regularised training gain, test gain and AUC. In the estimation using Jackknife training gain, elevation emerged as the best environmental variable contributing to the prediction in the model with the highest gain of 0.6. The second was vegetation cover type with gain of 0.4. The third was slope with gain of 0.1; the fourth was solar radiation with gain of 0.8 while aspect was the least contributing variable in this case with gain of 0.5. When compared with the Jackknife of test gain and AUC, the trend was the same for elevation and different for the other environmental variables.

Estimation using the jackknife of test gain, there was an increase in the gain for elevation to a value of 1.8 higher than that of the jackknife for training gain, which was 0.6. The second was vegetation cover type with a test gain of 0.9 which was higher than its value in training gain. The third was solar radiation which an increased value in the test gain of 0.1 if compared with the training gain. The fourth was slope which showed relatively the same gain as in the Jackknife for training of 0.1, the variable with the least gain was aspect as was the case for training gain of 0.5.

For the estimation using the Jackknife for AUC, elevation still emerged the best predicting environmental variable although there was an increase in the gain value if compared with the Jackknife for training gain from 0.6 to 0.95. The second was vegetation cover type which also increased from 0.4 to 0.9 AUC gain. The third was aspect with an increase in gain if compared with the Jackknife for training and test gain to 0.65. The fourth was slope with 0.6 while the variable with the least value was solar radiation. Both elevation and vegetation cover type when used in isolation produced high predictions for the distribution.

Response curves for Saxifraga italica

These curves show how each environmental variable affect the MaxEnt prediction. The curves show how the logistic prediction changes as each environmental variable is varied. The results are presented in terms of aspects, slope, solar radiation, elevation and vegetation cover type (Figure 3-6).

Results for aspect response curve indicated the North aspect to play the most important role in the prediction. This is shown in the curve where north aspect corresponds close to 1 and 360 degrees there are high values for the prediction while other aspects did not seem to be significant. For elevation, the probability for the occurrence of saxifraga increased with increase in elevation, from 2000m the predictions were more than half and the value reached maximum at elevation 2500m. This confirms to the results that *Saxifraga italica* is likely to occur in high elevation areas and mostly above 2000m which is above the timberline. For the vegetation cover type which played a role in this prediction included 13 representing open grassland and dwarf shrub, 15 representing mountain pine, and 20 representing bare ground and sparse vegetation. As slope was increased also the value for prediction increased up to close to 20%. Therefore more increase in slope percentage was not significant in the prediction. *Saxifraga italica* therefore has less probability to be found on very steep slopes. Solar radiation played non significant role in the prediction model predictions as it was being increased. This showed that *Saxifraga italica* could in habitat site with in a big range of solar radiation hence this did not have an important role in determining its distribution. Therefore, from the radiation curves elevation alone could be used to predict the distribution of *Saxifraga italica* because its contribution alone is 1.9 almost the same as 2.0 when all variables are included in the model.

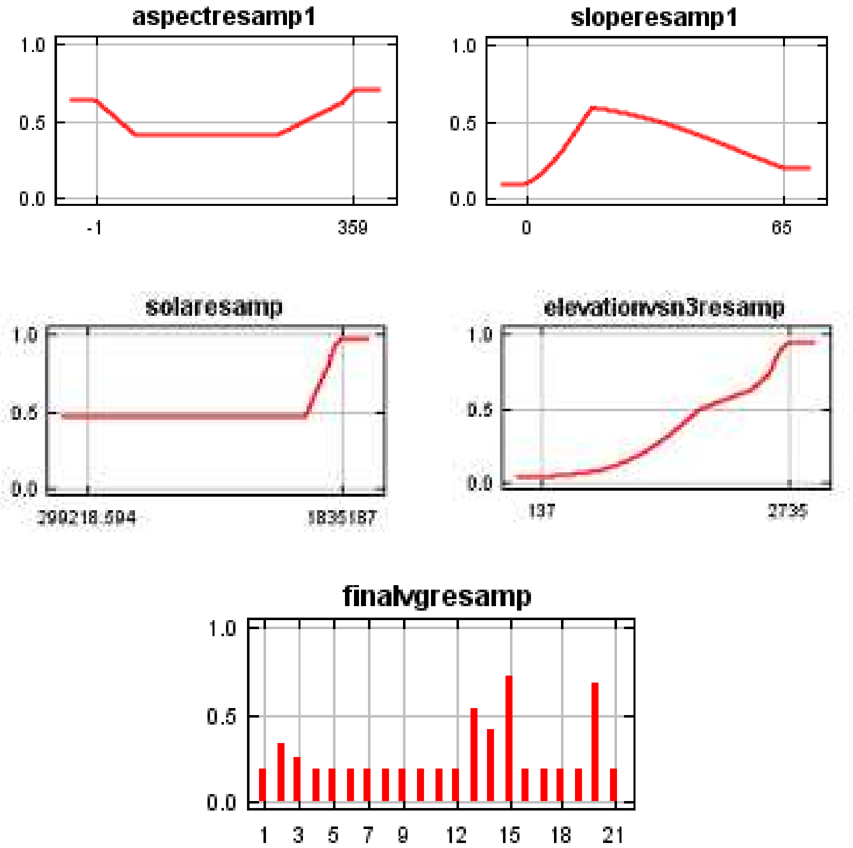


Figure 3-6: Response curves for Saxifraga _italica

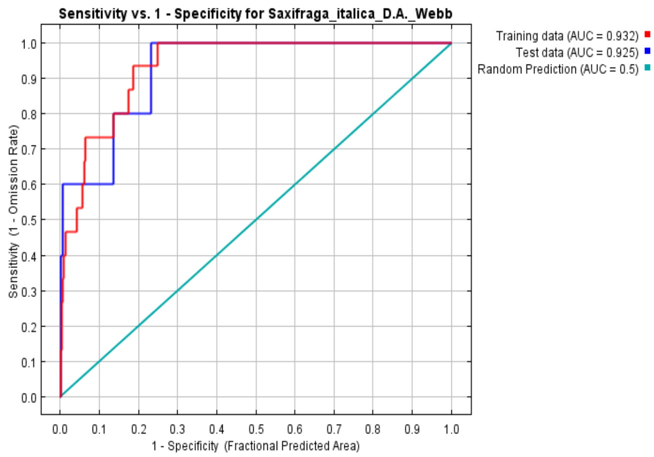
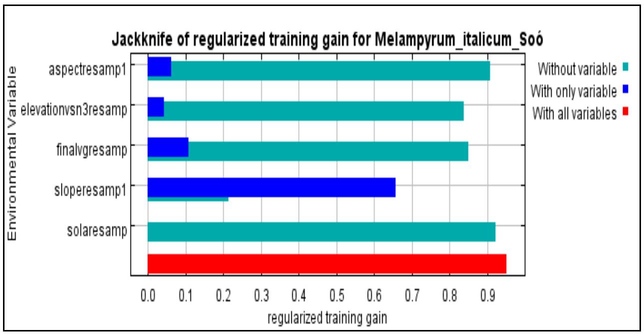


Figure 3-7: AUC curve for Saxifraga_italica

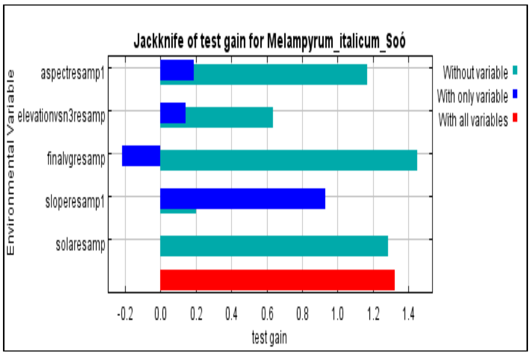
3.4.2. Malampyrum_italicum_Soo

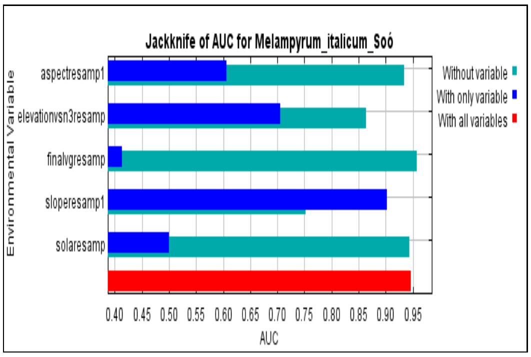
Jackknife test

Figure 3-8 shows the Jacknife of training gain for Malampyrum_italicum_Soo, illustrating environmental variables against regularised training gain, test gain and AUC.



a)





b) **c)**

Figure 3-8: Jackknife for Malampyrum_italicum_soo

a) Regularised training gain b) test gain c) AUC

Figure 15 show that, estimation using the Jackknife of regularised training gain indicates that slope had the highest predicting power with a value of 0.65. The rest of the environmental variables namely aspect, elevation and vegetation cover type had very low gain values of 0.05, 0.04, 0.1 in that order. Solar radiation in this case could not be used in isolation to make predictions in the model for this endemic taxon.

Similarly, for the estimation using the Jackknife of test gain, slope had the highest predicting power with a gain of 0.9. The corresponding values for aspect and elevation have gains of 1.9 and 0.15 respectively. Solar radiation is the only environmental variable which could not be used in isolation for predictions of the model. Vegetation in this case showed a negative gain which indicates that for this model it was not an important predicting variable.

For the estimation using the jackknife of AUC, slope had the highest predicting power compared with the jackknife for training gain and test gain and in this case with a gain of 0.9. The second was elevation with a gain of 0.7, the third was aspect with a gain of 0.6, the forth was solar radiation with a gain of and the least contributing environmental variable with a gain of 0.4.

In general estimation using the Jackknife results indicated that slope had the highest predicting power for the distribution of Melampyrum with all the three models. All the three models performed well in predicting the distribution because the total gain for the model when all environmental variables were used as inputs was better that when each of the variables was used in isolation.

Response curves for Melampyrum italicum

Figure 3-9 shows the response curves for *Melampyrum italicum*. It was very clear from these curves that slope really had a high predicting power as compared to the rest of the environmental variables. As far as vegetation cover type is concerned, most cover types are less significant due to the fact that majority are below 0.5, implying that probability is even less than a mere random prediction. Vegetation cover types “pubescent oak woods” and “mountain pine” seem to have influence.

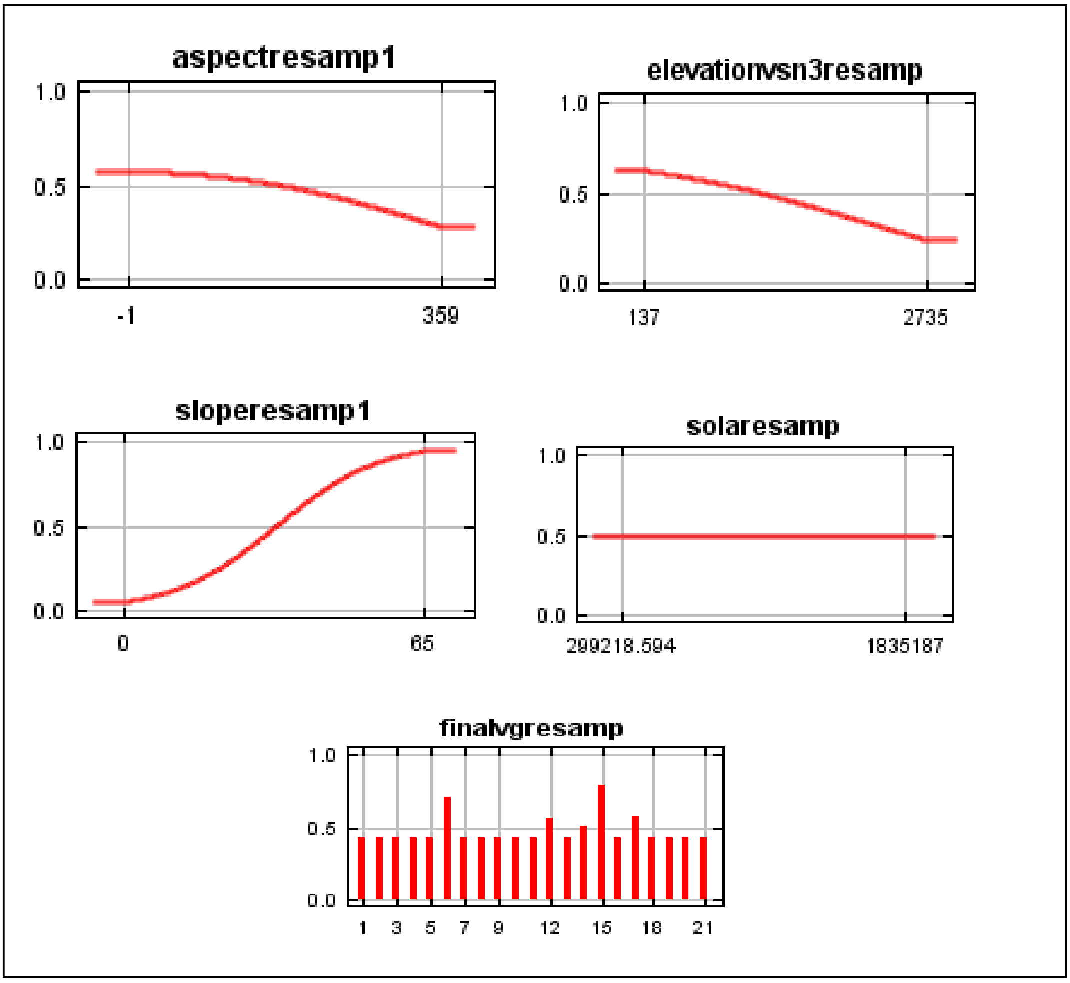


Figure 3-9: Response curves for Melampyrum italicum

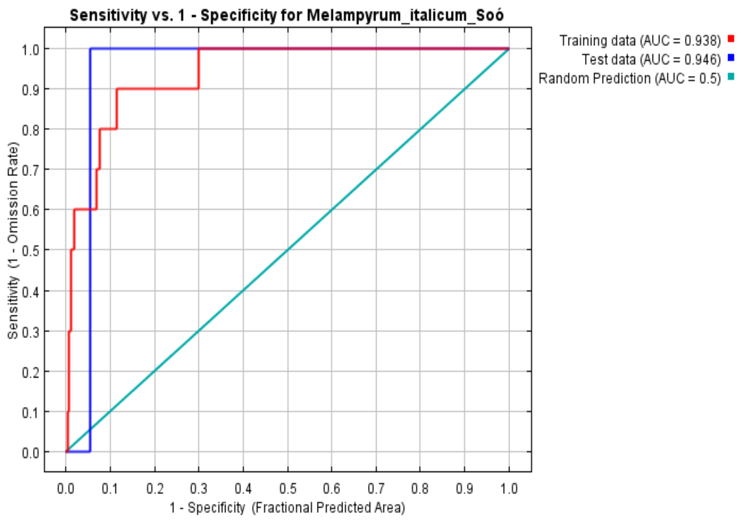


Figure 3-10: AUC curve for Melampyrum_italicum

3.4.3. Campanula

Jackknife test

Figure 3-11 shows the Jacknife of training gain for campanula illustrating environmental variables against regularised training gain, test gain and AUC.

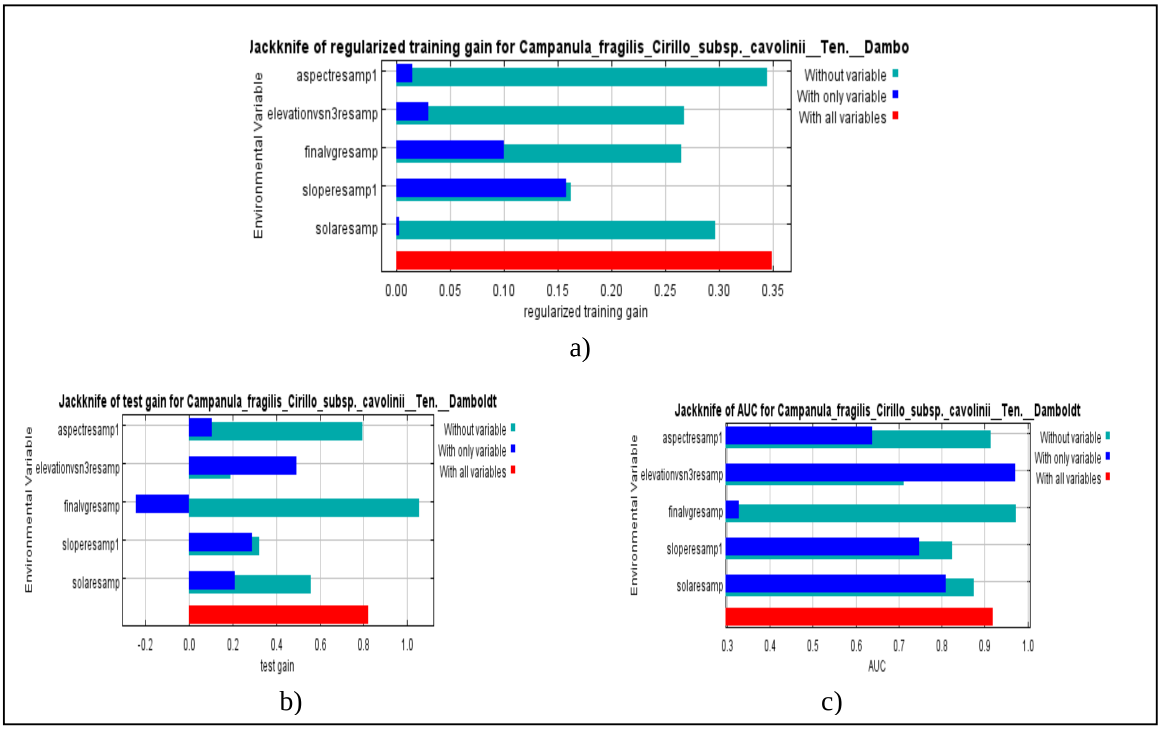


Figure 3-11: Jackknife test for Campanula

a) Regularised training gain b) test gain c) AUC

From Figure 3-11, slope had the highest predicting power for training gain with a value of 0.15. Vegetation cover type had training gain of 0.10, while elevation, aspect and solar radiations had gains of 0.025 each.

For test gain, elevation had the highest predicting power with a gain of 0.5, slope with a gain of 0.3 while solar radiation and aspect had least gain values of 0.1 each. Unlike the jackknife for training gain and that of AUC, vegetation cover type had a negative gain indicating that this environmental variable is not important in predicting the occurrence of Campanula in the model.

Estimation using the jackknife of AUC,e levation had the highest predicting power with a gain of 0.96, which indicated that this environmental variable could be used in isolation to predict the occurrence of Campanula, because of its value for gain is higher than when all the other environmental variables are used in the predictions of the model. The second was solar radiation with a gain of 0.8. The third was slope with a gain of 0.75. The forth was aspect with a gain of 0.65 and the environmental variable with the least predicting power was vegetation cover type with a gain of 0.34. In general all the three models were good in predicting the occurrence of Campanula.

Response curves for Campanula

Figure 3-12 shows the response curves for *Campanula*.

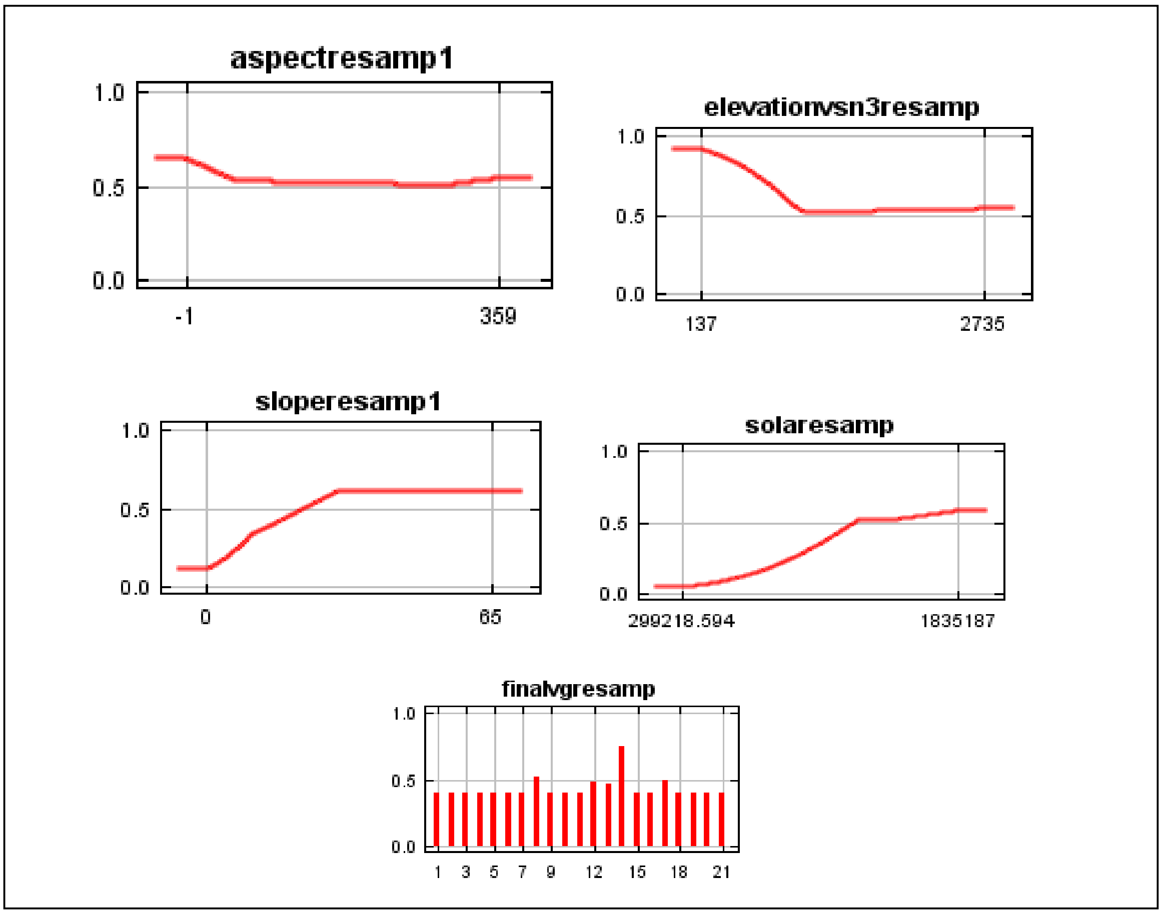


Figure 3-12: Response curves for Campanula

Figure 3-12 indicates slope to have better predictions than the rest of the environmental variables for Campanula. Vegetation cover type has only sub alpine grasslands which is not a good representation of that variable. However the fact that campanula is typical of grassland habitats can be established from the results.

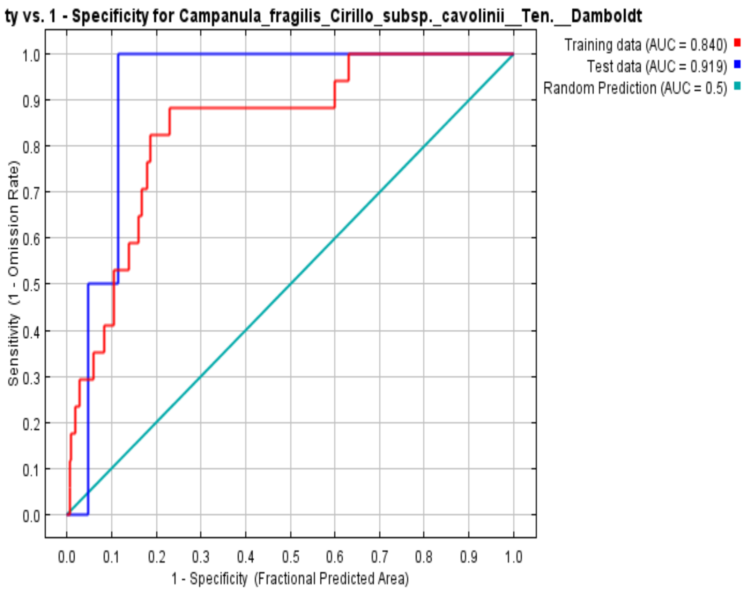


Figure 3-13: AUC curve for Campanula

3.4.4. Bunium

Jackknife test

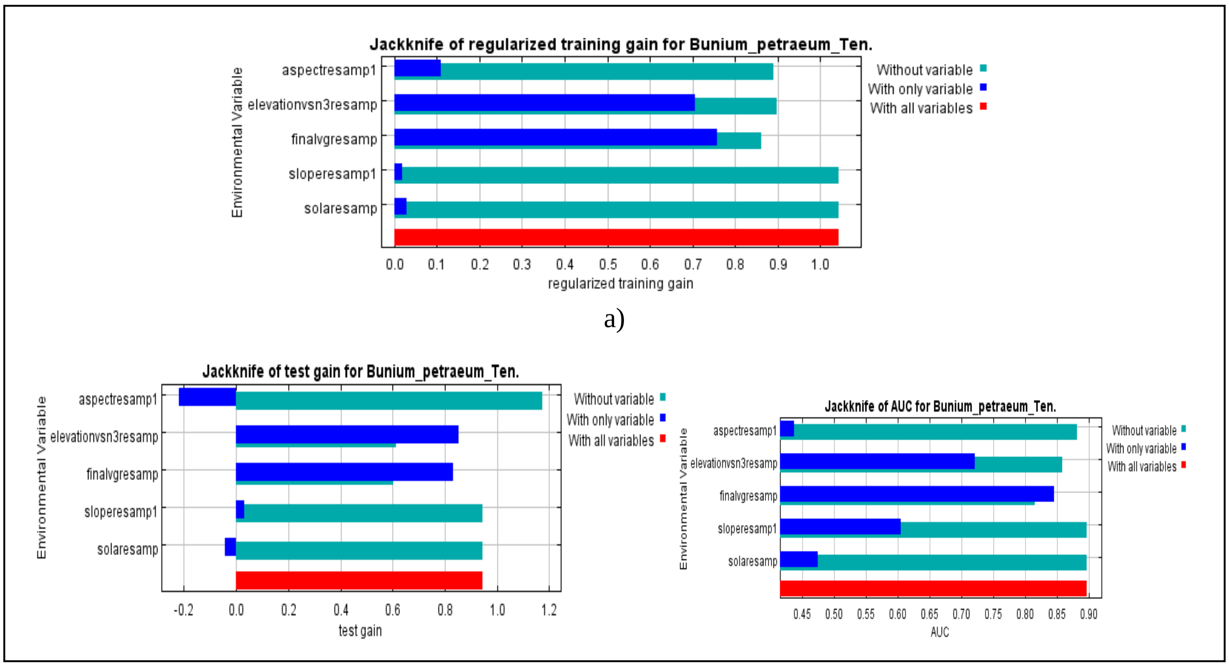


Figure 3-14: Jackknife for Bunium

a) Regularised training gain b) test gain c) AUC

From Figure 3-14, estimation using the jackknife of training gain, vegetation cover type was the environmental variable that had the highest predicting power with a gain of 0.75. Elevation, aspect, solar radiations had gain values of 0.7, 0.1, and 0.04 with slope having the least predicting power was slope with a gain of 0.02.

For the test gain, only three environmental variables contributed in the prediction of occurrence of Binium. Elevation had the highest predicting power with a gain of 0.85, vegetation cover type 0.82 and slope the least predicting power for the occurrence of Binium. The remaining two environmental variables namely aspect and solar radiation both had a negative gain, indicating that they did not have any contribution in the prediction of the model. Among the two, aspect had amore negative gain compared to solar radiation indicating that it was less important than solar radiation in the predictions of this model. For the AUC, the environmental variable with the highest predicting power was vegetation cover type with a gain of 0.84, elevation with a gain of 0.73, slope 0.6, solar radiation 0.45 and aspect, the environmental variable with the least predicting power with a gain of 0.4.

In general, vegetation cover type had the highest predicting power for Bunium because it had the highest gain in two of the three models. The Jackknife of training gain produced the best model, because overall it had a gain of 1.0 compared to 0.9 of AUC, both of which were good in predicting the occurrence of Binium.

Response curves for Bunium patraeum

Figure 3-15 shows the response curves for *Bunium patraeum*

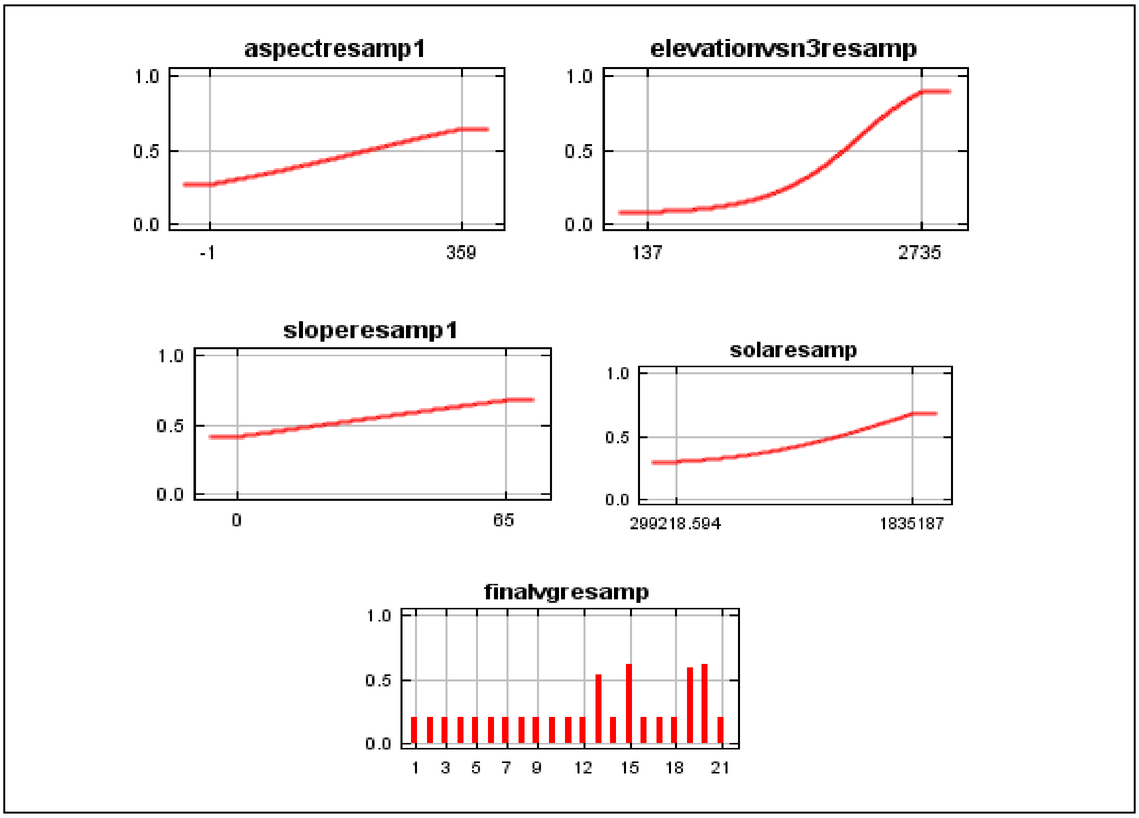


Figure 3-15: Response curves for Bunium patraeum

From the curves in Figure 3-15, it can be deduced that Bunium is predicted largely from vegetation cover types which included open grasslands, mountain pine, teen abandoned farmland and sparse vegetation. This also implies that the taxon is spread in a range of habitats relative to the others considered in this research. Elevation can also be observed to affect the predictions in a significant manner. Solar radiation appears to contribute to the prediction at the extent.

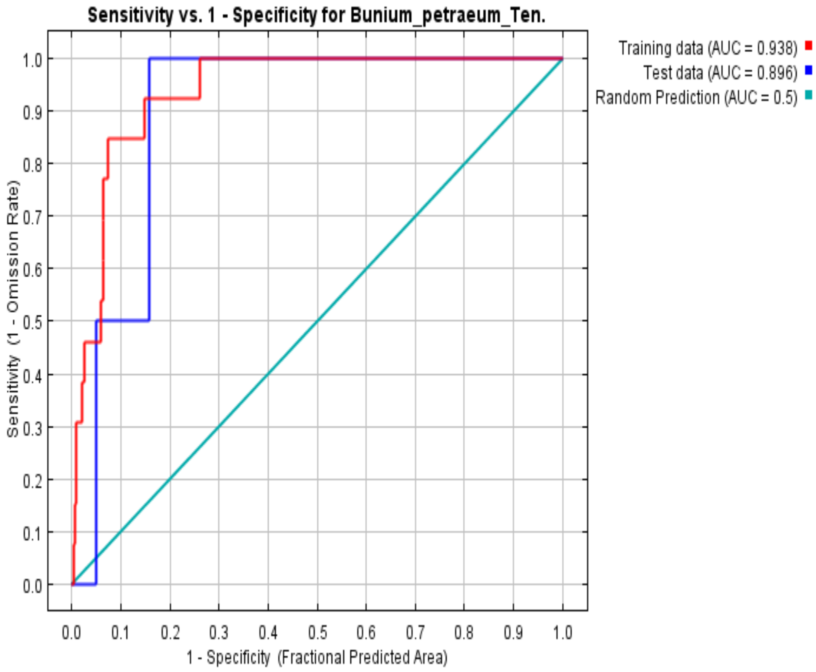


Figure 3-16: AUC curve for Bunium patraeum

3.4.5. Stipa dasyvaginata

Jackknife test

Figure 3-17 shows the results of the Jackknife test for Stipa dasyvaginata. From the figure, estimation using the jackknife for training gain shows that the environmental variable with the highest predicting power was vegetation cover type with a gain of 0.35. Aspect and solar radiations has a gain of 0.25 and less than 0.05. When elevation and slope are used in isolation did not have any significant role in the predictions of Stipa dasyvaginata.

Estimation using jackknife test of gain, the environmental variable with the highest predicting powers was vegetation cover type with a gain of 0.35.Aspect, solar radiation and slope has a gain of 0.15, 0.05 and less than 0.05 respectively. Elevation could not be used in isolation in the predictions of this model because it did not show any gain.

Estimation using jackknife for AUC the environmental variable with the highest predicting power was vegetation cover type with a gain of 0.9. The second was solar radiation with a gain of 0.8. The third was slope with a gain of 0.72. The third was aspect with 0.62 and the environmental variable with the least predicting powers was elevation with a gain of 0.5. In general the jackknife for AUC had the best model for predicting the occurrence of Stipa dasyvaginata.

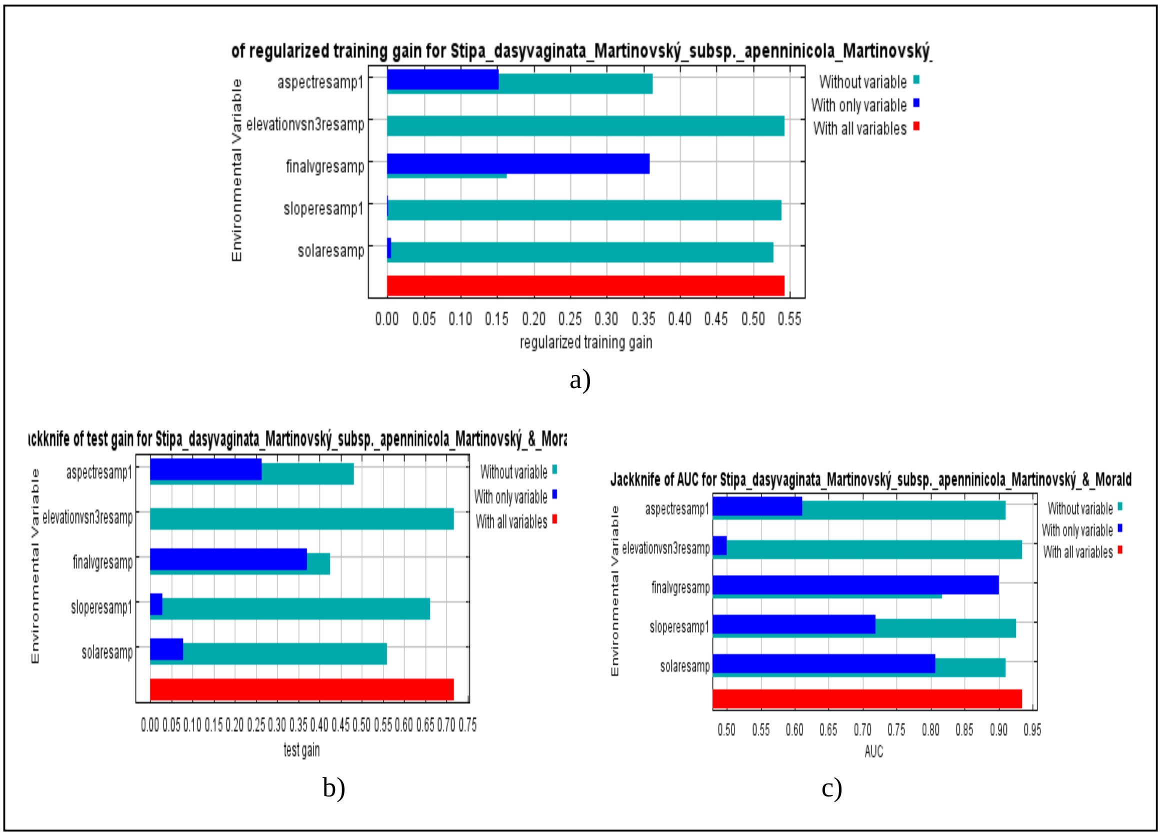


Figure 3-17: Jackknife test for Stipa dasyvainata

a) Regularised training gain b) test gain c) AUC

Response curves for Stipa dasyvaginata

Figure 3-18 shows the response curves for *Stipa dasyvaginata*

From the response curves for *Stipa dasyvaginata* vegetation cover type contributed best to its occurrence with montane pine, shrub land among others. Aspect had some contribution though low but better than slope and solar radiation.

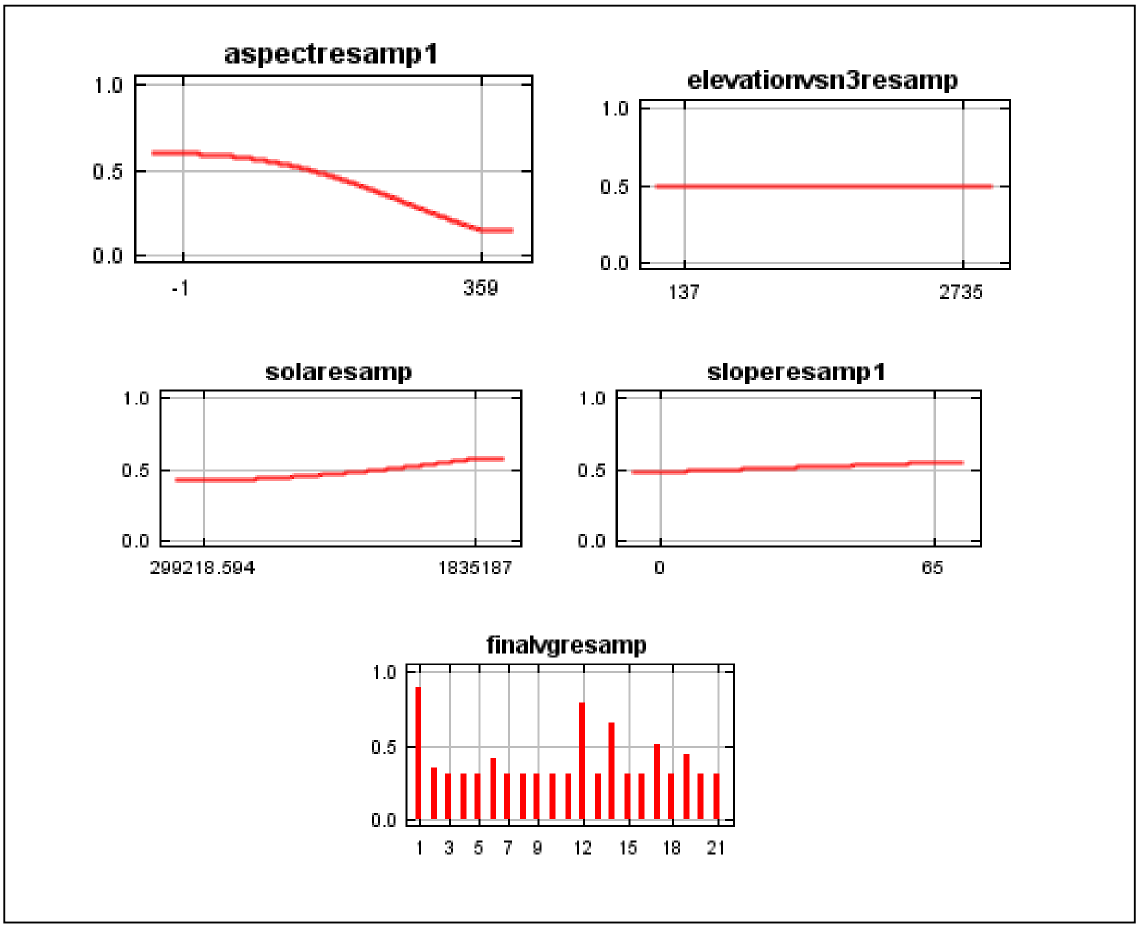


Figure 3-18: Response curves for Stipa dasyvaginata

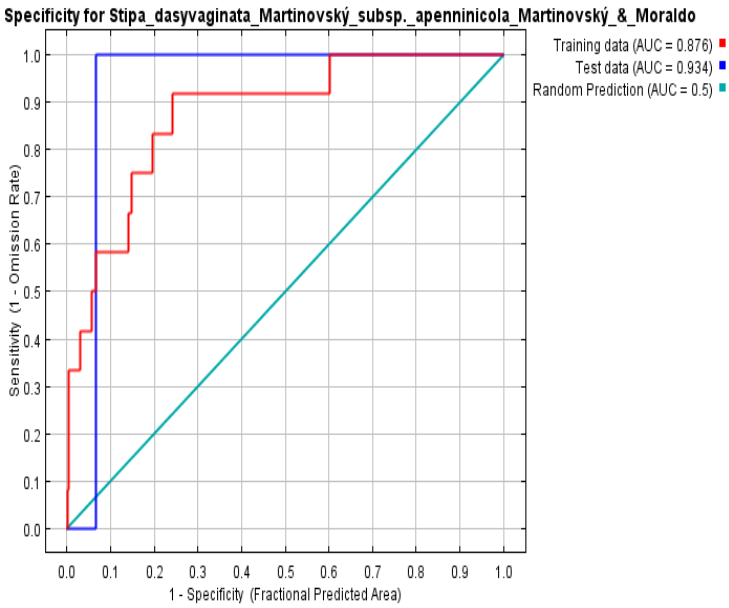


Figure 3-19: AUC curve for Stipa dasyvaginata

Table 3-3 shows the percentage estimation of how each variable contributed all endemic plant taxa. For each of the taxon, the percentage estimations was ranked in terms of the participation of each of the variable (1= lowest and 5 = highest). The results is summarised in Table 3-4.

Table 3-3: Percentage estimation of variables contribution in the modeling

Variable	**Taxa/Percentage contribution (%)**				
	Bunium	*Campanula*	*Melampyrum*	*Stipa dasyvaginata*	*Saxifraga italica*
vegetation	64.8	27.2	12.3	67.4	22.9
elevation	21.3	11.0	8.3	0	57.4
aspect	13.9	1.1	4.5	31.0	10
solar radiation	0	9.3	2.5	1.2	0.8
slope	0	51.3	72.4	0.5	8.9

Table 3-4: Ranking of each environmental variable for every taxa

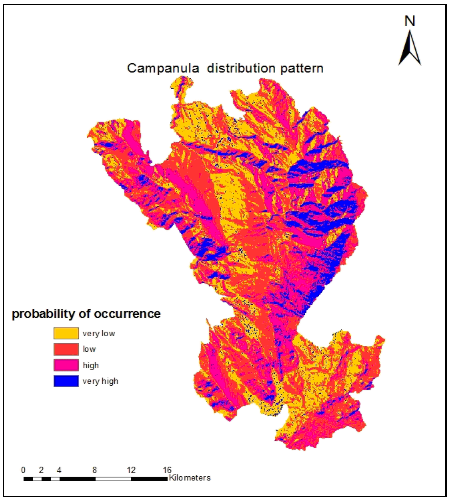
variable	*Saxifraga*	*Stipa dasyvaginata*	*Melampyrum*	*Campanula*	*Bunium*
Elevation	1	5	3	3	2
slope	4	4	1	1	5
aspect	3	2	4	5	3
Solar radiation	5	3	5	4	4

Vegetation	2	1	2	2	1

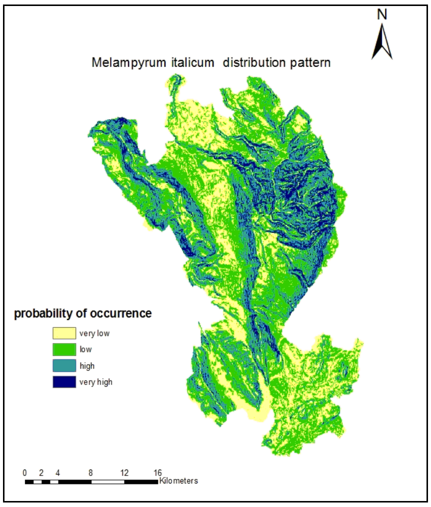
Table 3-4 indicate that vegetation cover plays the greatest role in determining the distribution of the endemics because for all the endemics put to test it came out to rank as 1 or 2. The results go ahead to show that for Stipa dasyvaginata and Binium vegetation cover is predicted to be the major determinant factor. The second was elevation this was a major predicting factor for only Saxifraga. The third variable was slope which again was predicted to be the major predicting factor for Campanula and Melampyrum. Aspect and solar radiation played a less significant role for most of the endemic taxa apart from stipa dasyvaginata where aspect ranked 2 and solar radiation ranked 3. While aspect ranked 3 for Saxifraga italica.

3.5. Mapping of distribution of endemic plant taxa of Majella N.P

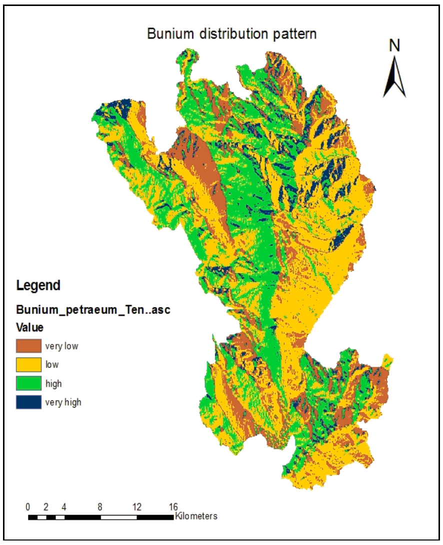
The ASCI raster that was produced during modeling of the respective endemic taxa was exported to ArcGIS and maps for the potential occurrence of the endemics plant taxa of the Majella were produced. These were used for further analysis. The resultant maps are shown in Figure 3-20.



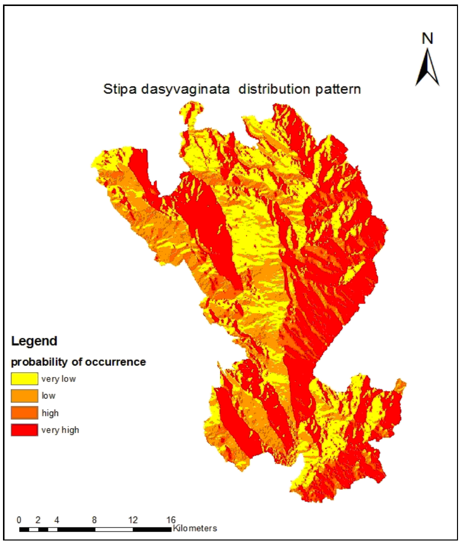
a)



b)



c)



d)

Figure 3-20: Map showing probability of occurrence of endemic species

Figure 3-20 shows that *Campanula* was highly predicted to occur on the eastern slopes of Majella Massif. Also, *Malampyrum* was highly predicted to occur on the eastern slopes of Majella Massif. Therefore *Campanula* and *Malampyrum* have similar ecological requirements. *Saxifraga* was highly predicted to occur on Amaro Mountains. While *Bunium and Stipa dasivaginata* were highly predicted to occur in the open grassland habitats.

4. Discussions

4.1. Hotspots of endemic taxa generated from Kernel density

The results of the kernel density revealed that the hottest spots of endemics plant taxa with in the park were found on mountain peaks of the Majella. These were mountain Amaro and mountain Cavallo respectively. Other minor hotspots also included highlands in the Majella National park and slopes of the Orfento canyon all which are high elevation areas. This confirms what has been done in previous studies that the number of endemic plant species is high at high altitude in Eurasia mountains (Casazza et al., 2005; Dhar, 2002; Tribsch and Nswetter, 2003).

Majella qualifies as an intra-Mediterranean endemic plant hotspot due to the fact that it has one hundred forty two endemic plant taxa which is relatively reasonable number compared to other hotspots of endemic plant taxa of the Mediterranean basin as is the case with in the Maritime and Ligurian Alps where there are, one hundred and fifteen endemic taxa sensu lato (Casazza et al., 2005).

Basing on the distribution bar chart for the life forms, chamaephytes which are the dwarf shrubs and hemicrypotophytes which are the perennial herbs were the most represented life forms of endemic plant taxa of the Majella. This is because plants of this nature are better adapted to the harsh environmental conditions typical of alpine habitats than the rest. Geophytes, therophytes and hydrophytes are less tolerant that is why they are less common. Such habitats include rocky slopes, screes and alpine grasslands which are typical of Alpine landscape above the tree line (Ellenberg, 1988).

The adaptations to survive in such habitats may require special structural and physiological features. These may include having a specialised root structure that can penetrate cracks in the rocks as is the case with *Saxifraga.* Another adaptation is having reduced leaves to adapt well to the high evapotranspiration during summer when the temperatures are high and ability to survive in soil which are poor in nutrients, among many others. This implies that because of such conditions trees are less likely to grow and therefore most of these endemics within this region are non trees as compared to endemic plants else where in the world.

4.2. Relative roles of environmental variables on endemic plant taxa occurrence and model validation

Model performance was assessed with the receiver operating characteristics (ROC) and area under ROC curve (AUC). It was also assessed using the jackknife of regularized training gain. This was conducted for all the five taxa. Saxifraga italica, the best predicting environmental variable was elevation because when used in isolation for the predictions. It had the highest gain and when removed and the model was run with the rest of the environmental variables elevation had the greatest reduction in gain. This means that it contains useful information for predicting it occurrence which is not in other variables (Figure 3-5a). Analysis of AUC plot indicated very good predictions; the AUC for training data was 0.93 while that of test data was 0.92.
Melampyrum italicum, the best predicting environmental variable was slope because when used in isolation for the predictions it had the highest gain and when removed and the model was run with the rest of the environmental variables slope had the greatest reduction in gain. This means that it contains useful information for predicting it occurrence which is not in other variables (Figure 3-8a). Melampyrum had AUC for training data as 0.94 and that of test data 0.95 it occurs with high probabilities at high slope 0.95.

Campanula fragils is the best predicting environmental variable was slope because when used in isolation for the predictions it had the highest gain and when removed and the model was run with the rest of the environmental variables elevation had the greatest reduction in gain. This means that it contains useful information for predicting it occurrence which is not in other variables (Figure 3-11a). Campanula had AUC 0.84 for training and 0.91 for test data sets, it occurs with high probabilities at high slope like the *Melampyrum*.

For *Bunium* the best predicting environmental variable was vegetation cover type because when used in isolation for the predictions it had the highest gain and when removed and the model was run with the rest of the environmental variables elevation had the greatest reduction in gain, This means that it contains useful information for predicting it occurrence which is not in other variables (Figure 3-14a). It had AUC 0.93 for training and 0.90 for test data.

Stipa dasyvaginata the best predicting environmental variable was vegetation cover type because when used in isolation for the predictions it had the highest gain and when removed and the model was run with the rest of the environmental variables elevation had the greatest reduction in gain. This means that it contains useful information for predicting it occurrence which is not in other variables (Figure 3-15a) and Stipa *dasyvaginata* had AUC 0.87 for training and 0.93 for test data.

Basing on this research, when each of the endemic plant taxa was modelled, they all resulted in different rankings for predictions of each of the environmental variables (Table 11). This is due to the fact that the occurrence of each taxa has different ecological requirements. This supports the null hypothesis which states that "the occurrence of endemic plant taxa is significantly determined by various combinations of elevation, slope, aspect solar radiation and vegetation cover type".

Results of Table 3-4 indicate that in general, vegetation cover type has a significant role in determining the distribution of the endemics compared to other environmental variables. This was because it was indicated as the first or second contributing environmental variable in all predictions. Vegetation cover type alone has a range of other factors including physical factors like, slope, aspect and elevation, human factors like farming and infrastructure or even biotic factors like competition, dispersal, etc, that determine which endemic taxa to occur in a give habitat.

The vegetation cover types which played a role in this prediction included 13 representing open grassland and dwarf shrub, 15 representing mountain pine, and 20 representing bare ground and sparse vegetation. Basing on analysis of results it is indicated that most endemic taxa are predicted to occur in open habitats where it may not have to compete for resources like light energy because it will not be prevented from receiving sunlight. The results also indicate that the taxon is a stress tolerant because it prefers open habitats where it can adapt well to the strong rays of the sun and the high evapotranspiration in dry season. This is also confirmed from that fact that the taxa inhabits sites with pine trees which have needle leaves that would not prevent light from reaching all layers.

The over all results after computing the percentages (Table 3-3) confirm that a combination of environmental variables is required to predict the occurrence of any of the endemic plant taxa because there is no evidence in any of the results when predictions had been contributed by one hundred percent a single variable. Two or more environmental variables may be needed to give good results for the predictions. Basing on computations of the percentages, elevation and land cover types were basically the best two environmental variables which were contributing a significant role in the predictions.

5. Conclusions and Recommendations

5.1. Conclusions

Endemic plant taxa occurrence in the Majella National Park followed the same pattern as described in the Eurasia Mountains, whereby the number of endemic plant species becomes higher when altitude increased. Highlands are confirmed to have a big number of endemics plant taxa because of high ecological specialization and the lack of competitiveness as pointed out also by (Lavergne et al., 2003). Habitats of endemism in this research are correlated with a range of environmental variables, aspect, slope and altitude, solar radiation and vegetation cover type. The environmental variable with the highest predicting power was in general vegetation cover type. Two environmental variables can be enough in predicting the occurrences of any endemic plant taxa. In conclusion, with the various hotspots of endemics identified in this study, it seems feasible to adapt an ecosystem approach for conservation in the Majella National Park.

Research question 1; Can endemic plant hotspots be identified in the Majjela National Park?

Endemic plant hotspots of the Majella National Park are found with in high altitude areas. These highlands include mount Amaro and Cavallo, slopes of Orfento canyon in the North mountain Morrone in the North west and slopes of the Majella massif located on the Eastern part of the park.

Research question 2; Is Majjela an intra-Mediterranean endemic taxa hotspot?
Majella is an intra –Mediterranean endemic plant hotspot basing on the results from analysis for this research. It was found to have one hundred forty two endemic plant taxa which is in the same range as that of other endemic hotspots in the Mediterranean Basin as is the case with the Maritime and Ligurian Alps where there are, one hundred and fifteen endemic taxa sensu lato.

Research question 3: *Can the occurrence of endemic plant taxa be explained using environmental variables?*
Occurrence of endemic plant taxa can be explained using environmental variables but the criteria for selecting them will depend on the type of taxa since different taxa are adapted to survive in a range of environmental conditions. Basing on findings in this research Saxifraga italica was predicted to occur with high probability in areas with high altitude, north facing slopes and vegetation cover type of mainly open grasslands. The environmental variables that resulted with good predictions were specific to particular endemic plant taxa.

5.2. Recommendations

More detailed analyses using modelling of all taxa are still necessary to establish a comparative study of endemism in the various endemic plant hotspots of Majella and the Mediterranean Basin as a whole. The Natura 2000 network in the Majjela National Park should incorporate the hotspots of endemism taxa as a priority.

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7. Appendices

7.1. Appendix A

ACCURACY	NUMBER	END_TAXON	FAMILY	LIFE_FORM
4	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf

3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
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3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
2	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
2	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
3	591	Arenaria bertolonii Fiori	Caryophyllaceae	Ch suf
4	621	Minuartia glomerata (M. Bieb.) Degen subsp. trichocalycina (Ten. & Guss.) F. Conti	Caryophyllaceae	Ch suf
1	621	Minuartia glomerata (M. Bieb.) Degen subsp. trichocalycina (Ten. & Guss.) F. Conti	Caryophyllaceae	Ch suf
2	621	Minuartia glomerata (M. Bieb.) Degen subsp. trichocalycina (Ten. & Guss.) F. Conti	Caryophyllaceae	Ch suf
3	621	Minuartia glomerata (M. Bieb.) Degen subsp. trichocalycina (Ten. & Guss.) F. Conti	Caryophyllaceae	Ch suf
4	621	Minuartia glomerata (M. Bieb.) Degen subsp. trichocalycina (Ten. & Guss.) F. Conti	Caryophyllaceae	Ch suf
2	621	Minuartia glomerata (M. Bieb.) Degen subsp. trichocalycina (Ten. & Guss.) F. Conti	Caryophyllaceae	Ch suf
4	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
2	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
1	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
2	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
1	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
2	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
2	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	628	Minuartia graminifolia (Ard.) Jáv. subsp. rosani (Ten.) Mattf.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
4	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
4	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
1	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf

1	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
2	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
2	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
2	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
2	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
2	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
2	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	674	Cerastium tomentosum L.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
2	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
2	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
2	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
3	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
2	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
2	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
2	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
2	682	Cerastium thomasii Ten.	Caryophyllaceae	Ch suf
4	768	Herniaria bornmuelleri Chaudhri	Caryophyllaceae	Ch ?
3	816	Silene roemeri Friv. subsp. staminea (Bertol.) Nyman	Caryophyllaceae	H ros
3	816	Silene roemeri Friv. subsp. staminea (Bertol.) Nyman	Caryophyllaceae	H ros
3	816	Silene roemeri Friv. subsp. staminea (Bertol.) Nyman	Caryophyllaceae	H ros
3	816	Silene roemeri Friv. subsp. staminea (Bertol.) Nyman	Caryophyllaceae	H ros
3	836	Silene notarisii Ces.	Caryophyllaceae	H caes
4	836	Silene notarisii Ces.	Caryophyllaceae	H caes
3	836	Silene notarisii Ces.	Caryophyllaceae	H caes
3	836	Silene notarisii Ces.	Caryophyllaceae	H caes