MODELING POTENTIAL ECOLOGICAL NICHE FOR SELECTED ENDEMIC SPECIES IN DARJEELING HILLS

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CERTIFICATE

This is to certify that Ms. Shruti Sinha has carried out the dissertation entitled “Modeling Potential of Ecological niche for selected Endemic species in Darjeeling Hills” in partial fulfilment of the award of degree of Master of Technology (M. Tech.) in Remote Sensing and GIS. The project has been carried out in Forestry and Ecology Department and is an original piece of work of the candidate under the guidance of Dr. Arijit Roy, Scientist/ Engineer – SE, Forestry and Ecology Department at the Indian Institute of Remote Sensing , Dehradun, India.

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Executive Summary

The study was undertaken to identify the potential niche and distribution and change in case of Climate and Land use and land cover change of *Aconitum napellus*, Agapetes *serpens* and *Rhododendron edgeworthii* three endemic and economically important species of Darjeeling Himalayas. The study identifies the core area of the species distribution across the Darjeeling hills. Using species occurrence points collected for all the three species as well as environmental layers (elevation, slope, aspect, fragmentation, land use/ land cover, and bioclimatic variables) the species niche was estimated using gene based and entropy based modeling approaches. For all the three species, land use/land cover was observed to be the most influential environmental layer in model development. The models were evaluated using the threshold-independent area under the curve (AUC) receiver operating characteristics analysis and the thresholds dependent minimum training presence. Contribution of two ecological niche modeling tool, the Genetic Algorithm for Rule - set Prediction (GARP) and Maximum Entropy (MaxEnt), in assessing potential ranges of the species. The level of agreement between GARP and MaxEnt prediction was low when < 50 occurrences were available. Unexpectedly, the results suggested that MaxEnt extrapolated more than GARP. A niche prediction was overlapped with current land use and location of protected areas to estimate the conservation status of each species.

Utilizing the result of GARP and MaxEnt model the new logistic approach was developed to run the best – fit against climate projections made by HADCM3 for 2050 under A2a and B2a scenarios to stimulate the likely distribution of *Aconitum napellus* , *Agapetes serpens* and *Rhododendron edgeworthii* . The model indicates an area with a higher probability of the presence of these species. The distribution of *Aconitum napellus* and *Agapetes serpens* showed decrease in their potential niche in case of IPCC climate change scenario while the *Rhododendron edgeworthii* showed an increased. This information could be used to help direct future conservation efforts and understand the ecology of these species.

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Chapter-1

INTRODUCTION

1 Background

The accelerated loss of flora and fauna has been one of the most critical issues due to the Global change across the world (IUCN, 2007). One of the most challenging works today is to prove and quantify the hypothesis of species loss and extinction using the modern tools and techniques so as to plan proper mitigation for conservation of the endemic flora and fauna. (Malcolm, and Markham, 200*0*, Mackey, 2007).For example *Aconitum napellus* which has been adopted in World Wildlife Fund (WWF) symbol could disappear in a matter of few decades' despites all current protection efforts. Accurate information regarding the projected changes in the distribution of the species can play an important role in making amendments in the conservation approach to ensure its survival in future.

Climate change is an important in environmental influence on ecosystems. Climate change not only affects ecosystems and species diversity, it also interacts with other human stressors such as development (NRC, 2010). Change in the timing of seasonal life-cycle events such as flowering and pollination. Pollution is also one of the important stresses with climate change that can contribute to species extinction and habitat destruction a lot (Fischlin et. al., 2007, Von Holle et. al., 2010). The IPCC estimates that 20-30% of the plant and animal species evaluated so far in climate change studies are at risk of extinction if temperature reach levels projected to occur by the end of this century (Fischlin et. al., 2007). Due to climate change, loss of biodiversity is occurring and one of the main and easily identifiable components of biodiversity is endemism (McCarthy et al., 2001).

1.1 Endemism

The degree of endemism increases with the increase in size of a homogenous biogeographical area having the same floristic history and ecological condition. A living organism is identified as endemic if it is both native and restricted to a particular geographic area. Some flora and fauna are actually limited in their distribution to the areas in which they were evolved and therefore are said to be endemic to that region (Townsend and Watson, 1998). Confinement may be due to physical barriers to dispersion, as in the case of many island faunas and flora on the other hand, they may have simply a moment ago evolved and have not yet had time to spread from their region of origin. Because all species of living organism evolve in one particular and constrained area, the barriers that surround its area of origin will restrict its distribution. Therefore, all such areas will contain endemic organisms those that are found there and nowhere else.

In general, there are two major factors influencing the degree of endemism in an area is isolation and stability (Gaston and Lawton, 1990). Thus isolated islands and mountains are often rich in endemics (MacArthur and Wilson, 1967). Island environments exhibit a superior degree of vulnerability than do continents, because of the limited diversity of ecological niches and the miniscule number of people living in a reduced space. Similarly, species restricted to unduly narrow or fragile environments such as springs, dunes, tops of mountains, and valleys run the risk of disappearing with the first change of their ecological niche (MEA, 2005).

1.2 Ecological Niche

The term ecological niche is the position of species within an ecosystem, describing both the range of circumstances indispensable for the perseverance of the species, and its natural role in the ecosystem (Hutchinson, 1957). Ecological niche counts all of the interactions between a species and its biotic and abiotic atmosphere, and thus represents a fundamental ecological concept (Pidwirny, 2006). The uncertain definition presented above is a sign that conception of niche has two sides which are not so firmly related, one concern the special effects environment has on a species, the other shows the special effects the species have on the environment. In most of ecological assessment, however, both meanings are unconditionally or unequivocally mixed. The explanation is that ecology is about interactions between organisms, and if perseverance of a species is dependent upon the occurrences of other species naturally both are influenced by environment, and at the same time investigate the environment for other species. In most of the region's climate change assessments have focused on models of vegetation types and individual species and their properties over a decade (Mackey, 2007). This study has provided the raw material for improved conservation plans in the case of climate change. Yet conservation planning tools need to be updated climate change scenario, since most of them were created under the premise of a stable climate (Trivedi et. al., 2008). Ecological niche models have been developed as a tool, which can be help to predict the future of individual species.

1.2.1 Why niche modelling

The precise prediction of the future impacts of climate change on plant diversity is significant is designing the conservation and prioritization strategy. These predictions have come largely from Bioinformatics strategy involving modeling a particular species, group of species such as well-designed, communities, ecosystems or biomes. They can also involve modeling species observed ecological niches, or experimental physiological processes (Phillips and Dudik, 2008). Even though useful, modeling has various restrictions. Initially, there is a question about the future levels of greenhouse gas emissions driving climate change and considerable uncertainty in modeling how this will affect other aspects of climate such as local rainfall or temperature. The majority of species importance of specific climatic variables in determining the distribution (e.g. Minimum rainfall or maximum temperature) is unknown. To recognize the particular climate and biologically relevant temperature or rainfall are very difficult task for each species. Interactions between species and their spreading rates and lengths are also naturally difficult and complicate prediction (Thuiller, 2004). Advancement of models in a dynamic area of research, with new models involving factor such as biography, individuality of species or process such as relocation into consideration when predicting allocation changes (Morin and Lechowicz, 2008). Nonetheless, potential trade-offs between local precision and generalization is predictable. Climate change is also predicted to interact with other variables of biodiversity change such as habitat loss, porosity and fragmentation, or the preface of unknown species. (Berry et. al., 2002).

1.2.2 How ecological niche modeling has been developed over the last decade in climate change science

The term ecological niche was counted by Grinnell (1910). Grinnell thought of the niche as a subdivision of the habitat containing the environmental conditions that enable individuals of a species to survive and reproduce. The distribution and abundance of species can be found through these conditions. Elton (1920) defined the functional purpose of a species in a community. The focus was less on where a species could occur and more on its interactions with other species in a community. Simplistic theory of niche, invented in 1910s and 1920s was challenged in the late 1970s by Lack (1949), Hutchinson (1958) and MacArthur (1972). They have elaborated the Elton's and Grinnell views in terms of inter specific competition between the species. The enduring insight from Hutchinson's work is in the distinction between the fundamental and realized niche. Hutchinson regarded the fundamental niche as the set of physical and biological factors that a species could use that would enable it to exist indefinitely. Therefore, the fundamental niche is firm by the intrinsic properties of a species how it reacts to the environment rather than by extrinsic properties of the environment independent of the species. The realized niche is the role of the fundamental niche to which a species are constrained by interactions with other species with which its fundamental niche overlaps (Soberón and Peterson 2005). The ecological niche model helps to correlate ecological niche of endemic species in a very precise manner (Fig.1).

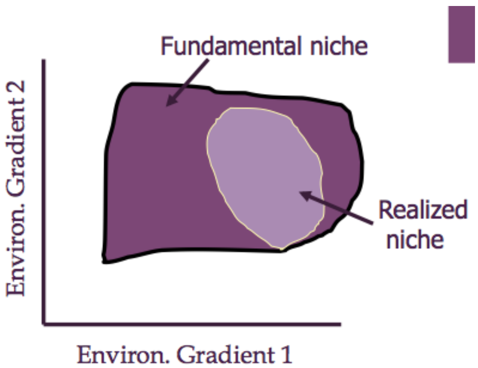

Fig.1. The relation between environmental gradients under ecological niche (http://www.google.co.in/imgres fundamental+and+realized+niche).

1.3 Endemism and ecological niche

There is a long history in quantifying the relationship between species distribution and their interactions with biotic and abiotic environmental variables in ecological research. In addition, it is now an integral tool in providing biography in order about species assemblage, predominate in this case where the data is deficient (Anderson et. al., 2009). The Species Distribution Model (SDM) approach is based on the principles of ecological niche theory, it include the fundamental niche, which is mainly a role of physiological tolerance and ecosystem limitations and realized niche, which comprise to the effect of biotic exchanges and competitive exclusion. An ecological niche is defined as the set of conditions and resources in which individuals of species continue to exist, nurture, and produce, and the climatic variables and ecological interactions that control the species distribution. Accordingly, the SDM approach was developed as a probability distribution in geographic spatial, predict entire spatial coverage of a particular species distribution, whose event data is also not available (Thuiller, et al., 2004). Ecological niche is very sensitive to change according to the climatic variable this is the important factor in predicting the potential of future species.

1.4 Impact of climate change on ecological niche

Climatic factors such as temperature and precipitation change in a region beyond the allowance of a species' ability of an organism to alter its phenotype in response to changes in the environment and the distribution changes of the species may be expected (Price, et al., 2003). There is already substantial evidence that plant species are shifting their ranges in altitude and latitude as a response to changing regional climates (http://climap.net/biodiversity). When compared to the reported past migration rates of plant species, has increased in the present due to current change has the potential to not only alter species distributions, but also render many species as unable to follow the climate to which they are adopted (Davis and Shaw, 2001). Like as alpine region species disappear altogether due to sudden change in the environmental conditions. (Davis and Shaw, 2001) The result of these changes is likely to be a rapid increase in extinction danger. Adaptation to new climatic conditions may also be of great importance in the physiology of plants. Along with climatic variables, land use and land cover change also play an important role in species loss. Infact (Sala, et al., 2000) has shown that among all the drivers responsible for biodiversity loss, land use and land cover changes have the maximum impact followed by climate change, global warming, N-loading and CO_2 enrichment.

Predicting the extinction risk of plant species is not so easy. However, estimations from particular periods of rapid climatic change in the past have shown relatively few species extinct in some regions, e.g. however, knowledge of species adaptation and persistence in rapid climate change is still relatively confined. All species are likely to be not only directly impacted by the changes in environmental conditions but also in some manner through their interactions with other species. While straight impacts may be easier to predict and conceptualize, it is likely that indirect impacts are being equally important in regulating the reaction of plants to climate change.

An urgent need is for conservation planning tools that allow identification of landscape connectivity to support species movements in response to climate change (Lee Hannah et al., 2012). This segment traces the development of one such tool, and its application to Darjeeling hills. The results of this study demonstrate the usefulness and functionality of this new tool. The spatial results of the analysis are preliminary and have been grown primarily as proof of concept for new tool. Many refinements will be required before final spatial recommendations can be generated. Nonetheless, these early results provide some indication of possible spatial priorities under climate change, and so may prove important in helping to generate conservation hypothesis that can be further tested (Lee Hannah et al., 2012).

Traditional approaches to conservation are often less effective under climate change, due to potential shifts in species ranges. Darjeeling hills are particularly vulnerable because of their large numbers of endemic and threatened species (Midgley et al., 2002). Conservation planning under climate change faces the critical problem that suitable climate space for species shifts through time, while species' abilities to disperse may not be compatible with the velocity of shifting climates of the landscape (loaire 2009). Additionally, traditional conservation instruments ranging from strict reserves to conservation assessments are static and are probably not positioned with the changing climate in mind (Hannah, 2005).

1.5 Concept of ecological niche model

The mathematical concept of ecological niche is a complex process involving large number parameters (climatic, topographical, edaphic and associations) and adequate location data collected from the field. Modeling using various optimization technique concepts is practiced to spatially determine ecological niche and it termed as ecological Niche modelling (Hutchinson, 1957). A Model predicts the potential distribution of species, emphasizing the need for reliable methods to evaluate the accuracy of their predictions (Boyce and McDonald, 1999; Guisan and Zimmermann, 2000). As many available datasets do not provide reliable information about species absences, several presence-only based analyses have been developed. However, methods to evaluate the accuracy of their predictions are few and have never been validated. It is correct that we can predict the distribution of species by using models, but the illustrations are also sites specific so we cannot say that which model will provide the best results (McKelvie, et. al., 2010.). This proposed research will develop ecological niche modeling potential of species distribution of selected species of endemic species in the Darjeeling Hills.

1.5.1 MaxEnt Model (Maximum Entropy) – Description and Assumptions

MaxEnt Model was developed by E.T. Jaynes in1957. According to them the best approach is to ensure that the approximation satisfies the constraints on the distribution and it should have maximum entropy. Its work on principle is to estimate the probability distribution, such as the spatial distribution of a species, that is most spread out subject to constraints such as the known observations of the species. MaxEnt uses entropy as the means to generalize specific observations of the presence of a species, and does not require or even incorporate absence points within the theoretical framework. Presence points are observations of the presence of a species and absence of a species is not normally recorded. The advantages of MaxEnt model are as follows, requires presence data only, Can use both, continuous and categorical data, Efficient deterministic algorithms; Output is continuous, Generative approach and works well in limited data.

1.5.2 GARP Model (Genetic algorithm for rules set prediction) – Description and Assumptions

Genetic Algorithm for Rule Set Production (GARP) is a computer program based on genetic algorithm that creates ecological niche models for species. The generated models describe environmental conditions (precipitation, temperatures, elevation, etc.) Under which the species should be able to sustain populations. As input, local observations of species and related environmental parameters are used which describe potential limits of the species' capabilities to survive? Such environmental parameters are commonly stored in geographical information systems (Stockwell, et. al., 1999). A GARP model is a random set of mathematical principles, which can be read as limiting environmental conditions. Each rule is conceived as a gene; the set of genes is combined in random ways to further generate many possible models describing the potential of the species to come about.

1.6 Unsuitability of MaxEnt and GARP for predicting future ecological niche

A genetic algorithm for rule-set prediction (GARP): the desktop version (B/http://beta.lifemapper.org/desktopgarp_/) of this artificial intelligence-based approach uses four distinct modeling methods: atomic, logistic regression, bioclimatic envelope, and negated bioclimatic envelope rules to derive several different rules (Stockwell and Peters, 1999). GARP uses these rules to iteratively search for non-random correlations between the presence and background absence observations and the environmental predictors. GARP makes the occurrence data by resembling the occurrence points in environmental space into equal presence and equal non-presence pixels randomly selected from the background. A GARP run begins by using 50% of these occurrence observations to develop the model and then examines the resulting model with the remaining observations. It then resembles the observation points again, splitting the data set into new training and test data sets and attempts to improve on the first model produced.

This procedure has to be repeated iteratively generating a set of principles that are altered in a generic fashion until the best possible model is achieved or a set number of iterations are performed. The output of a GARP run is a binary map of predicted presence and absence.

Maximum entropy (MaxEnt): MaxEnt utilizes a statistical mechanics approach called maximum entropy to make predictions from incomplete data. MaxEnt estimates the most uniform distribution of species (maximum entropy) across the study area given the constraint that the expected value of each environmental predictor variable under this estimated distribution matches its empirical average (average values for the set occurrence data) (Phillips , 2004, Phillips , et. al., 2006). Continuous environmental data can also be used to define quadratic features and product features (for this study only quadratic terms were counted), thereby adding further constraints to the estimated probability distribution by restricting the variance of each environmental predictor and covariance of each pair of environmental predictors to match the variance and covariance on the occurrence dataset. Similar to logistic regression, MaxEnt weights each feature (environmental variable or its square, in this study) by a constant. The estimated probability distribution is exponential in the totality of the weighed features, divided by a scaling constant to ensure that the probability values range from 0-1 and the sum is equal to 1. The program begins with a uniform probability distribution and iteratively alters one weight at a time to maximize the likelihood of the occurrence dataset. The algorithm has guaranteed to converge to the optimum probability distribution and because the algorithm does not use randomness, the outputs are deterministic. Given that the traditional implementation of maximum entropy is prone to over fitting, MaxEnt employs a relaxation. It constrains the estimated distribution so that the average value for a given predictor is close to the empirical average (within empirical error bounds) rather than equal to it. This smoothing process is called regularization and the user has the option to change the parameters of this procedure to potentially pay for small sample sizes. In this study, we maintained a constant regularization parameter throughout. MaxEnt’s predictions for each analysis cell are cumulative values, represented as a percentage, the probability value for the current analysis cell and all other cells with equal or lower probability values. The cell with a value of 100 is the most suitable, while cells close to 0 are the least suitable within the study area (Phillips, 2004).

All ecological niche models are primarily based on presence data or pseudo-absence data. In this study, also the models, which have been used, where presence data only like as MaxEnt and GARP. These models can only used for present climate scenario because the location points, which have collected, based on vegetation type would not be remain same for later fifty years vegetation type. So, for future prediction these models can’t use future climate data.

1.7 Target Species

Over time the region has evolved various traditional knowledge pertaining, to its rich Bio-resources and their practices. These patterns have a strong basis in the socialreligious system native to the region and have been evolved over 100s of years. Nevertheless, we are still to document the traditional knowledge bases of Darjeeling and Sikkim. For instance, there are thousands of plants that the hill tribes in the region have been traditionally using for the medicinal purposes and such knowledge is the product of a long period of development in the field. These hill people also have their own agricultural practices, crop varieties, and water harvesting practices. They have also evolved rich knowledge with respect to their fauna; for instance, a mammal locally called Dumsi is believed to have great medicinal value, there are many such creatures with immense medicinal value that are confined to the knowledge of handful of the locals. All these traditional knowledge bases have evolved by through the experiences of numerous generations' years; hence they are their original assets. Considering these things in order to select target species the method of the utilization of a checklist was taken. Following are the criteria in the list.

- Their known distribution must be within the study area.
- The size of the niche should be medium (170 – 300 km^2) or large (>300 km^2) in the target species.
- Target species should be endemic.
- The secondary source concerning distribution of species is available.

The first criterion is a requirement. The second criterion is based on the opinion of Dawson (1994), who states the choice of species protected in the respective networks depends on the size of the niche and core area. The third criterion is established based on consideration of time and human and financial resources available for this study.

Based on the criteria established above, *Agapetes serpens, Aconitum napellus* and *Rhododendron edgeworthii* were identified as the target species among the Endemic species in Darjeeling hills (Appendix 1-3).

1.7.1 Why three species have identified for the study

Species distribution models are very limited used in predicting the future distribution of endemic species. In this study, data analyzed on the basis of species distribution, climate, ground cover and topography. Judge by the large differences in climate niches even for closely related species, species seem to adapt fast to changing climatic conditions. This in turn makes predictions based on current distributions are unreliable. In this study, distribution models are produced for endemic species and calculated the climate niche overlap. For example, species such as *Agapetes serpens*, *Vaccinium vaccineaum*, *Aconitum napellus* and *Rhododendron edgeworthii* are closely related, but seem to occupy different Climate niches.

1.7.2 Importance w.r.t. Conservation and prioritization

Endemic species of a country once lost or became extinct; it is a loss forever for the country as biodiversity is a sovereign right of each country as per conservation on biodiversity. It is necessary to understand and appreciate the future gains to the country through conserving and maintaining our endemic species. It is necessary to identify at national, regional and local level conservation area of priority like species diversity (Nayar, 1996). In order to develop priority conservation of quick identification of species diversity, threatened species and ecological niche. For example, species such as *Agapetes Serpens*, *Vaccinium vaccineaum*, *Aconitum napellus* and *Rhododendron edge* are important endemic species which contribute main part in creating biodiversity of West-Bengal state in Darjeeling. In this case, study the research objectives, questions and hypothesis are based on future prediction of endemic species of Darjeeling hills.

1.8 Research objectives

- To model potential Ecological Niche for selected Endemic species in the Darjeeling Hills.
- To identify the species vulnerable to local extinction in the event of projected climate change A1 & A2 (IPCC) Scenario.

1.9 Research questions

- What are the impacts of environmental factors on the ecological niche for selected species?
- How projected climate change scenarios will influence the ecological niches of the selected species?

Chapter -2

LITERATURE REVIEW

A better understanding of bioclimatic regimes is necessary for establishing a niche of particular species flora and fauna for prioritization and conservation of biodiversity. Since biodiversity is the biological capital of earth, conservation of endemic flora and fauna of a region is of prime importance. A lot of work has been done to predict the potential of habitat modeling of endemic species to understand the contribution of climatic variable of a particular endemic species. These studies have set center stage for research on future prediction of ecological niche and other issues like presence and pseudo absence scientific data.

2.1 Forest cover/LULC Change

A number of studies have been undertaken in India with regard to forest type and forest cover using satellite remote sensing and visual and digital image interpretation techniques (Kushwaha, 1990; Jadhav 1993). Kushwaha (1994) reported that forest is the most conspicuous feature on the satellite imagery and thus, their monitoring using remote sensing is relatively easier. (Singh, 2001) Landuse/Landcover classification was performed using traditional methods of image interpretation. The environmental association, intermixing of species/vegetation and topography was used to discriminate among the various forest types using satellite data. Use of remotely sensed data for mapping provides a cost-effective method.

2.2 Climate change Global Scenario

It is now well recognized that understanding of climate and topographical regimes is more important for the prediction of niche either on the global or regional level. The Earth's climate is constantly changing, but there is increasing evidence that a warming trend is underway (Mac Cracken et al., 2003; Wigley et al., 1996). It has been also observed that human activities have a disrupting influence that is accelerating this dynamic process of global warming (http://www.gutenberg.org/files/29904/29904-h/29904-h.htm#chap03). The berg, global warming is expected to cause major changes in all living systems, including forests. It has been estimated that the composition of one-third of the planet's forests could be altered markedly due to climate changes (Shriner and Street, 1998; Melillo, 1999). The increasing concentrations of carbon dioxide (CO_2) and other greenhouse gases in the Earth's atmosphere likely will lead to warming, perhaps by as much as 3° to 4°C globally over the next century and even more in the higher latitudes (Watson, 2001). There is compelling empirical evidence that climate change affects life on Earth in many ways. Prominent examples are physiological characteristics like flowering time of plants (Walther et al. 2002;

Parmesan 2006; Hoye et al. 2007), procreation and onset of migratory species (Both and Visser 2001; Walther et al. 2002). Today there are evidences if an evolutionary adaptation of species to the varying environmental (Bradshaw and Holzapfel 2006).

The report presented by the Intergovernmental Panel on Climate Change (IPCC) in 2007, projects that by the end of this century the global rise in the temperature will be 2 - 4.5°C. It has been evaluated on the basis of global temperature have increased due to emission of greenhouse gases carbon dioxide (280 ppm to 379 ppm), methane (715 ppb to 1774 ppb), and nitrous oxide (270 ppb to 319 ppb) between pre-industrial period and 2005 (IPCC, 2007). Since 1850, eleven of the last twelve years rank among the 12 warmest years in the instrumental record of global surface temperatures. The updated 100 years linear for 1906-2005 is 0.74°C. Globally, average sea level rose at a regular rate of 1.8 mm per year from 1961 to 2003 (IPCC, 2007). During the last three decades Global climate warmed by about 0.68˚ C (Hansen et al. 2006). Over the last 50 years the mass of warming observed can be with high firmness certified for human-induced greenhouse gas emissions (Raupach et al. 2007). In the current century, Global warming is expected to proceed at a rapid rate, and some scenarios indicate a global temperature rise by up to 6 - 8˚ C by 2100 (IPCC 2007; Richardson et al., 2009).

2.3 Climate change Indian Scenario

India is the second most heavily populated and seventh in terms of GDP on the planet. It is surrounded by the Himalayan Mountains in the north and enclosed by Arabian Sea, Indian Ocean and Bay of Bengal in the south. The countryside includes some of the most unique ecosystems such as Himalayan Mountains, Indo- Gangetic plains and the Deccan Plateau. India's landscape has a wide variety of diverse climatic conditions due large number of different regions and all would face significant but different impacts from climate change. India's population, most of them depend on the climatic regimes and natural resources, is vulnerable to the impacts of climate change such as changes in forest cover and species composition, water resources and sea level rise. Due to its large and increasing population, and a financial system that is closely tied to its natural resource base, a growing population, rapid industrialization and urbanization coupled with Climate Change will create additional pressure on India's overall ecology and socioeconomic system. IPCC, 2007 report, predicts that temperatures will rise by 2.7- 4.3°C over India by the 2080s.The panel also predicted an enhance in rainfall over the Indian subcontinent by 6-8 percent and that the sea level would rise by 88 cm by 2100.

An average annual surface temperature rise by the end of this century, underneath A2 IPCC scenario (3°Cto5°C) and B2 IPCC scenario (2.5°C to 4°C) with the warming predicted to be more pronounced in the northern regions of India. A 20 percent rise in all over India summer monsoon rainfall and a further rise in rainfall are projected over all excluding (Punjab, Rajasthan, and Tamil Nadu) which are expected to show a slight decrease. An extreme in temperature regimes is expected and similarly extreme rainfall has been forecast, mainly over the West Coast of India and West Central India. Observations over India show that the mean annual surface air temperature has increased by 0.4-0.6°C in the last 100 years (Hingane 1985; Kumar 2001). The warming may be more pronounced in the northern regions of India. On the basis of these detail deciding factors for the species is which regional climate data should be selected to predict the future scenario.

2.3.1 Climate change impacts in Himalayas

The Himalayas, a global biodiversity hotspot (Myers et al. 2002), have experienced a mean temperature rise in the Himalayan alpine zones from 0.6 to 1.3 ° C between 1975 and 2006 (ICIMOD 2011; Dimri and Dash 2011). Local perceptions are important is that most climate change data and projections are on regional or national scales and are often difficult to apply to the local scale (Bridges and McClatchey 2009). It is important to take into account the experiences of indigenous people who have been experiencing local changes in their climatic conditions for millennia, as they have an intimate familiarity with the natural rhythms and processes of their ecosystem (Vogt et al. 2002; Turner, 2009). In the Himalayas, there is concordance between scientifically recorded changes and local observations (Byg and Salick 2009; Chaudhary and Bawa 2011; Chaudhary et al. 2011). In Eastern Tibet, Byg and Salick (2009) recorded observations of climate change experienced by the villagers, variations in perceptions, impacts of the perceived changes and their interpretation of these perceived changes. In the Indian Himalayas, Vedwan and Rhoades (2001) examined how apple farmers in Himachal Pradesh, in Western Himalayas have experienced a shift in time of flowering as a result of climatic changes. The impacts of climate change have been recorded on blossoming, yield, fruit quality and increase of new pests and diseases.

Chaudhary and Bawa (2011) studied indigenous knowledge about climate change and its consequences for biodiversity and agriculture in the Darjeeling Hills region in the Eastern Himalayas with one of the largest sample sizes for such a study. Chaudhary et al. (2011) and Chaudhary and Bawa (2011) confirmed numerous weather and ecosystem-related indicators as well as biodiversity and agriculture and livelihood based climate change indicators and suggested that people at higher altitudes appear more sensitive to climate change than those at low altitudes. The study highlights the importance of documentation of local knowledge and its use in policy to combat the numerous cascading impacts of changing climatic conditions.

2.3.2 Climate change impacts on species

One of the most interesting impacts of climate change is shifting in the range of endemic species and their distributions. Climate change can also influence the species richness as well as the composition of various vegetation assemblages (Parmesan and Yohe 2003; Root et al. 2003; Tyler et al. 2008). It is hypothesized that species may either keep their current range or respond to changing environmental conditions with range expansions, contractions or shifts. Retreat of species from unsuitable sites with harsher environmental conditions in fragmented landscape may lead to local and even global extinction events (Thomas et al. 2004; Thuiller et al. 2005). The period of changing climatic conditions on the size and location of species ranges can be calculated by applying niche models that take into account information on ecological niche derived from known occurrence data (Guisan & Zimmermann 2000; Scott et al. 2002; Phillips et al. 2006). Ecological models provide a distribution of species niche and geographical distribution on the basis of present location that can be used for future climate scenarios (Sykes et al. 1996; Midgley et al. 2002; Pearson and Dawson 2003; Skov and Svenning 2004; McClean et al.2005; Thuiller et al. 2005; Arau´ jo and Rahbek 2006; McKenney et al. 2007).

2.4 Distribution of endemic species Global and National level

Richardson (1978) and Nayar (1980) has described that the distribution of endemics usually follows biogeographic provinces, patterns of unique ecological features, topographical and climatic interfaces. Recently (Yang et al., 2013) have modeled the potential distribution of *Adhatoda vasica* using MaxEnt. The degree of endemism increases with the increase in size of a homogenous biogeographical area having the same floristic history and ecological conditions. For example the Himalayan mountains which straddle through Afganistan, Pakistan, India, Nepal, Tibet, Bhutan, N. Myanmar and S.W china have about 70 % endemics. It is also seen that many endemics occur in areas of topographical contrast and borders of floristic provinces example, S.W. Australia, Cape provinces of S. Africa, and California in United States. Some of the islands are rich in endemic plants such as Hawai islands 97% Madagascar 80%. India possesses a rich flora of flowering plants (33.5%).

Being bounded in the north by the Himalayas and in the south of the peninsular region surrounded by the oceans, the isolation in Indian flora to a large extent has helped in the development of endemism. Endemic plants in India largely occur in the three major geomorphological divisions i.e. Himalayan endemics, Peninsular Indian endemics and Andaman & Nicobar endemics. Kanai (1966) explains the phytogeography of eastern Himalayan endemic zones consist 1808 endemic species. In that all endemic species include epiphytes, Tree, shrubs and herbs. Eastern Himalaya also includes Darjeeling hills which comprises of large varieties of endemic species. In this study three endemic species has been selected based on their medicinal importance, rarity and conservation value i.e. *Agapetes*

Serpens, *Vaccinium vaccineaum*, *Aconitum napellus* and *Rhododendron edgeworthii*. These important endemic species contribute towards biodiversity of Darjeeling district in West-Bengal.

2.4.1 Distribution and importance of *Agapetes Serpens* in Darjeeling

Khursani, or Himalayan Lantern Huckleberry *Agapetes Serpens* (Wight) Sleumer is an epiphyte and grows on the branches of trees without soil, sometimes even at ground level. It requires well drained acid soil and regular moisture and grown upto 6–12″. New stems and leaves are reddish in color (Shenga, 1994; Panda and Reveal, 2012). The plant grows in bright sunlight where it has a bright red color flower as well as in the shade where it exhibits lush, green leaves. The branches are very long (3-5') and arch and would make a great plant for a bulky hanging basket and blooms from the month of February to June. *Agapetes* are related botanically to the *vacciniums* and both are members of the wider Ericaceae family which take in the heaths and heathers as well (Nayar, 1996).

2.4.2 Distribution and importance of *Aconitum napellus* in Darjeeling

The sub genus of *Aconitum napellus* L. subsp. *Vulgar* (DC.) Ruy & Fouc. revised by Kodota (1987) belongs to Family Ranunculaceae. The common name of *Aconitum* is aconite or monkshood. The genus Aconitum belonging to the family Ranunculaceae is widely distributed in the alpine and sub-alpine regions of the tropical parts of the Northern hemisphere Alpine Himalaya. There are over 250 species that have been reported in this genus (Lane, 2004). These are herbaceous perennial plants growing in moisture retentive but well drained soils of mountain meadow. The main purpose of cultivation was for its tubers. Aconite produced from the roots of a number of different species of Aconitum is used in curing a wide range of diseases. Different species of Aconitum with their medicinal properties and distribution pattern in Himalayas (Shah, 2005) .The genus Aconitum finds the key position in the field of research. Many species of this genus have been listed in Red Data Book, due to which many conservation programs came into existence, this includes in situ, ex situ/in vitro model of conservation. Phytochemical analysis as well as Molecular facet of medicinal plant species of this genus have been and are being explored in many research institutes globally. Extremely poisonous; but then also very useful in many hereditary diseases etc., also used as a sedative and diaphoretic; applied in the form of paste in cases of neuralgia and rheumatism.

2.4.3 Distribution and importance of *Rhododendron edgeworthii* in Darjeeling

Hora (1981) first observed the distribution of *Rhododenron* according to the forest types. Species heights range from 2.5 cm alpine plants to 30 m tall trees and are either evergreen, semi deciduous or deciduous. Noshiro and Ohba (1993) explained the altitudinal distribution and tree form of *Rhododendron* in the Jaljale Himal, east Nepal. The genus is divided into eight subgenera (Chamberlain, 1996). *Rhododendron* has the greatest number of species of all genera in the family Ericaceae, with more than 850 species. It is distributed throughout northeast Asia and Eurasia, Western Europe and North America (Chamberlain, 1996). *Rhododendron edgeworthii* (Hook. f. Ericaceae family distributed in the Darjeeling Hills. *Rhododendron* is a relatively primitive group of flowering plants that have flourished in the temperate zones of the northern hemisphere for almost100 million years (de Milleville, 2002). Towards the equator, this genus is mainly distributed at higher altitudes, and today some species have significant ecological and economic importance (Mao, 2001).

2.5 Niche and Its concepts

Perhaps the simplest, most general definition of the ecological niche is an organism's "ecological position in the world" (Vandermeer 1972). Even though this may seem straightforward, determining what constitutes an organism's position in the greater scheme of things is not a trivial pursuit. In fact, the concept of niche is a notoriously difficult one for beginning (and even advanced) students of ecology. The first ecologist to use the word, Joseph Grinnell, in a series of papers published between 1917 and 1924, is generally credited with being the first to develop the ecological concept of the niche. Grinnell defined niche as the "ultimate [distributional] unit... occupied by just one species or subspecies." To be more specific, Grinnell was interested in determining which factors governed a species' potential geographical distribution and usually considered these to be physical or climatic factors, as opposed to relationships with other species such as competition or predation.

At about the same time, one of the most important ecologists of the early part of this century, Charles Elton, was developing his own concept of niche. (Elton's, 1927) niche concept differed from that of Grinnell in several fundamental ways as evidenced by his definition of niche as an organism's "place in the biotic environment, its relations to food and enemies." When Elton uses the word "place" he really means the organism's role in its community—what it does, how it makes its living—as opposed to the geographical sense used by Grinnell. In practice, Elton tended to define niches based on an animal's size and feeding habits.

A few years later, Russian scientist (Gause, 1934) combined Elton's view of the niche with the observation that very similar species cannot co-exist within a community. This is because resources such as food generally are in limited supply. Very similar organisms would have to compete with each other for the resource in question and inevitably one species would prove to be the superior competitor. Although Grinnell and even Darwin had stated much the same thing, Gause based his concept on mathematical reasoning by the Italian mathematician Vito Volterra. This idea, now often referred to as "Gause's principle or the competitive-exclusion principle" can be restated succinctly as "no two species in a community may possess the same niche," and has become a central tenet of modern niche theory.

Two niche concepts have been discussed so far. The first, propounded by Grinnell, is geographically oriented and we can term it a place niche. The second, championed by Elton and Gause, is defined on behavioral considerations and we might call this as functional niche. Ecologists were relatively happy accepting these views of the niche until the late 1950s when the eminent limnologist and ecologist G. Evelyn Hutchinson devised a rigorous and quantitative concept of niche that, with slight modifications from his original concept, incorporated both place and functional elements and has remained the standard niche model for over thirty years. Prior to Hutchinson the niche was a rather nebulous concept defined only by words; that is, niches could not be measured. Hutchinson's new idea not only allowed a way to measure niches but also a way to compare niches of two or more species.

2.5.1 Ecological niche modelling in climate change studies

The number of species per area is stoutly affected by climatic constraint, and the relation with the water energy are the strongest and most pervasive predictors of broad-scale gradients of plant species richness among different environmental variables (O'Brien 1998; Hawkins et al. 2003; Currie et al. 2004; Field et al. 2005; Kreft and Jetz 2007). Among these, water-energy-richness hypothesis have received ample empirical support (Field , 2009). It states that at high latitudes, plant species richness is more strongly controlled by ambient energy, whereas at low latitudes, the availability of liquid water becomes more important (Hawkins et al. 2003). Vascular plants most probably evolved under wet tropical conditions (Crane and Lidgard, 1989) and needed to expand their niche breadth by developing additional adaptations of survival under less favorable climate conditions (Wiens and Donoghue 2004). Hence, the potential distribution of species is mostly constrained by their physiological level of tolerance, for example, their ability to deal with frost and drought (O'Brien 1998; Hawkins et al. 2003; Currie et al. 2004). Moreover, biotic interactions influence the realized ranges of species (Arau´ jo and Pearson 2005; Sobero´n 2007).

In addition to climatic controls, topography and habitat heterogeneity also affect the species richness of an area. Especially in warmer climates, topographically diverse regions have a generally higher potential to maintain high species numbers (e.g. Kerr and Packer 1997; Kreft and Jetz 2007; Jimenez et al. 2009). While climate and other environmental variables are strong predictors of species richness, recent studies have shown significant differences in the species richness of different biogeographical regions after controlling these effects (Kreft and Jetz 2007; Qian 2009). For plants, prime examples are winter rainfall regions that have higher richness than that expected from their current climate (Cowling et al. 1996; Linder 2001). This suggests that idiosyncratic regional events as well as long-term climate fluctuations play an additional role in shaping species-richness patterns (Dynesius and Jansson 2000).

2.5.2 Future prediction using Niche model

Despite the fact that these models indicate potential rather than realized niche, the variation among current and future potential distribution provides valuable information on possible range shifts (Guisan and Thuiller 2005), the current risk status of the particular ranges and required dispersal rates to reach new suitable habitats (Jump et al. 2009). Plant distribution datasets have been assembled and analyzed at regional to continental extents (e.g. Linder 2001, Crisp et. al., 2001, Thuiller et. al., 2005, Ku¨per et. al., 2006, Jime´nez et. al., 2009), but comparative analyses of these datasets at a global scale remain intractable owing to their uneven taxonomic and geographical representation (Yesson et al. 2007). The alternative of species distribution data for future prediction information on species richness for operational geographic units can be used for mapping of geographical patterns of plant diversity (Barthlott et. al., 2005), for developing ecological relationships (Ricklefs , 2004; Kreft and Jetz 2007) and also for developing models for future changes in plant distribution (Algar et. al., 2009).

Chapter-3

STUDY AREA

3.1 Study Area

This study was carried out in the Darjeeling hill located in the West Bengal province of the India refer Fig.3.1. The name Darjeeling derived from the Tibetan word 'Dorje' which is the scepter of God INDRA, which also named as God of thunderbolt and 'ling' means the place. The study area can be divided into Darjeeling hills and Darjeeling plains. Darjeeling hills consist of Darjeeling, Kurseong and Kalimpong tehsil. Headquarter of the study area is Darjeeling pulbazar. These areas were dominated by Temperate forest which consist of Cryptomeria, Rhododendron etc.

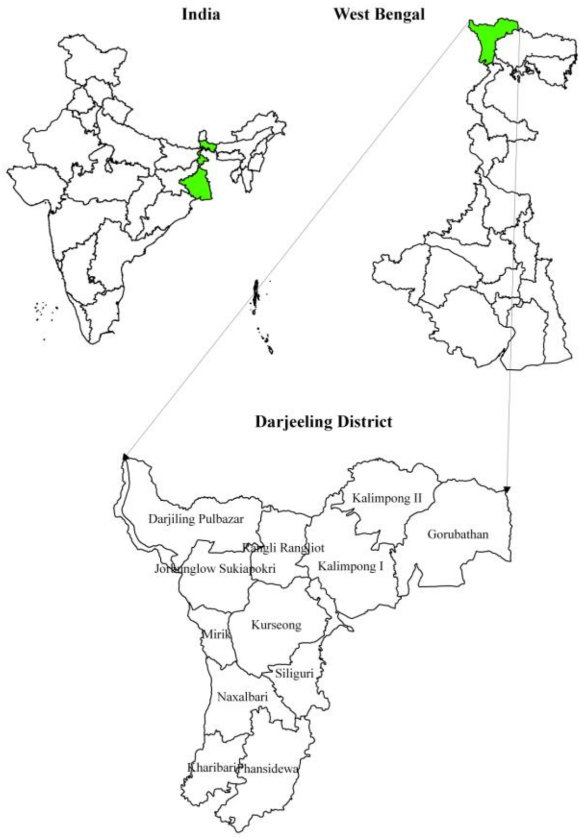

Fig. 3.1. Location of study area Darjeeling.

Reason for the selecting study area

The study area is rich in biodiversity, homogenous forest types and mainly it consists of varieties of endemic species. It was chosen as it had very much elevation gradient and large variety of endemic flora will be found due to this gradient (http://www.darjeeling.gov.in/dist-prof.html). The chosen (Darjeeling hills) has about 30%

of the forest cover are deciduous and evergreen forest constitute only about 6% of the total forest coverage. Tropical lower Montane evergreen forests are found on steep higher slopes, where the drainage condition is good; Dhupi (*Cryptomeria japonica* D. Don.). Darjeeling nestles in the Lower Himalayas in groups of smaller hills called the Shiwalik hills (http://www.zubin.com/darjeeling/general.htm) To the other area of the Darjeeling Hills plantation the study area approaches the Himalayas gaining an elevation of more than 3500 m within a distance of about 75 km.

3.2 Study Area Characteristics

3.2.1 Location and extent

The study area lies between 87° 59' and 88°53' east longitude 26° 31' and 27°13' north latitude. The district has twelve sub-divisions namely Darjiling Pulbazar, Gorubathan, Jorbunglow Sukiapokri , Kalimpong I , Kalimpong II, Kharibari, Kurseong, Mirik, Naxalbari, Phansidewa, Rangli Rangliot , Siliguri.. The district has a total geographical area of 3,149 km^2. The study area is surrounded By Nepal on the west, Sikkim on the north, Bhutan on the northeast, Purnea district of Bihar and Jalpaiguri of West Bengal on the southeast.

3.2.2 Topography

The whole area possesses relatively undulating topography. The average altitude of Darjeeling is 2134 meters above sea level. The landscape of Darjeeling is mountainous with steep terrain.

3.2.3 Geology

Siwalik system in the Darjeeling hill areas is comprised of along with the bands of metamorphic rocks . Darjeeling district was sub-divided into five groups, viz, Gneiss, mudstones, sandstones, metamorphic rocks, shale and conglomerates. Gondwanas and the Tertiary system Lying south of the metamorphic occurs and the Gondwana belt passing through Tindharia.

3.2.4 Physiography

Physiographically, this district can be divided into two part *viz*., the Tarai directly below the hills and the ridges and deep valleys of the lower Himalayas . The Tarai portion of the district is a low lying belt, traversed by numerous rivers and streams rushing down from the hills and by the upland ridges, which mark their courses.

3.2.5 Soils

Soil is the basic resource for sustaining all life forms. There are wide variation in soil properties such as soil texture , structure, soil depth, stoniness, color, soil moisture, organic matter content and cation exchange capacity depending on the topography, intensity of erosion , parent materials and other factors. Geographically , this region is characterized by the soil of the upland is red and gritty while that of the plains aredark and more fertile. The soil everywhere is residual, i.e., derived by the weathering of the underlying rocks.

3.2.6 Climate

The forest area's has temperate climate even though significant local changes in the composition and aspect control climatic condition which frequently vary throughout a wider range. In Darjeeling winter is extremely cold which is from December to March. The summer is also very pleasing in Darjeeling from April to mid June. June to September are the rainy months when most of the rainfall occurs with appreciable amounts in May and October as well.

3.2.6.1 Rainfall

The Monsoon generally begins in the middle of June and the rains continue until the middle of August. There can be frequent showers in the month of May and also between September to October. The average annual rainfall 3092 mm. The maximum rainfall occurs in July . The humidity level is high in Darjeeling in this time highest and can easily go past 90% of saturation.

3.2.6.2 Temperature

Darjeeling's temperate climate has five distinct seasons are spring, summer, autumn, winter, and monsoons. Annual mean maximum temperature is 14.9 °C , mean minimum temperature is 8.9 °C , with monthly mean temperatures range from 5–17 °C . The lowest temperature recorded was 5 °C (23.0 °F) on 11 February 1905. The average temperature during monsoon ranges between 13°C to 19°C. However, in the night time, the temperature can fall and it can get quite cold.

3.2.6.3 Frost

Rains continuously and the weather is always foggy or misty for most times**.** During the peak monsoon time in Darjeeling (June, July, August), the sky can be barely seen for 10 days in a month.

3.2.7 Forest

According to champion and Seth (1968), there are five classes in Darjeeling hills and there were several land use land cover classes such as described mainly Tea garden was found in whole Darjeeling district .

i) Tropical Semi-Evergreen Forest: This type of forest is restricted to the foothills. The important species are *Michelia champaca*, *Terminalia myriocarpa*. *Ailanthus grandiose* , *Phoebe* species. All these species yield valuable commercial timbers.

ii) Tropical Moist Deciduous Forest: Most deciduous forest has *Shorea robusta* as the main species. Amongst its connections, the species like *Michelia champaca*, *Schima wallichii* and *Chukrassia velutina* which are interspersed with riverain forests of *Acacia catechu*, *Dalbergia sissoo* and *Bombax ceiba*, exist.

ii) Subtropical Forest: These forests occur up to an elevation of 1,824 m .The general species are *Betula cylindrostachys* and *Alnus nepalensis*, *Schima wallichii* and *Engelhardtia spectata* etc.

iv) Eastern Himalayan Wet Temperate Forest: These forests are from 1,824m to 3000m (refer under Montane wet temperate forests by Champion and Seth, 1968). The major species are *Michelia excelsa*, *Abies densa*, *Tsuga brunoniana* and species of *Machilus*, *Acer*, *Quercus* (oaks) etc.

v) Sub- Alpine Forest: These forests are found over 3000 m (refer sub-alpine, dry and moist alpine forest of Champion and Seth, 1968). The characteristic stunted species are *Rhododendron*, *Salix*, *Berberis*, often *Juniper*s, *Abies* and *Tsuga*.

The many other important classes consider in this study were bamboo, Tree clad area ,scrub and Tea garden. These are the important classes which helps in proving economic growth for the locality.

Vi) Plantation :

Tea garden is an important scenic beauty of Darjeeling hills. Today there are 86 tea gardens in Darjeeling produce tea on a total area of 190 km^2. The total production ranges from 10-11 million kgs annually. The name of some tea garden which was visited in field survey Makaibari T.E., Kurseong , Happy Valley T.E. Darjeeling. The Happy Valley Tea Estate is a tea garden established in 1854, it is Darjeeling's oldest tea estate. Spread over 437-acre, it is situated at a height of 2,100 m above sea level, 3 km north of Darjeeling, and employs more than 1500 people. Bamboo is an important Non Timber Forest Produce (NTFP) of West Bengal. It covers an area about 25 % area of Darjeeling.

Fig.3.2. (a) Temperate broadleaved forest, Singalila NP, (b) *Rhododendron falconry*, Singalila NP, (c) Subtropical pine forest, Kalimpong, (d) *Cryptomeria* Sp., Darjeeling, (e) Mixed moist deciduous forest, (f) Bamboo, Kalimpong (g) Teak forest, Kalimpong (h) Tea Garden, Darjeeling (i) *Arundinaria mailing*, *Sinchal WLS*, (j) Ground truth, (k) Agriculture, (l) Alpine Grassland, Singalila NP, (m) Tree clad area with Agriculture, Kalimpong (n) Tista valley with tropical evergreen forest, (o) panoramic view of Darjeeling

Vii) Shrub land:

Shrubland may either occur naturally or be the result of human activity. It may be the mature vegetation type in a Darjeeling and remain stable over time, or a transitional community that occurs temporarily as the result of a disturbance, such as fire. A stable state may be maintained by regular natural disturbance such as fire or browsing. All different vegetation type of study area shown in Fig.3.2.

3.2.8 Biodiversity

The forest of the state is mainly concentrated in the north, the south and the south west. The vegetation in the Himalayas varies from tropical evergreen to sub-alpine scrub. In between above two vegetations sub-tropical evergreen, semi-evergreen, temperate conifer and temperate leaved broad forests occurs. About 3580 species belong to 1333 genera and 200 families are reported to occur in the state. Species and genera Leguminosae, Poaceae, Asteraceae and Ericaceae have the highest number of genera and species (Roy et al., 2012). The Eastern Indian Himalaya has been named as one of the 25 global hotspots in terms of biodiversity (Myers, 2000). A part of this system Darjeeling includes two National parks and three wildlife sanctuaries. They are Neora valley National Park, Singalila National Park and senchal wildlife sanctuary (Fig.3.3.).

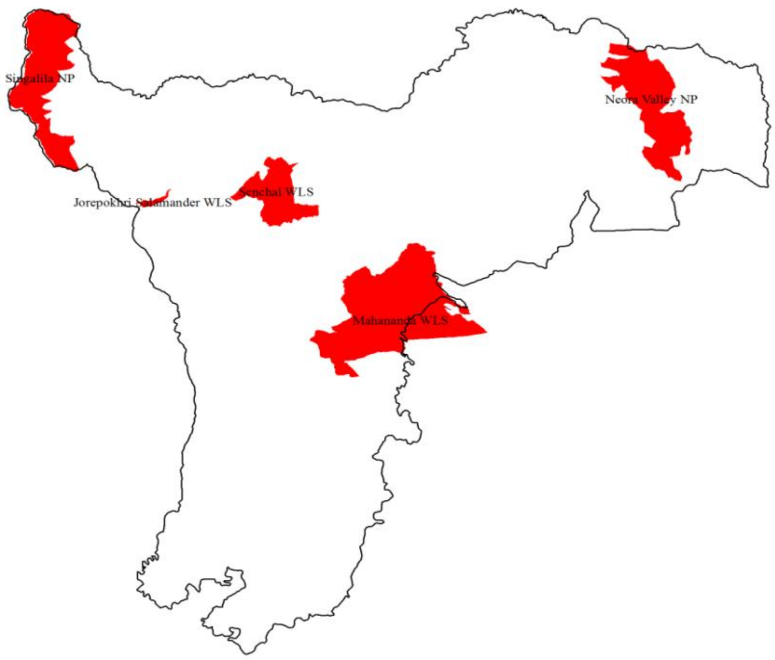

Fig.3.3. The major national park and wildlife sanctuary of Darjeeling.

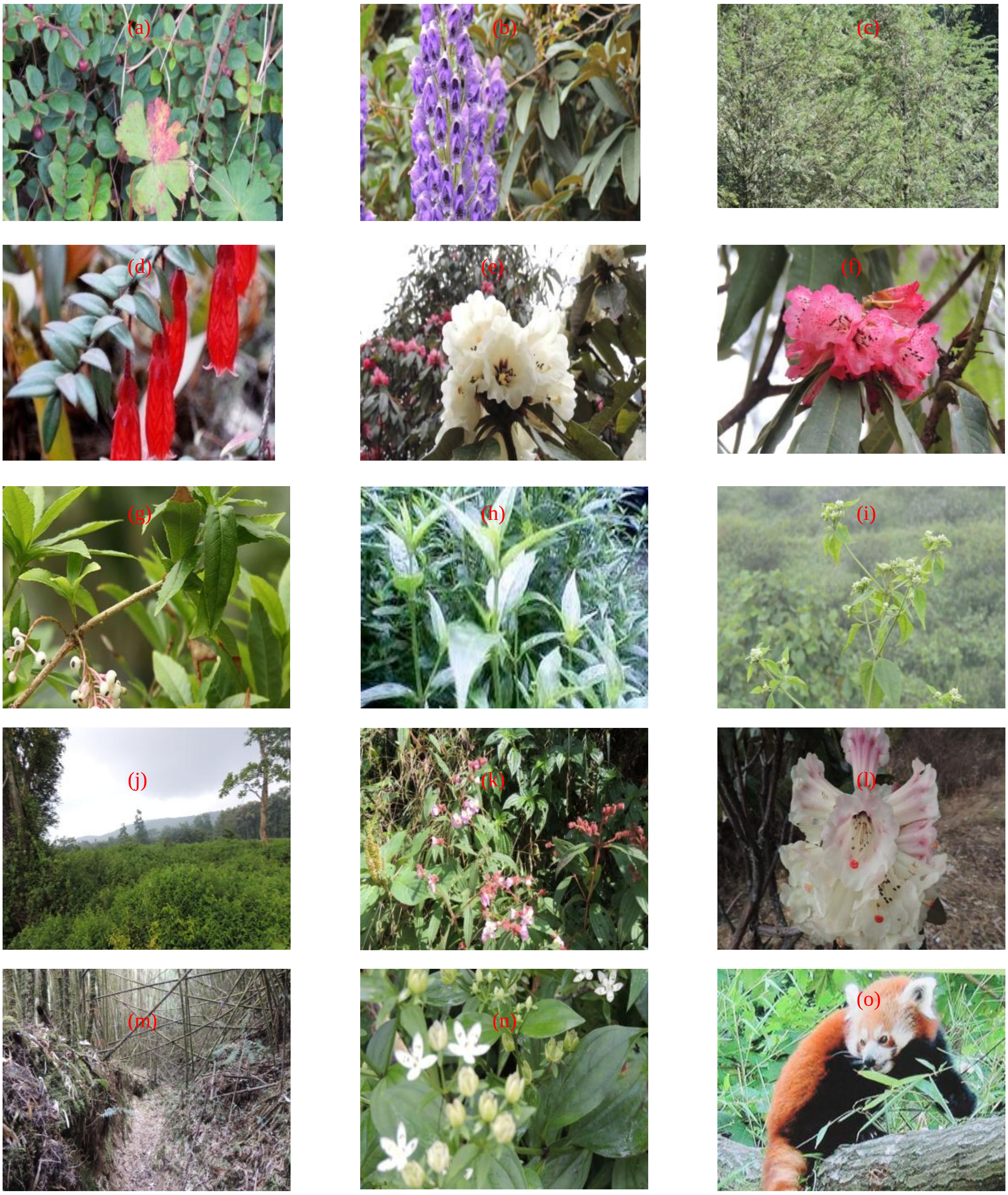

Fig.3.4. (a) *Agapetes serpens* in Singalila NP, (b) *Aconitum napellus in* Singalila NP, (c) *Taxus wallichiana* in Singalila NP, (d) *Agapetes serpens* flower , (e) *Rhododendron arboretum* in Neora valley NP , (f) *Rhododendron wallichii* in Neora valley NP , (g) *Swertia Chirata* in Singalila NP, (h) *Vaccinium vaccineaum* in Darjeeling surroundings, (i) *Hyptis suvalensis* in Sivok hills, (j) *Eupatorium odoratum* in Mahananda wildlife sanctuary, (k) *Gaultheria akaensis* in Singalila NP , (l) *Rhododendron edgeworthii* in Neora valley NP ,(m) *Arundinaria mailing* in Neora valley NP , (n) *Gaultheria hookeri* in Singalila NP, (o) Red panda in Neora valley NP.

3.2.8.1 National Park

The Neora valley National park is one of the oldest reserve forest in India since 1881. It is situated in Kalimpong hills in Darjeeling district and it spread over 78 km^2. NVNP rich in biodiversity, It include 83 medicinal, 59, edible, 18 ornamental and 21 poisonous (Rai and Das, 2004).The common species of *Rhododendrons* found here are *Rhododendron arboruem, R. barbatum, R. falconeri*, *R.dalhousiae* and R. edgeworthii. It is also renowned for the medicinal plants found there (Pragya, 2007) including Swertia chirata, Lycopodium spp., Aconitum spp., Aristolochia spp., Berberis cristata, Costus speciosa , Didymocarpus pedicellate, Rouwolfia serpentine, etc. (Biswas et al. 1999) identified 32 species of mammals in the upper NVNP, belonging to 16 households and 5 orders, representing more than 17% of the total mammalian diversity in West Bengal. Of these, 9 species are protected under Schedule I of the Indian Wildlife (Protection) Act, 1972.Some other records of species richness in NVNP are also available (Sharma, 1990; Mukhopadhyay, 1996; Singhal, 1999; Chakra borty *et al*., 2008a, 2008b; UNESCO World Heritage Centre, 2009; Anonymous, 2010). Singalila National park earlier Wildlife Sanctuary in 1986 and it was declared as a park in 1992. The Vulnerable Red Panda is found in two national parks (NP), Singalila and Neora Valley, of Darjeeling District (Saha and Singhal 1996, Ghose et al. 2007). Red Panda also inhabited Senchal Wildlife Sanctuary (Darjeeling District) in the past (Bahuguna and Mallick 2010). Fig 3.4. Shown major species occurred in the study area.

3.2.8.2 Wildlife Sanctuary

Senchal Wildlife Sanctuary was set up in 1915 in the Darjeeling District of West Bengal, India. It is one of the oldest wildlife sanctuaries of India. It spreads over a surface area of 40.24 km2 and elevation ranges from 1,500 to 2,600 m. High-altitude animals such as barking deer, wild pig, Himalayan black bear, leopard, jungle cat, common rhesus monkey, Assam macaque, Himalayan flying squirrel, etc. are found in their natural habitats. The sanctuary is rich in bird life. The two Senchal lakes supply drinking water to the town of Darjeeling. Mahananda Wildlife Sanctuary covers an area of 156.30 km^2. In 1959, it got the status of a sanctuary mainly to protect the Indian bison and Royal Bengal Tiger, which were facing the threat of extinction. The Jorpokhri wildlife sanctuary covers an area of 2.07km^2It got the status of a sanctuary to protect the Indian Salamander.

3.9 Rivers

The River of the district drain ultimately to the south, through the west to ridge across it causes a series of Tista tributaries rising on its northern face to flow northwards and others flow east or west before joining the main river. The rivers of the district are, Tista which rises in a glacier, in North Sikkim, 21 000ft above sea level, Great Rangit, Jaldhaka, Mahanadi, Balasonand Mech.

Chapter-4

MATERIALS AND METHODOLOGY

4.1 Data Used

The study involved procurement of satellite data, ancillary data, world-clim data, reconnaissance survey , on–screen visual interpretation for the assessment of potential niche modeling using different satellite data and climate data.

4.1.1 Satellite data

Multi-temporal satellite data have been used to prepare the land use and land cover map of the study region. Glimpses are shown in Appendix-4. Table 4.1 shows the used satellite data.

Table 4.1. Description of used Satellite data.

S. No.	Data	Year	Path/ Row	Wavelength (μm)	Spatial Resolution (m)	Swath (km)	Source
1.	Landsat MSS	1977	149/ (41,42)	0.5-0.6 (G) 0.6-0.7 (R) 0.7-0.8 ((NIR) 0.8-1.1 (NIR)	60	185	USGS
2.	Landsat 5 TM	1985	139/ (41,42)	0.45-0.52 (B) 0.52-0.60 (G) 0.63-0.69 (R) 0.77-0.90 (NIR) 1.55-1.75 (SIR) 10.40-12.50 (TIR) 2.09-2.35 (SIR)	30	185	USGS
3.	IRS-1D LISS-III	1997	107/ (52,53)	0.52-0.59 (G) 0.62-0.68 (R) 0.77-0.86 (NIR) 1.55-1.70 (MIR)	70.5	141	NRSC
4.	IRS-P6 LISS-III	2005	107/ (52,53)	0.52-0.59 (G) 0.62-0.68 (R) 0.77-0.86 (NIR) 1.55-1.70 (MIR)	23.5	141	NRSC
5.	IRS-P6 LISS-III	2012	107/ (52,53)	0.52-0.59 (G) 0.62-0.68 (R) 0.77-0.86 (NIR) 1.55-1.70 (MIR)	23.5	141	NRSC
6.	Cartosat Dem				30		Bhuvan

USGS : U.S Geological Survey

NRSC : National Remote Sensing Centre

Bhuvan : ISRO's Geoportal http://bhuvan.nrsc.gov.in

4.1.2 Ancillary Data

The topographic sheets viz., 78A/4, 78A/8, 78A/12, 78A/16, 78B/1, 78B/2, 78B/3, 78B/5, 78B/6, 78B/7 and 78B/9 on 1:50000 scales were used in the study. The forest working plan of the area was also used in the study. Historical data available to the West Bengal Forest Department, Research Circle, Darjeeling was also used.

4.1.3 Climate data

Precipitation, maximum temperature and minimum temperature all were downloaded from the WorlClim database at the spatial resolution of 1km by 1 km (30 arc~ seconds) for current condition. Future scenario 2050 a2a AND b2a from HADCM3 model data has been also downloaded on the scale of 1km by 1km (30 arc~ seconds). (http://www.worldclim.org/download)

4.1.4 Instruments

Various instruments have been used during the field visits. Following instruments were used in the study:

- Global Positioning System (GPS)
- Ranger compass
- Measuring tape
- Photographic camera

4.2 Software

Following softwares were used for satellite data interpretation and for image processing and GIS analyses.

- ERDAS Imagine 10.0 for image analysis
- Arc GIS 10.0 and Arc View 3.2a for database creation and analysis
- MS Office 2007 for field data analysis and report preparation
- DIVA – GIS 5.4 used for creating 19 bioclimatic variables
- Statistica 7 for statistical analysis

4.3 Methods

Intensive field work (30 days in month of sep- Oct and 20 days in month of march) was undertaken for identification of species basically Darjeeling hills part was covered whole mainly two National parks and three wildlife sanctuaries. They are Neora valley National Park, Singalila National Park, senchal wildlife sanctuary, Mahnanda wildlife sanctuary and Jorepokhri Salamander wildlife sanctuaries. The species' occurrence point has been collected. The study areas were generated and systematic study has been carried out to correlate the ground observations with the satellite data. The approach puts in use of land use / land cover and technical suggestion generated through RS and GIS. The methodology applied in the study is categorized into three parts: pre-field work, field work and post field work. Fig.4.1. Schematic methodology of this study.

4.3.1 Pre-Field Work

The satellite images were produced from NRSC, Hyderabad. Raw image was rendered to geometric corrections. Satellite images for 1977, 1985 were downloaded from Glovis (WGS-84). LISS –III images were rectified to the Landsat 4-5 TM with RMS error of 0.3. After this area of interest was extracted, vegetation type map was delineated using LISS-III and Landsat 4-5 TM image on the scale of 1: 50000 and accuracy assessment is also considered.

4.3.2 Field Work and data collection

The base map was prepared using toposheets. Major routes and places layers were put on the base map for accessibility in the forest during field survey. Detailed field inventory was carried out for the identification species and vegetation type. The field work was done on the basis of previous information about the location of the species from the literature and herbarium of the Lloyd botanical garden of Darjeeling. On the basis of this reconnaissance survey was carried out presence location was also collected using GPS and satellite imagery.

4.3.3 Post-Field Work

Post-field work such as validation of vegetation type, field data compilation, database creation was done.

4.3.3.1 Vegetation type Mapping

False color composite of satellite data were mosaic, projected to LCC and clipped to the study area. Further, it has been used for preparation of vegetation type both by visual and digital interpretation methods. The images were visually interpreted to classify the vegetation type. The interim map was field verified and correction was made wherever necessary. Different strata were finally delineated using image element and ground truth.

4.3.3.2 Generation of topographical variables

The altitude data was derived from Carto – Dem (http://bhuvan.nrsc.gov.in) the data were mosaic, projected to LCC and clipped to the study area. The data were resampled at a resolution of 60m by 60m of the nearest neighboring method. From the altitude data, slope and aspect were calculated by using software ArcGIS 10.0.

4.3.3.3 Generation of Bioclimatic variables

Download and install DIVA-GIS 5.4. The three climatic variables such as Minimum temperature, Maximum temperature and precipitation variables were downloaded for current climatic condition (1955 – 2012) and for future scenario 2050 IPCC a2a and 2050 IPCC b2b. After this the .BIL files were converted to ESRI GRID, format. The data was projected to LCC WGS 84 and were resampled to 60m by 60m using nearest neighboring resampling method than clipped to the study area. The selected layers were exported to ASCII format (. ASC) and imported into a GRID format using DIVA-GIS to .CLM files. DIVA-GIS was used to create the bioclimatic variables and were subsequently exported the 19 variables to an ASCII format (. ASC). These layers used in niche model. Appendix-5.

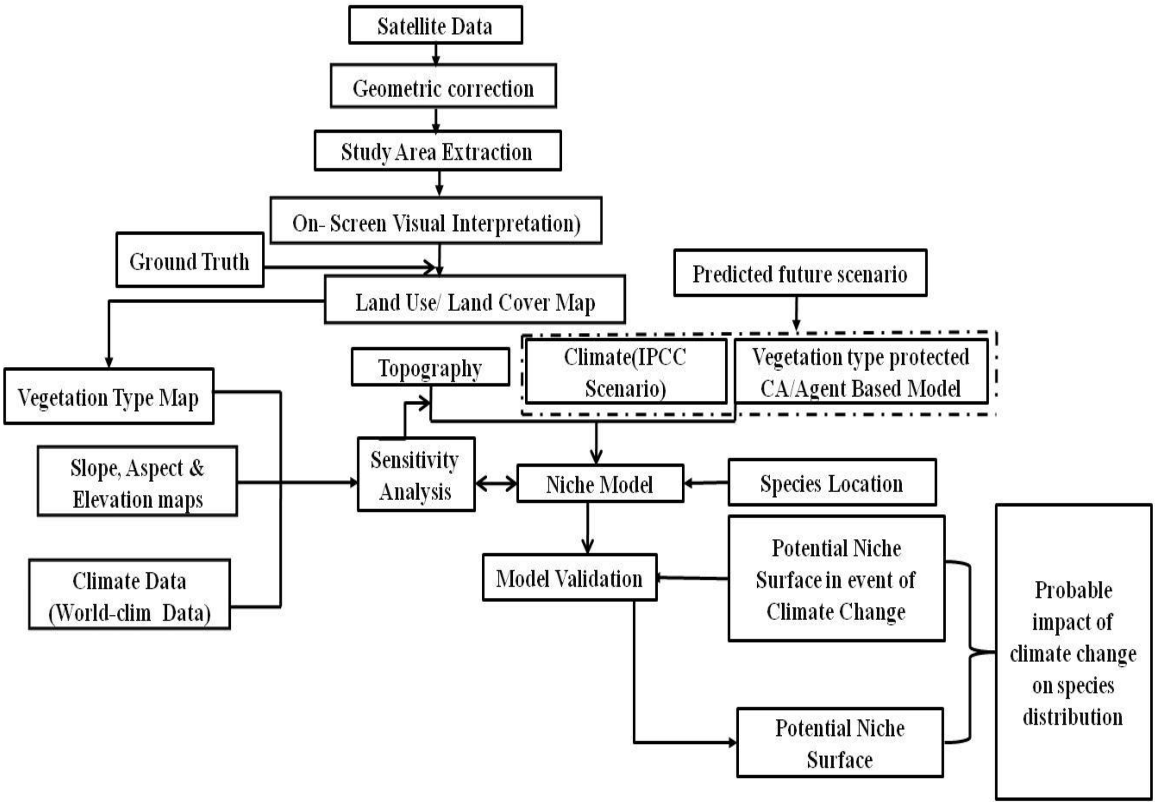

Fig. 4.1. Schematic methodology of this study.

4.4 Prediction of LULC scenario for 2050

The technique of modeling used for land cover done by cellular automata. A Markov chain analysis (MARKOV) is performed in order to estimate the transition matrix between the 1977 and 2012 to estimate probabilities of change for the 2050 to be predicted. A cellular automata predicting model (CA-MARKOV) estimates the spatial distribution of land cover at a future date. Using the output data produced by Markov chain analysis, the predicting model will apply contiguity filter to growing out land cover from 2012 to 2050 Fig. 4.2.

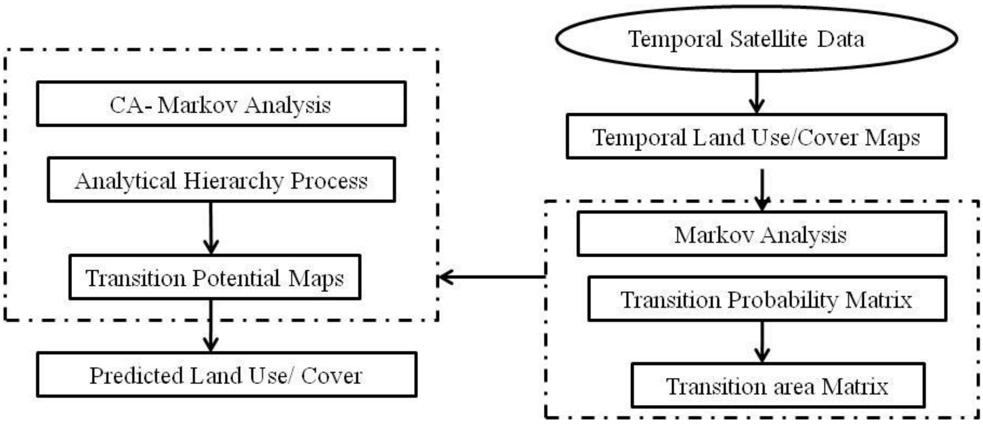

Fig. 4.2. Methodology for LULC prediction.

4.5 Niche modeling technique

There are a number of modeling technique and algorithm to predict the probability of the species occurrences by the environmental variables as limiting factors for species survivals. Two modeling algorithms: MaxEnt model (Maximum entropy) and GARP model (Genetic Algorithm for Rule-set Production) were employed in this study.Two models have their advantages and disadvantages (Appendix-6). The deficiency of MaxEnt and GARP is to extrapolate their algorithm blindly from sample to population without user customizable statistical analysis. The advantage of MaxEnt model and GARP model is that these algorithms require only presence data of species. MaxEnt model and GARP model are specialized to produce predictive maps for the area of interest. The MaxEnt implements a jackknife test and response curve which helpful for analyzing which environment variable can be good predictors, but GARP model does not have this function, which means before running a model GARP, importance of predictors should be recognized. GARP model has a capacity to consider categorical variables. MaxEnt model is also compatible with categorical.

4.5.1 MaxEnt model

The MaxEnt program version 3.3.3 was used to implement maximum entropy modeling of species geographical distribution. The principle of maximum entropy discrete probability distribution is the uniform distribution, In order to apply Jaynes' information theory formalism; one has to define the objects of interest. Once the events of interest have been defined, Jaynes' information theory formalism can be utilized. It consists of the maximization of Shannon's information entropy $SI = -_i \Sigma pi \ln pi$ with respect to pi, where pi is the probability of the occurrence of the i-th event, provided the constraints are taken into account. This algorithm is known as MaxEnt.

The MaxEnt model requires point location where species are known to occur. The environment layers as predictors that might limit the species capabilities to survive. For the input the ASCII environment layers were used and the species presence records, a CSV file of the species location was customized for use in the model. From that CSV file, only the columns of species scientific names X and Y coordinates, and values of each environment variable to point localities were extracted for use. As the input of environmental layers, instead of using ASCII data background pixels were prepared. First 10,000 points were distributed randomly within the study area and then the values of each environment predictor of those items were extracted in Arc Map 10.0. Finally a new CSV file which contains geographic coordinates and environment values on each environment layers respectively was prepared. In order to make images and output grids, and then projected onto the entire grid using ASCII layers. MaxEnt methodology is presented in Fig. 4.5.

For the experimental model, all environment layers were used for three species respectively. The user specified parameters were set as regularization multiplier = 1, maximum iteration = 5000, convergence threshold = 0.0001, maximum background points = 10000, replication 15 and use of linear, quadratic, product, threshold and hinges features. As output, a predicted distribution map in the ESRI raster grid format is five averages, minimum, maximum, median and standard of deviation, Area under curve, omission and commission for prediction, response curves were created and jackknife test of variable importance was carried out as Sub- sampling method. The best contribution for each species was also calculated. Later on the statistical analysis of predictor importance, the last model was run with the only selected predictors. The parameters were the same as above experimental model. After analyzing the jackknife and response curves, the second model was run with the variables which have high training gains and contribute to the total training gain. The environmental variables which have no effect to the MaxEnt prediction in response curves were excluded in the second model.

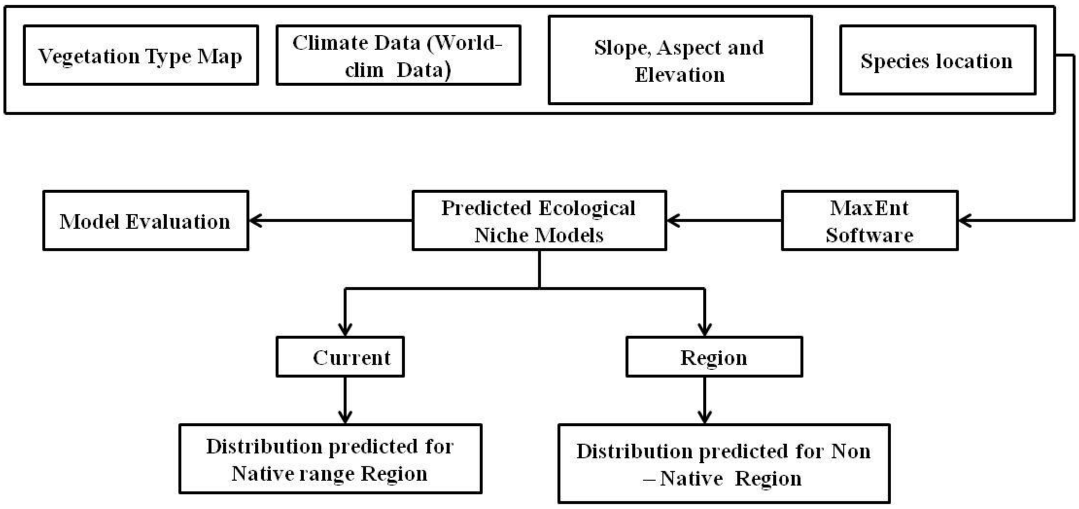

Fig. 4.3. MaxEnt MODEL methodology.

4.5.2 GARP model

The Desktop GARP version 1.1.6 was used to predict and to analyze endemic species distribution .This is a software package produced by the “university of Kansas” Center for research to implement a GARP algorithm. The GARP algorithm that creates ecological niche models of species. The models describe environmental condition under which the species should be able to sustain populations.

For input, species’ presence records of train data in CSV format. Geographical environment layers in ASCII format were prepared by ArcView3.2a. The environmental layers were selected based on the result of statistical analysis. All approaches available in GARP software i.e.: atomic, logistic regression, bioclimatic envelope and negated bioclimatic envelope rules were used. Each rule type implemented a different method for building species prediction models. For each species, the model was run 20 times under the condition of 0.01 convergence limit and 1000 maximum iterations. Among samples points of a train dataset, 50% was used as training. The best subset selection procedure was implemented and the model only under a threshold of 10 % of extrinsic hard omission error was selected. The predicted distribution maps by GARP give only absence and presence as binomial values: 0 or 1. MaxEnt methodology is shown in Fig. 4.9.

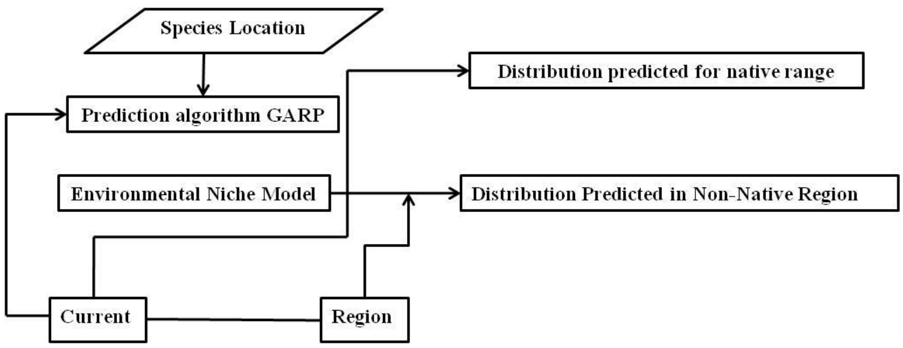

Fig. 4.4. GARP MODEL methodology.

Therefore, the 20 best-subset predictive maps were averaged in ArcMap10.0 after GARP modeling. The averaged map can represent a probability map, which has continuing value (0 % to 100 %) as a probability of occurrence of species. After this sensitivity analysis was done with regard to the specific location with other environment variables. For this process layer stacked was done of all selected environment variables and species occurrence point. After this Principal component analysis (PCA) was done which rotates multivariate dataset into a new phase which is easier to interpret. This procedure was done in Arc Map 10.0 it provides correlation matrix, eigen value and eigen vector. This process simplified the data and establishes the relationship between variables.

4.6 Analysis of LULC on niche

Based on the approach of Land use Land cover change for five temporal data set of 1977, 1985, 1997, 2005 and 2012. Both the predictive model was run and for each year and the average result were analysis for all. For this the comparison of predictive models, the predictive maps by the best modeling algorithm for each species were chosen to estimate local population under different vegetation type. First, the predictive raster maps were reclassified into presence and predicted absence using optimum probability as cutoff values. The predicted present location was conceived to represent the suitable niche of the species. Then the reclassified raster maps were used to run Zonal summary in ERDAS 10.0 with the respective LULC of a particular year. The area of suitable niche calculated for species in an individual class in a particular year. In the same way, for future scenario has to do. After analyzing these results, it was concluded that, the prediction of future scenario with these two models was not possible as these two models were based on the presence data and for 2050 LULC it works as the absence data. The new model has been developed on the basis of a logistic approach to analyze the niche prediction for 2050 on the basis of 2012.

4.7 Niche prediction for 2050

Based on the logistic approach, a new model has been generated to predict the future scenario. On the basis of two models of variable selection has been done and for those variables Zonal statistics has been done for year 2012 and scenarios a2a, b2b of 2050.Later the data has been reclassified in 10 classes for all the variables. Than model generated by ERDAS using model maker tool and run for each time period with 10 replications . On the basis of reclassified values. This model has been used to get the suitable niche for 2050 on the basis of 2012 and three images were generated for all three time periods (Fig.4.10.). Then Zonal statistic was run for the reclassified raster maps with LULC of a particular year in Arc Map10. The area of suitable niche has calculated for particular species in an individual class in the year. The accuracy of the predictive model was measured by the Receiver Operating Characteristic (ROC) and Kappa statistics. The data set was used for the purpose of validation, the training dataset was used to compare the difference in the accuracy with a test data set. The pixel values of the predictor maps were generated by a different modeling algorithm that extracted to the details of both train and test data set for each species respectively by using Arc Map 10.0 The spreadsheets containing columns with the presence-absence data (value is either 0 or 1) as ground truth, and the predicted value by MaxEnt and GARP were prepared for each species train and test datasets respectively.

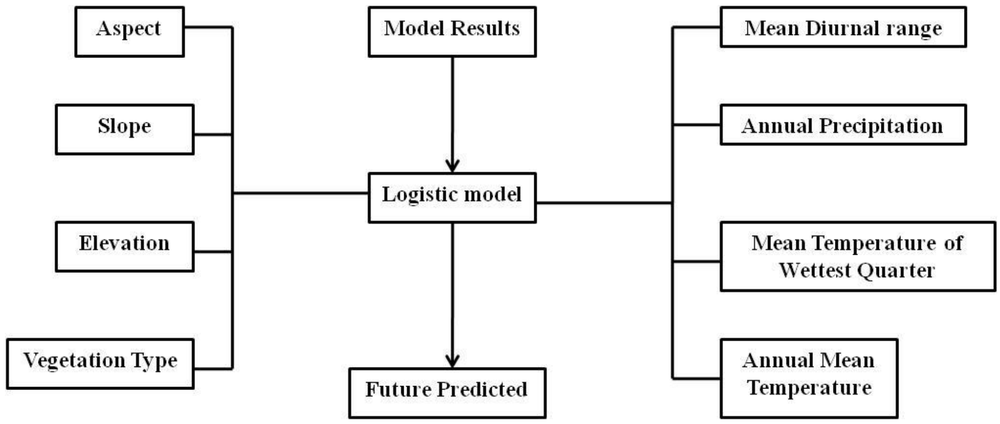

Fig. 4.5. Methodology for future predictive models.

4.8 Receiver Operating Characteristics (ROC) curves

The Receiver Operating Characteristic (ROC) curve is a widely used statistical technique for assessing accuracy of predictive models. An ROC plot is obtained by plotting the fraction of correctly classified cases on the y axis (sensitivity) against the fraction of wrongly classified cases (1- specificity) for all possible thresholds on the x axis at different threshold. The sensitivity and specificity are calculated based on a confusion matrix . The ROC curve can be summarized by area under the ROC curve (AUC) as a measure of overall accuracy that is not dependent upon a particular threshold. The values of AUC vary from 0.5; the higher value (close to 1) has AUC the more accurate is the model. The area under ROC curve was graded on AUC = 0.5 (no discrimination), 0.7 < AUC < 0.8 (acceptable), 0.8 < AUC < 0.9 is (excellent), AUC > 0.9 (outstanding).

The ROC plotting and AUC Calculation transferability Test was used to compute AUC, the standard error SE, z-value with probability *p*, 95 % confidence interval , optimized threshold of probability and sensitivity and specificity. The advantage of this program is that the optimal cut off – values can be calculated. The software can estimate optimum cut off values regarding maximized Kappa, minimized the difference between sensitivity and specificity, maximized correct classification rate taking into account different costs of false positive or false negative predictions, and probability = 0.5. In this study, the process adopted maximized correct classification rate. It can be used to assess the transferability of habitat models as described in (Bonn *et al*., 2001). Therefore, all indices above mentioned were calculated at a threshold of optimized probability and at a threshold of probability of 0.5. To get an estimation if there are significant differences between predictions by chance and AUC values, the standard sub-sampling method was used at 95 % confidence interval and 1000 subs sampling samples were used. In order to visually compare the two ROC curve of Different modeling algorithm together ROC curve were plotted by Ms-office excel

4.9 Kappa statistics for accuracy assessment

Kappa statistics is an index which compares the agreement against that expected by chance. Kappa can be thought of as chance corrected proportional agreement and possible values ranges from 1 (perfect perfect agreement) via 0 (no agreement above that expected by chance) to -1 (complete disagreement). When Kappa statistics are applied to the predicted of species occurrences species absent point are considered to be 0 and species present points to be 1. The cutoff point was established to define species occurrences to be absent or present based on confusion matrix (table) that cross tabulate the observed and predicted presence/absence pattern. Based on the values of the confusion matrix, the kappa statistics (K) were calculated. The strength of the agreement was graded according to K < 0 Poor, K = .21-. 40, Fair, K = .41 - .60 moderate, K= .61-. 80 substantial and K= 0.81- 1.0 almost perfectly.

Chapter-5

RESULTS

Using a set of environment variables the three endemic species of Darjeeling viz. *Aconitum napellus*, *Agapetes serpens* and *Rhododendron edgeworthii* have been modeled using various niche modeling approaches to the current as well as climate change scenario.The following subsections in the chapter describes in detail the spatial distribution of the three endemic species as well as their variables due to LULC and climate change scenario.

5.1 Potential Niche of *Aconitum napellus* , *Agapetes serpens and Rhododendron edgeworthii*

The potential niche of *Aconitum napellus*, *Agapetes serpens and Rhododendron edgeworthii* was known for elevation range 1000–3300m. The potential niche map was prepared and the area also calculated according to percentage suitability for both the model. Appendix 7-12. The total area of Darjeeling is 3149 km^2 , out of that suitable area for *Aconitum napellus*, 85.521 km^2 and 80.396 km^2 and non-suitable area 3063.479 km^2 and 3068.603 km^2, suitable area for *Agapetes serpens* 948.97 km^2 and 825.24 km^2 and non-suitable area was 2200.03km^2 and 2323.76 km ^{2} and for *Rhododendron edgeworthii* suitable area 131.89 km^2 and 286.04 km^2 and non-suitable area 3017.11km^2 and 2862.9646km ^{2} were calculated from MaxEnt and GARP model respectively illustrated from table no. 5.1. , 5.2. and 5.3.

Table 5.1 Suitable and Non – suitable area of *Aconitum napellus*.

	MaxEnt			**GARP**	
SL. No.	**Probability level (%)**	**Areasq_km**	**SL. No.**	**Probability level (%)**	**Areasq_km**
1	50	981.43	1	50	3068.60
2	60	2082.05	2	60	11.00
3	70	27.32	3	70	11.85
4	80	17.84	4	80	20.31
5	90	26.47	5	90	18.62
6	100	13.89	6	100	18.62
		3149			3149
Suitable Area	85.521 sq_km		Suitable Area	80.396sq_km	
Non - suitable area	3063.4788 sq_km		Non - suitable area	3068.603sq_km	

Table 5.2 Suitable and Non – suitable area of *Agapetes serpens*.

	MaxEnt			**GARP**	
SL.No.	**Probability Level (%)**	**Areasq_km**	**SL.No.**	**Probability Level (%)**	**Areasq_km**
1	50	2200.03	1	50	2323.76
2	60	278.33	2	60	120.05
3	70	136.10	3	70	37.78
4	80	184.01	4	80	39.46
5	90	179.91	5	90	140.20
6	100	170.62	6	100	487.75
		3149			3149
Suitable area	948.97sq_km		Suitable area	825.24sq_km	
Non - suitable area	2200.03sq_km		Non - suitable area	2323.76sq_km	

Table 5.3 Suitable and Non – suitable area of *Rhododendron edgeworthii*.

	MaxEnt			**GARP**	
SL.No.	**Probability level (%)**	**Areasq_km**	**SL.No.**	**Probability level (%)**	**Areasq_km**
5	50	3017.11	5	50	2862.96
6	60	46.28	6	60	22.00
7	70	15.74	7	70	7.62
8	80	16.54	8	80	3.39
9	90	26.86	9	90	4.23
10	100	26.47	10	100	248.81
		3149			3149
Suitable Area	131.89sq_km		Suitable Area	286.04sq_km	
Non - suitable area	3017.11sq_km		Non - suitable area	2862.9646sq_km	

5.1.1 Model Validation

5.1.1.1 Sensitivity Analysis *Aconitum napellus Agapetes serpens and Rhododendron edge worthii*

Among the 24 environmental variables, each species had a few variables which accounted to > 95 % for predicting the potential niche. Jackknife tests were performed to know the sensitivity of the variables using Maxent model the major variables which played role for *Aconitum napellus* are such as Precipitation such as (Bio12, Bio13, Bio14, Bio15, Bio16, Bio17, Bio18 and Bio19), Temperature such as (Bio1, Bio5, Bio6, Bio8 and Bio9) and Terrestrial such as (Elevation, Land use/ Land cover, fragmentation and slope), for *Agapetes serpens* are such as Precipitation such as (Bio19, Bio17, Bio14, Bio16, Bio12, Bio13, Bio18 and Bio15), Temperature such as (Bio3, Bio6, Bio9, Bio8, Bio1, Bio11, Bio10, Bio5, Bio2, Bio7, and Bio4) and Terrestrial such as (Elevation, slope, Land use/ Land cover and fragmentation) and for *Rhododendron edgeworthii* Precipitation such as (Bio17, Bio15, Bio19, Bio13, Bio12, Bio16, Bio18 and Bio14), Temperature such as (Bio4, Bio9, Bio11, Bio6, Bio1, Bio10, Bio8, Bio5, Bio3, Bio2, and Bio7) and Terrestrial such as (Elevation, Land use/ Land cover, fragmentation, aspect and slope)Variables were arranged according relative importance in this sequence.

There was no inbuilt sensitivity analysis for GARP, So a different method was used for correlation analysis of selected variables using layer stacking. The sensitivity of variables was analyzed using the statistical method obtain from PCA and correlation of variables with the species occurrence r^2 value at 95 % confidence level. There were eight variables such as BIO2, BIO12, BIO1, BIO8, Aspect, Slope, Elevation and Land use/ Land cover showing significant correlation (significant at 95 % significance level) for *Aconitum napellus* in the order of 0.99, *Agapetes serpens* in the order 0.98 – 0.99 and *Rhododendron edgeworthii* in the order of 0.97 – 0.99 . Appendix 13-15.

5.1.1.2 Receiver Operating Characteristics for *Aconitum napellus Aconitum napellus Agapetes serpens and Rhododendron edge worthii*

MaxEnt and GARP modeling algorithms predict for *Aconitum napellus* approximately analogous Kappa statistics (K = 0.6534 for MaxEnt , K = 0.7076 for GARP) at the threshold of optimized probability, for *Agapetes serpens* Kappa statistics (K = 0.7826 for MaxEnt , K = 0.7980 for GARP) and for Rhododendron edgeworthii Kappa statistics (K = 0.7267 for MaxEnt , K = 0.7295 for GARP) table no.5.4 – 5.9 respectively. Shows that the variables were considered more towards the optimized probability as compared to the threshold probability of 0.5. Area under the curve (AUC) of the training data showed a perfect score (~1), but the prediction was not significant (p = 1.00). In case of *Aconitum napellus* AUC for the test data from MaxEnt showed a good score in order of 0.998 and the GARP showed a score of around

0.866 , for Agapetes serpens the AUC for the test data from MaxEnt showed a good score in order of 0.950 and the GARP showed a score of around 0.825 and for Rhododendron edgeworthii the AUC for the test data from MaxEnt showed a good score in the order of 0.997 and the GARP showed a score of around. For all the cases, the prediction was highly significant (p = 0.0001) . Hence, the present analysis suggests that the MaxEnt model is better than GARP model, while considering all indices except the accuracy assessment. Appendix 16-18.

Table 5.4. Acurracy assesment of MaxEnt model output for *Aconitum napellus*.

	ACCURACY TOTALS				
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Class 5	0	0	0	---	---
Class 6	0	0	0	---	---
Class 7	0	0	0	---	---
Class 8	0	0	0	---	---
Class 9	37	29	29	78.38%	100.00%
Class 10	13	21	13	100.00%	61.90%
Totals	50	50	42		

Overall Classification Accuracy = 84.00%
KAPPA(K^) STATISTICS
Overall Kappa Statistics = 0.6534

Table 5.5. Accuracy assessment of GARP model output *for Aconitum napellus*.

	ACCURACY TOTALS				
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Class 5	0	0	0	---	---
Class 6	0	0	0	---	---
Class 7	0	0	0	---	---
Class 8	0	0	0	---	---
Class 9	33	33	33	100	100
Class 10	17	11	11	64.71%	100.00%
Totals	50	50	44		

Overall Classification Accuracy = 88.00%
KAPPA (K^) STATISTICS
Overall Kappa Statistics = 0.7076

Table 5.6. Acurracy assesment of MaxEnt model output for *Agapetes serpens* .

	ACCURACY TOTALS				
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Class 5	1	1	1	100.00%	100.00%
Class 6	1	1	1	100.00%	100.00%
Class 7	1	1	1	100.00%	100.00%
Class 8	3	2	2	66.67%	100.00%
Class 9	28	23	20	71.43%	86.96%
Class 10	139	144	136	97.84%	94.44%
Totals	174	174	162		

Overall Classification Accuracy = 93.10%
KAPPA (K^) STATISTICS
Overall Kappa Statistics = 0.7826

Table 5.7. Accuracy assessment of GARP model output for *Agapetes serpens* .

	ACCURACY TOTALS				
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Class 8	0	0	0	---	---
Class 8	0	0	0	---	---
Class 8	0	0	0	---	---
Class 8	4	5	4	---	---
Class 9	17	12	11	64.71%	91.67%
Class 10	153	157	152	99.35%	96.82%
Totals	174	174	167		

Overall Classification Accuracy = 95.98%
KAPPA (K^) STATISTICS
Overall Kappa Statistics = 0.7980

Table 5.8. Acurracy assesment of MaxEnt model output for *Rhododendron edgeworthii*.

	ACCURACY TOTALS				
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Class 5	0	0	0	---	---
Class 6	0	0	0	---	---
Class 7	0	0	0	---	---
Class 8	0	0	0	---	---
Class 9	5	3	3	---	---
Class 10	39	41	39	100.00%	95.12%
Totals	44	44	42		
Overall Classification Accuracy = 95.45% KAPPA (K^) STATISTICS Overall Kappa Statistics = 0.7267					

Table 5.9. Accuracy assessment of GARP model output for *Rhododendron edgeworthii*.

	ACCURACY TOTALS				
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producer's Accuracy**	**Users Accuracy**
Class 5	0	0	0	---	---
Class 6	0	0	0	---	---
Class 7	0	0	0	---	---
Class 8	0	0	0	---	---
Class 9	7	6	5	71.43%	83.33%
Class 10	37	38	36	97.30%	94.74%
Totals	44	44	41		
Overall Classification Accuracy = 93.18% KAPPA (K^) STATISTICS Overall Kappa Statistics = 0.7295					

5.2 Influence of Land use/ Land cover change on species niche

5.2.1 Land use/Land cover

The LULC was prepared using on-screen visual interpretation at the scale of 1:50,000. 16 classes were stratified on the basis of tone, texture and color. Appendix The area of the natural forest ecosystems of the LULC for year 1977, 1985, 1997, 2005 and 2012 were 1411.78, 1488.09, 1401.00, 1431.92, 1347.76 km^2 respectively. The statistics showed that natural forest ecosystem has increased between 1977 to 1985 and 1997 to 2005 by 76.31 km^2 and 30.92 km^2 respectively. Out of 16 classes, 5 classes *viz*., Subtropical broadleaved, Sal, temperate broadleaved, mixed moist deciduous and temperate coniferous were considered as natural forest ecosystems in this study. According to LULC 1977 in natural forest ecosystems the maximum area was observed in temperate broadleaved (579.79 km^2), Mixed moist deciduous (325.16 km^2), subtropical broad leaved (297.98 km^2), Temperate coniferous (112.49 km^2), Sal (96.37 km^2). In accordance with LULC 1985 in the natural forest ecosystem the maximum area was observed in temperate broadleaved (599.92 km^2), subtropical broad leaved (363.84 km^2), Mixed moist deciduous (288.87 km^2), Sal (121.33km^2), Temperate coniferous (114.14 km^2). For LULC 1997 in the natural forest ecosystem the maximum area was observed in temperate broadleaved (488.68 km^2), subtropical broad leaved (374.16 km^2), Mixed moist deciduous (299.26 km^2), Temperate coniferous (121.07 km^2), Sal (117.83km^2). For LULC 2005in natural forest ecosystem the maximum area was observed in temperate broadleaved (488.81km^2), subtropical broad leaved (405.32 km^2), Mixed moist deciduous (297.25 km^2), Temperate coniferous (127.49 km^2), Sal (113.04km^2). And for LULC 2012 in the natural forest ecosystem the maximum area was observed in temperate broadleaved (440.61km^2), subtropical broad leaved (343.43 km^2), Mixed moist deciduous (290.97 km^2), Temperate coniferous (171.62 km^2), Sal (101.14km^2).The area of the other vegetation types in the study area for the year 1977, 1985, 1997, 2005 and 2012 were 339.81 km2, 264.59 km2, 320.36 km2, 342.51km2, and 279.01km 2 respectively. The area of the non-forest in the LULC for year 1977, 1985, 1997, 2005 and 2012 were 1397.40, 1396.31, 1427.6, 1461.02, 1522.23 km^2 respectively. The accuracy assessment was calculated for each LULC and it is varied from 80 – 85%. Appendix 19.

5.2.2 LULC Change

The maximum loss in the area (111.23 km^2) was observed in the temperate broad leaved forest in between 1985 and 1997, while it had increased in the area between 1977 and 1985 by 20.13 km^2. The area of Mixed moist deciduous forest has decreased between 1977 and 1985 by 36.29 km^2. But it has increased between 1985 and 1997 (10.39 km^2) and again decreased during 1997-2005 and 2005-2012 by 2.01 and 6.28 km^2 respectively. During 1977-2005 the area of the subtropical broad leaved had increased by 107.35 km^2 but it becomes decreased by 61.89 km^2 during 2005-2012. The tree clad area has also decreased by 84.63 km^2 and 66.99 km^2 during 1977-1985 and 1997-2005 respectively. The area of Sal forest has increased by 24.96 km^2 during 1977-1985 afterwards it decreases by 20.19 km^2 during 1985-2012. The overall maximum loss was observed in Temperate broad leaved by 139.18 km^2, followed by the tree clad area (74.24), Mixed moist deciduous (34.19) and in bamboo (11.07) during 1977-2012. Temperate coniferous forest has received an increment in the area throughout the study period.

5.2.3 *Aconitum napellus*

The influence of land use/ land cover change has been analyzed by two different models for five temporal data series. The *Aconitum napellus* distribution range is best generated from

GARP model itself provided both right and left range of species. In case of MaxEnt the result which was generated on the basis of occurrence point it is same range where the species location has been collected Appendix 20, 21. On the basis LULC the analysis of different sixteen vegetation type was done for both the model between *Aconitum napellus's* absence and presence records for all the years 1977, 1985 , 1997, 2005 and 2012.

The niche potential increases in 1985 to 1977 afterwards the potential niche of *Aconitum napellus* decreases continuously till now. In case of MaxEnt model for 80 – 90 % probability the presence of species has been found in three classes such as Sub-tropical broad leaved, Temperate broadleaved and Temperate coniferous. The trend was analyzed for the presence record such as it shows that a continuous decrement in Subtropical broad leaved and continuous increment in Temperate broadleaved and Temperate coniferous (Fig. 5.1.). In case of a GARP model for 80 – 90 % probability the presence species has been found in two classes such as Temperate broadleaved and Temperate coniferous. The trend was analyzed for the presence record such as it shows the continuous decrement in Temperate broadleaved and Temperate coniferous (Fig. 5.3.).

In case of MaxEnt model for 90 – 100 % probability the presence of species has been found in three classes such as subtropical broad leaved, Temperate broadleaved and Temperate coniferous. The trend was analyzed for the presence record such as it shows that a continuous decrement in Subtropical broad leaved and continuous increment in Temperate broadleaved and Temperate coniferous (Fig. 5.2). In case of a GARP model for 90 – 100 % probability the presence species has been found in two classes such as Temperate broadleaved and Temperate coniferous. The trend was analyzed for the presence record such as it shows that it shows the continuous increment in Temperate broadleaved and decrement in Temperate coniferous (Fig. 5.4.).

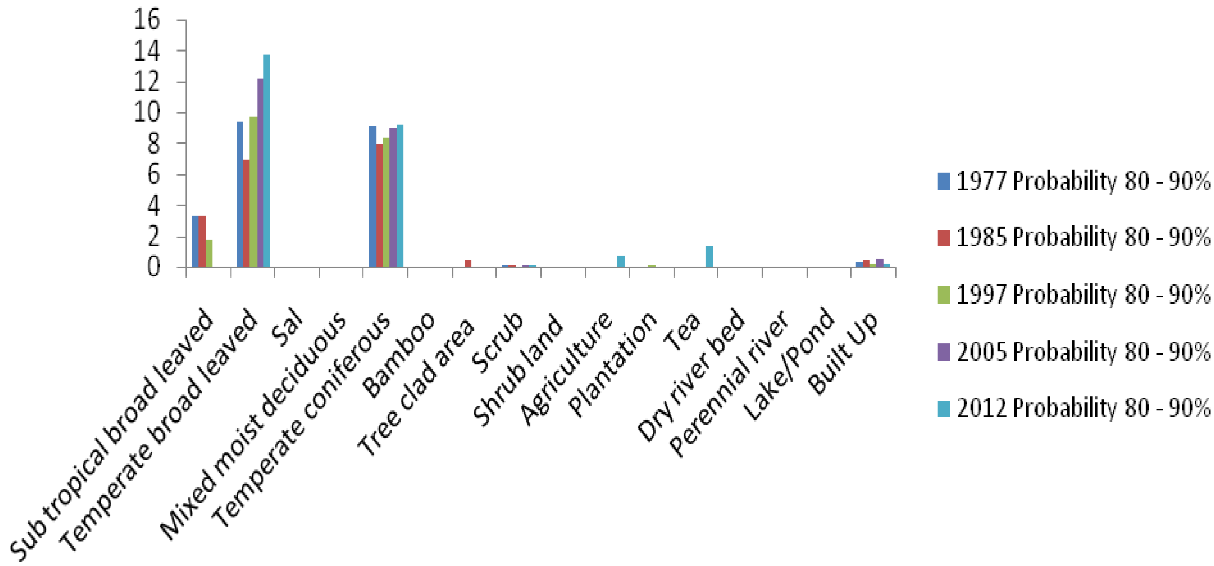

Fig. 5.1. Analysis of presence and absence of *Aconitum napellus* in particular vegetation type from MaxEnt model (80- 90% probability).

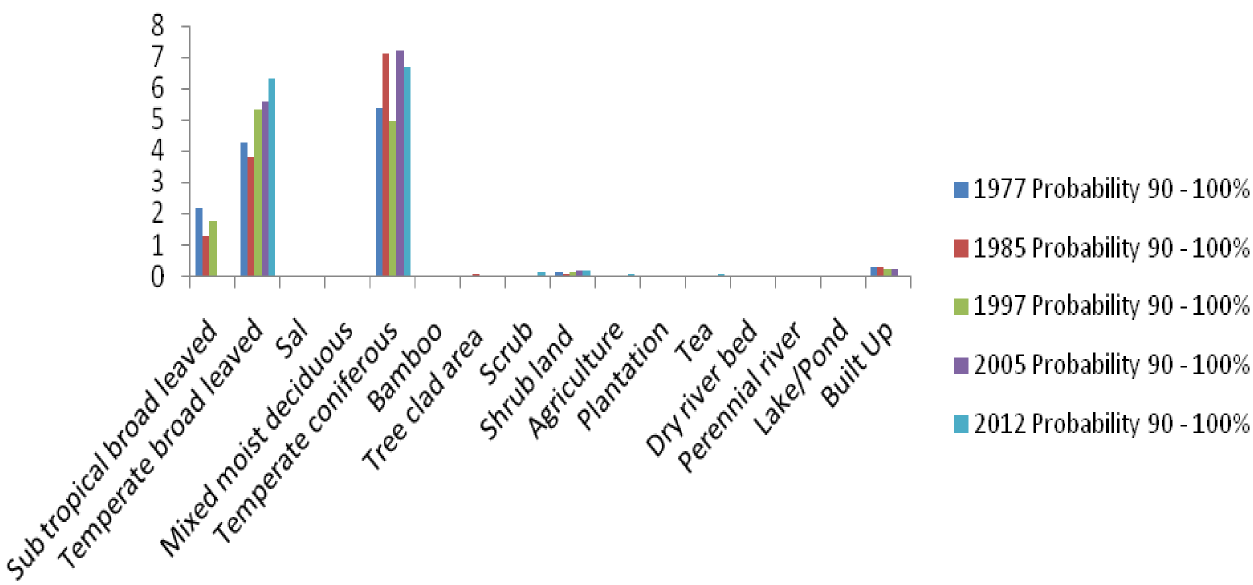

Fig. 5.2. Analysis of presence and absence of *Aconitum napellus* in particular vegetation type from MaxEnt model (90-100% probability).

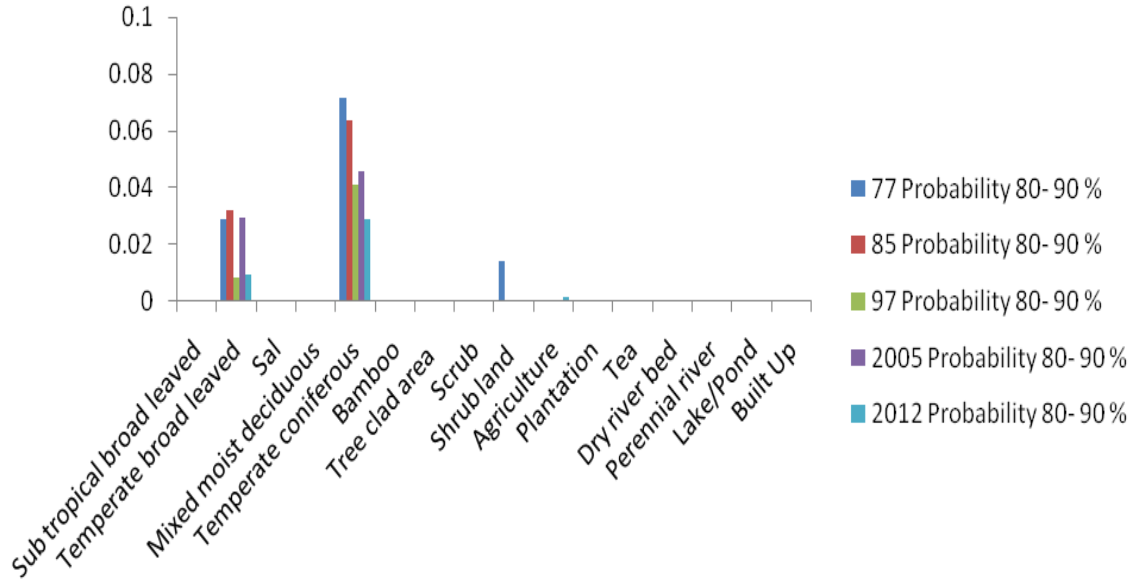

Fig. 5.3. Analysis of presence and absence of *Aconitum napellus* in particular vegetation type from GARP model (80- 90% probability).

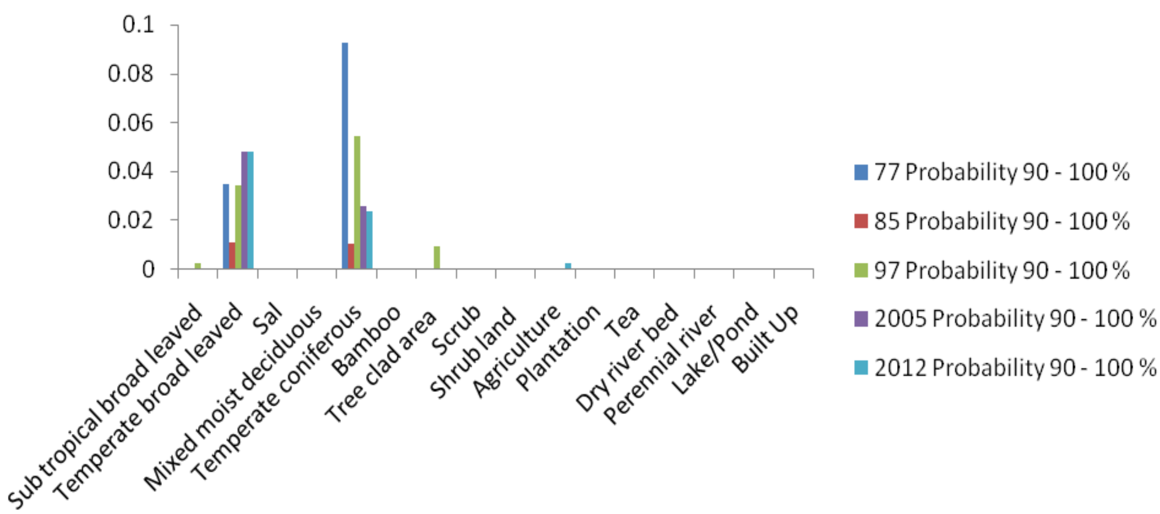

Fig. 5.4. Analysis of presence and absence of *Aconitum napellus* in particular vegetation type from GARP model (90-100% probability).

5.2.4 Agapetes *serpens*

The influence of land use/ land cover change has been assessed by two different models for five temporal data series. The *Agapetes serpens* distribution range is well generated from both the model MaxEnt and GARP provide result for both the ranges right and left (Appendix 22, 23). On the basis LULC the analysis of different sixteen vegetation type was done for both the model between *Agapetes serpens*'s absence and presence records for all the years 1977, 1985 , 1997, 2005 and 2012. The niche potential mainly increase from 1977 – 2012 but presence location of species percent shift from one class to other. In case of MaxEnt model for 80 – 90 % probability the presence of species has been found in nine classes such as Sub-tropical broad leaved, Temperate broadleaved , Mixed moist deciduous, Temperate coniferous, Bamboo, Tree clad area, Scrub, Agriculture, Tea and Built up. The trend was analyzed for the presence record such as it shows that continuous decrement in Sub-tropical broad leaved and continuous increment in Temperate broad leaved, Tea, Temperate coniferous, Mixed moist deciduous, Scrub and Built up in sequence of percent presence of species. Random trend was analyzed in Tree clad area and Agriculture (Fig. 5.5.). In case of GARP model for 80 – 90 % probability the presence species has been found in nine classes such as Sub-tropical broad leaved, Temperate broadleaved , mixed moist deciduous, Temperate coniferous, Bamboo, Tree clad area, Scrub, Agriculture, Tea and Built up. The trend was analyzed for the presence record such as it shows the continuous decrement in Sub-tropical broad leaved and Temperate broadleaved and Built up it shows the increment. In case of Mixed moist deciduous and Temperate coniferous except 1985 it shows the normal trend in all other years. Tree clad area; Scrub, Agriculture and Tea shows presence in 2012 (Fig. 5.7.).

In case of MaxEnt model for 90 – 100 % probability the presence of species has been found in nine classes such as Sub-tropical broad leaved, Temperate broadleaved , Mixed moist deciduous, Temperate coniferous, Bamboo, Tree clad area, Scrub, Agriculture, Tea and Built up. The trend was analyzed for the presence record for Sub-tropical broad leaved it shows increase in presence percent in 1985 after ward it continuously decrease in presence percent and finally in 2012 it shows increment in presence percent. Temperate broadleaved and Temperate coniferous continuously shows the trend of increment and finally in 2012 shows decrement in presence percent. Bamboo and Tree clad area shows the sustained trend, Scrub continuously show increasing trend, Agriculture initially showed decreasing trend afterwards continuously increased (Fig. 5.6.). In case of GARP model for 90 – 100 % probability the presence species has been found in nine LULC classes such as Sub-tropical broad leaved, Temperate broadleaved , mixed moist deciduous, Temperate coniferous, Bamboo, Tree clad area, Scrub, Agriculture, Tea and Built up. The trend was analyzed for the presence record for Sub-tropical broad leaved it shows increase in presence percent in 1985 after ward it continuously decrease in presence percent and finally in 2012 it shows increment in presence percent. Temperate broad leaved decrease first afterward increase continuously till now. Mixed moist deciduous first increase than continuously decrease. Temperate coniferous continuously increase. In Bamboo presence shown only in 1985. Tree clad area, Scrub, Agriculture and Tea shows decrement in 1985 after that it continuously shows increment till now. Built up shows continuously increasing trend 2012. Another class shows presence for this specie shrub land (Fig. 5.8.).

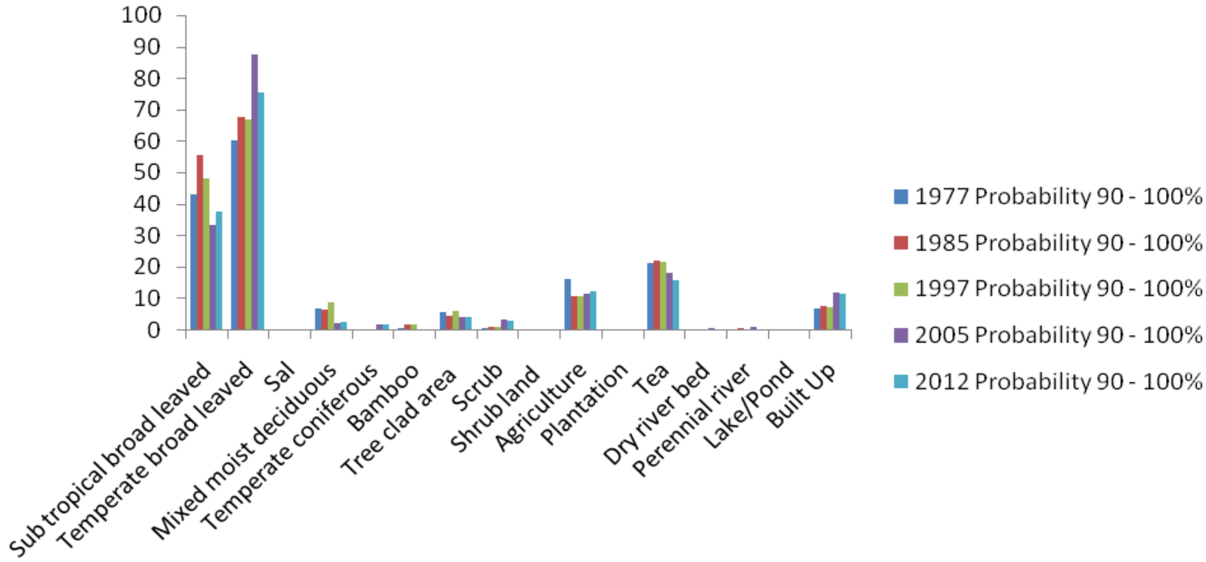

Fig. 5.5. Analysis of presence and absence of *Agapetes Serpens* in particular vegetation type from MaxEnt model (80- 90% probability).

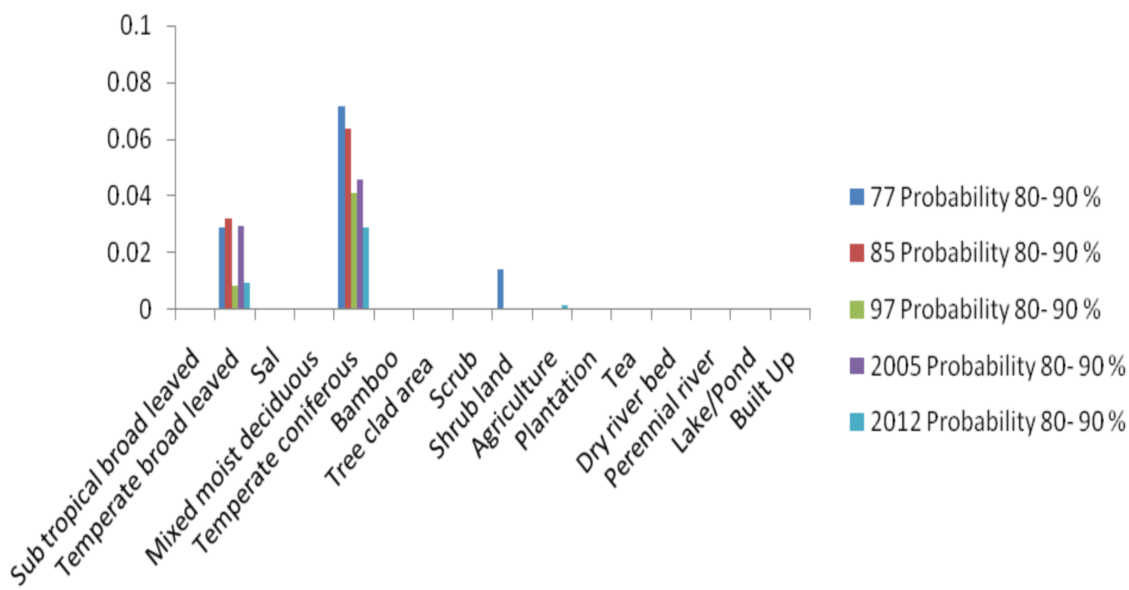

Fig. 5.6. Analysis of presence and absence of *Agapetes Serpens* in particular vegetation type from MaxEnt model (90-100% probability).

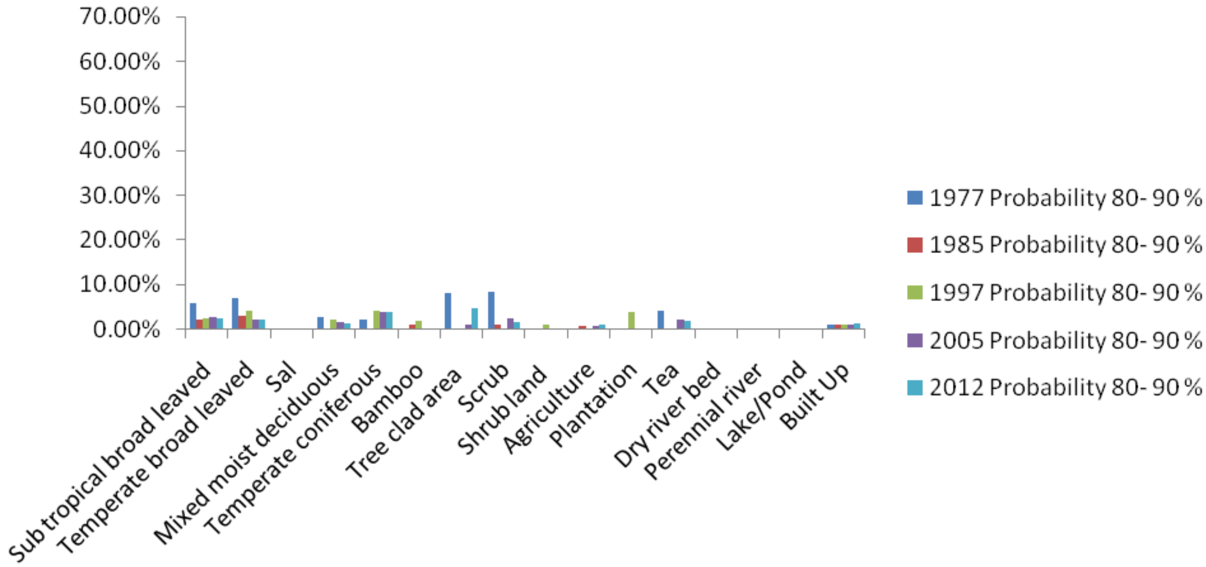

Fig. 5.7. Analysis of presence and absence of *Agapetes Serpens* in particular vegetation type from GARP model (80- 90% probability).

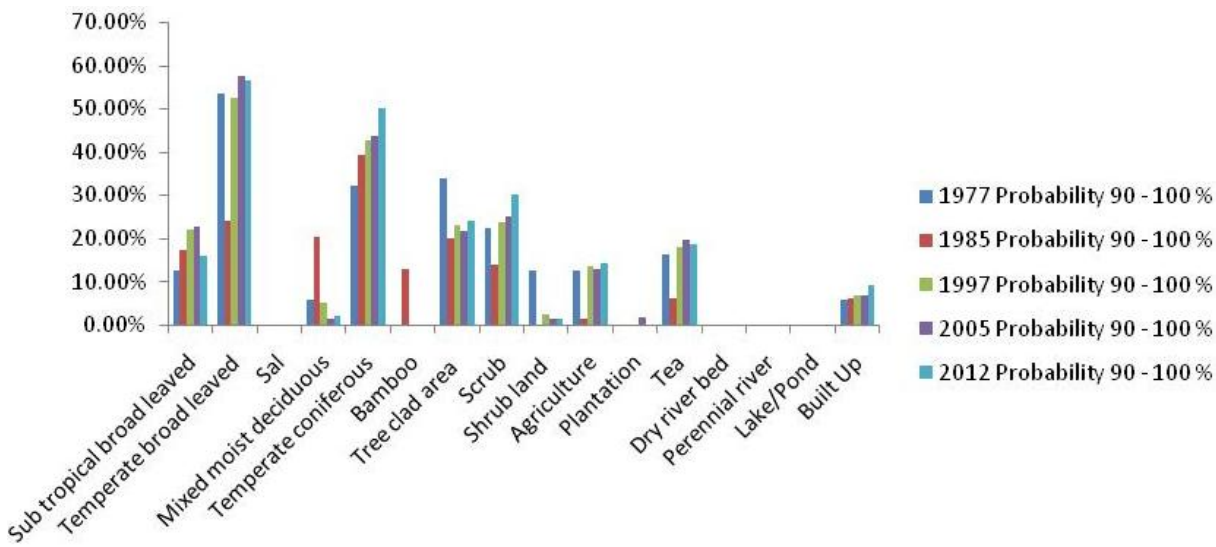

Fig. 5.8. Analysis of presence and absence of *Agapetes Serpens* in particular vegetation type from GARP model (90-100% probability).

5.2.5 *Rhododendron edgeworthii*

The influence of land use/ land cover change analysis has been done by two different models for five temporal data series. The *Rhododendron edgeworthii* distribution range is best generated from GARP model itself provided both right and left range of species. In case of MaxEnt the result which generated on the basis of occurrence point it is same range where the species location has been collected but one amazing result found that sudden fall in distribution this is due to natural disaster forest fire (Appendix 24, 25). On the basis LULC the analysis of different sixteen vegetation type was done for both the model between *Rhododendron edgeworthii*'s absence and presence records for all the years 1977, 1985 , 1997, 2005 and 2012.

The niche potential mainly increase from 1977 – 2012 but presence location of species percent shift from one class to other. In case of MaxEnt model for 80 – 90 %probability the presence of species has been found in seven classes such as Sub-tropical broad leaved, Temperate broad leaved, Temperate coniferous, Tree clad area, Agriculture, Tea and Built up. Sub-tropical broad leaved first show increase in 1985 and then decreases continuously. Continuous increment in Temperate broad leaved, Temperate coniferous does not show much change in its trend (Fig. 5.9.). In case of GARP model for 80 – 90 % probability the presence of species has been found in nine classes such as Sub-tropical broad leaved, Temperate broadleaved , Mixed moist deciduous, Temperate coniferous, Bamboo, Tree clad area, Scrub, Agriculture, Tea and Built up. The trend was analyzed for the presence record in 1977 it only found in Temperate coniferous and for Sub-tropical broad leaved it shows presence in 1985. The presences of this species were recorded in other class from 1977. The presence of this species shown from 1997 in other classes such as Sub-tropical broad leaved, Temperate broad leaved , mixed moist deciduous, Temperate coniferous, Bamboo, Tree clad area, Scrub, Agriculture, Tea and Built up. Temperate broad leaved and Temperate coniferous shows decrease trend for presence of species (Fig. 5.11.).In case of MaxEnt model for 90 – 100 % probability the presence of species has been found in seven classes such as Sub-tropical broad leaved, Temperate broad leaved, Temperate coniferous, Scrub, Agriculture, Tea and Built up. The trend was analyzed for the presence record for Sub-tropical broad leaved, Scrub, Agriculture, Tea and Built up do not shows much change in its trend. Temperate broad leaved and Temperate coniferous trend remains almost same increasing (Fig. 5.10.). In case of GARP model for 90 – 100 % probability the presence species has been found in ten classes such as Sub-tropical broad leaved, Temperate broadleaved , mixed moist deciduous, Temperate coniferous, Tree clad area, Scrub, Shrub land, Agriculture, Plantation, Tea and Built up. The trend was analyzed for the presence record for Sub-tropical broadleaved, mixed moist deciduous, Shrub land, Plantation and Built up shows decrease in trend. Temperate broad leaved and Temperate coniferous shows the sudden decrease then increment for other years. Tree clad area, Scrub and Agriculture continuously shows increment till now. Tea shows consistent trend of presence for all the years (Fig. 5.12.).

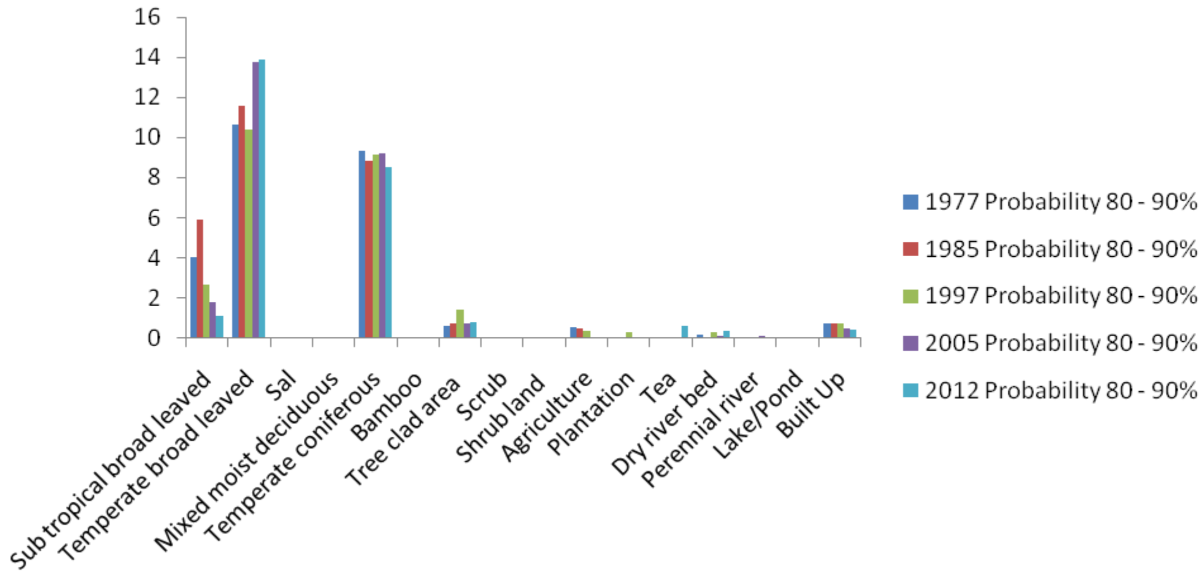

Fig. 5.9. Analysis of presence and absence of *Rhododendron edgeworthii* in particular vegetation type from MaxEnt model (80- 90% probability).

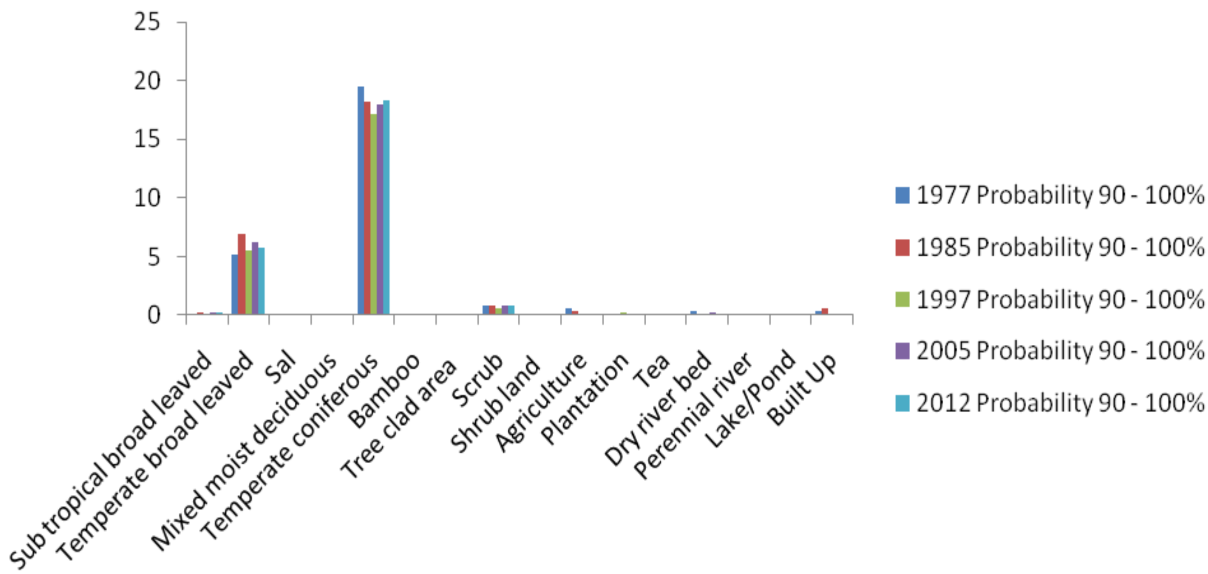

Fig. 5.10. Analysis of presence and absence of *Rhododendron edgeworthii* in particular vegetation type from MaxEnt model (90-100% probability).

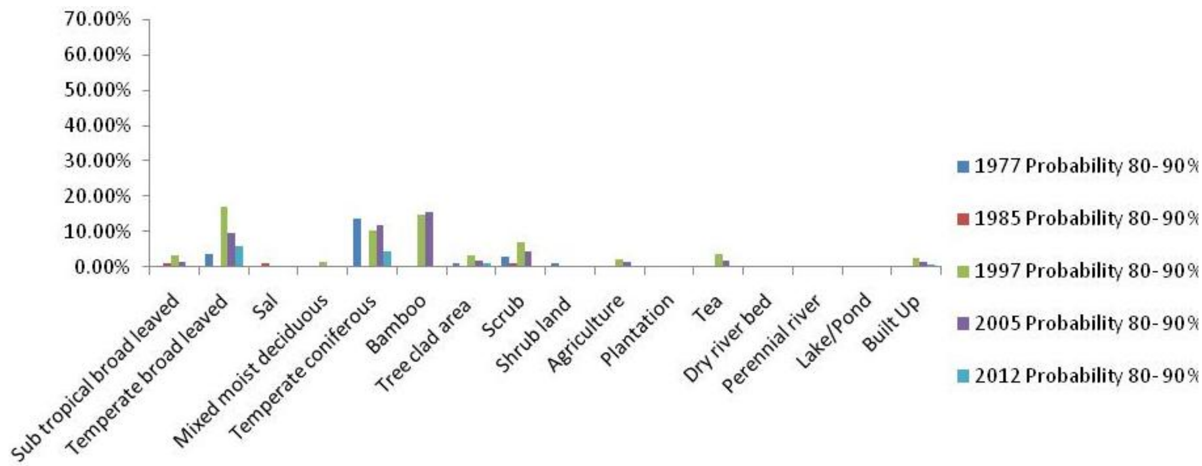

Fig. 5.11. Analysis of presence and absence of *Rhododendron edgeworthii* in particular vegetation type from GARP model (80- 90% probability).

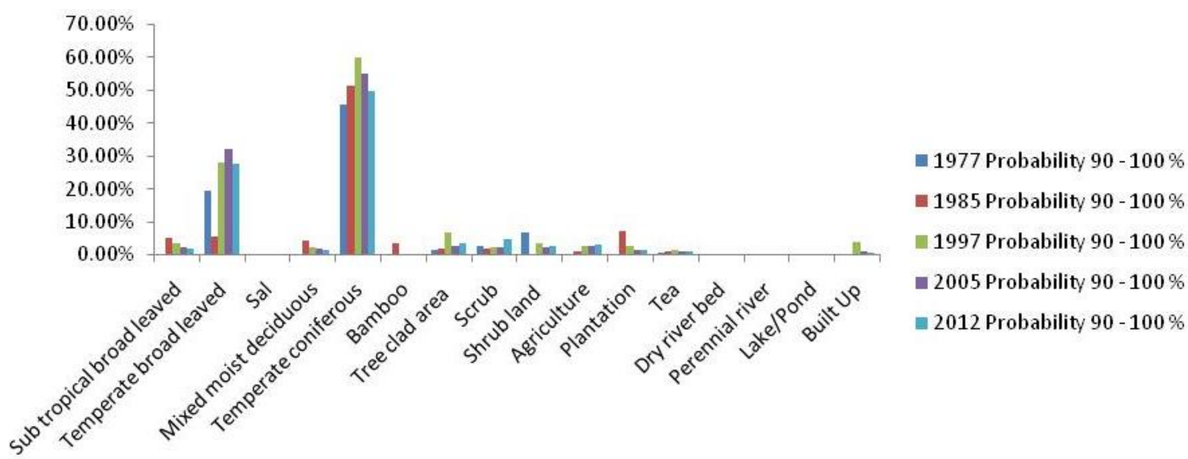

Fig. 5.12. Analysis of presence and absence of *Rhododendron edgeworthii* in particular vegetation type from GARP model (90-100% probability).

5.3 Percentage contribution of different bio-climatic variables on all three species

On the basis of five temporal dataset the analysis of variables has been done for all the years such as 1977, 1985, 1997, 2005 and 2012.Based on the results of 24 variables statistical analysis, for *Aconitum napellus* following variables were selected for best prediction such as annual mean temperature, minimum temperature of coldest month, mean temperature of wettest quarter, annual precipitation, precipitation of wettest month, precipitation of driest month, precipitation of driest quarter , Precipitation of coldest quarter , elevation, aspect, fragmentation and land use / land cover (Fig. 5.13.) , for *Agapetes serpens* following variables were selected for best prediction such as annual mean temperature, mean diurnal range, isothermality, maximum temperature of warmest month, minimum temperature of coldest month, temperature annual range, mean temperature of wettest quarter, mean temperature of driest quarter , mean temperature of warmest quarter, mean temperature of coldest quarter, precipitation of driest month, Precipitation seasonality, slope, elevation, fragmentation and land use / land cover and (Fig.5.14.) for *Rhododendron edgeworthii* following variables were selected for best prediction such as annual mean temperature, temperature seasonality, minimum temperature of the coldest month, temperature annual range, mean temperature of coldest quarter, precipitation of wettest month, precipitation of driest month, land use / land cover (Fig.5.15.).

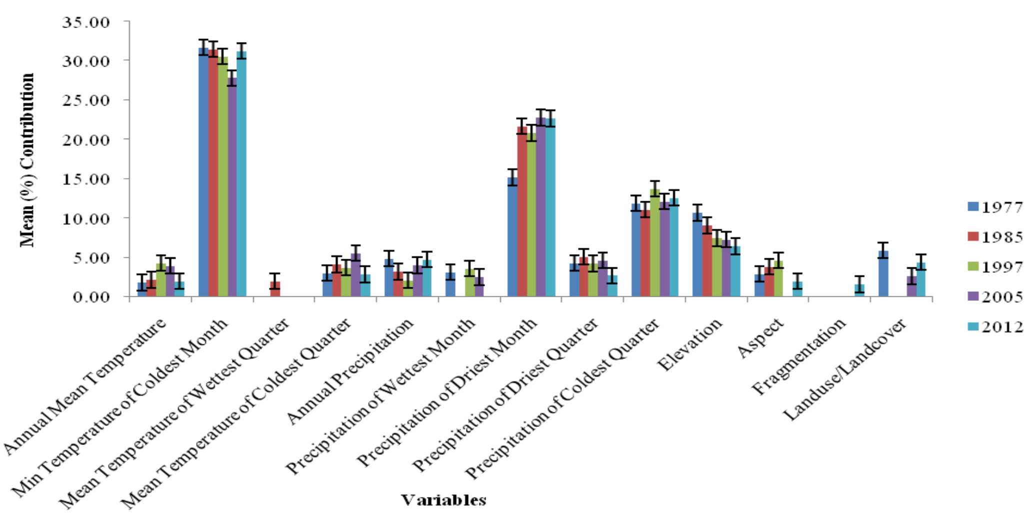

Fig. 5.13. Analysis of variables percentage contribution on potential niche distribution of *Aconitum napellus* (1977 – 2012).

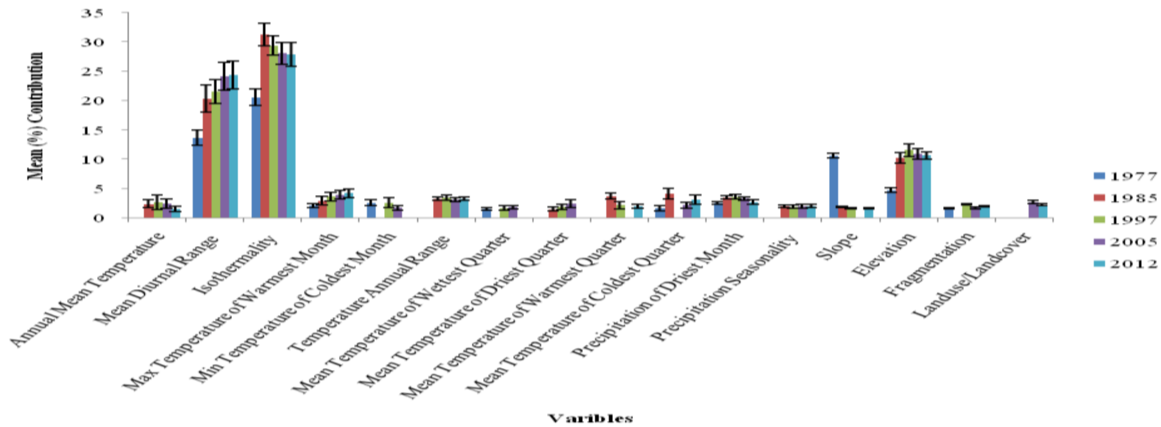

Fig. 5.14. Analysis of variables percentage contribution on potential niche distribution of *Agapetes serpens* (1977 – 2012).

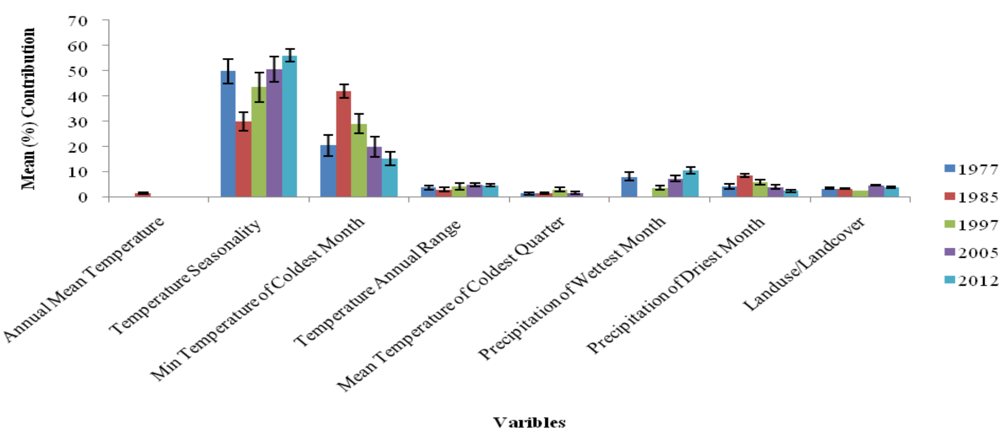

Fig. 5.15. Analysis of variables percentage contribution on potential niche distribution of *Rhododendron edgeworthii* (1977 – 2012).

5.4 Predicting the species distribution in Climate change Scenario

5.4.1 Model development

After analysis the result of MaxEnt and GARP model for future prediction of 2050 scenario A2a and B2a using predicted LULC from CA- Markov. The result which both the model produced is not accurate. The predicted LULC 2050 shows some shift in the individual classes on the basis present LULC 2012. Due this analysis the idea generated that the presence location point which was used in the model is remain same but the classes of that particular place got changed. Hence, on the basis of this further carried out a forward stepwise logistic regression of the training distribution of data of the species with elevation, slope, aspect, diurnal range temperature, mean annual precipitation, mean annual temperature and mean temperature of wettest quarter and LULC with respect to particular year the variables were selected. The model was developed on the basis the basis of variables. For each variable equation has been generated and in last all equation had been summed and final result produced. This model has been developed for the three species for future prediction of year 2050 both scenario A2a and B2a (Fig. 5.16).

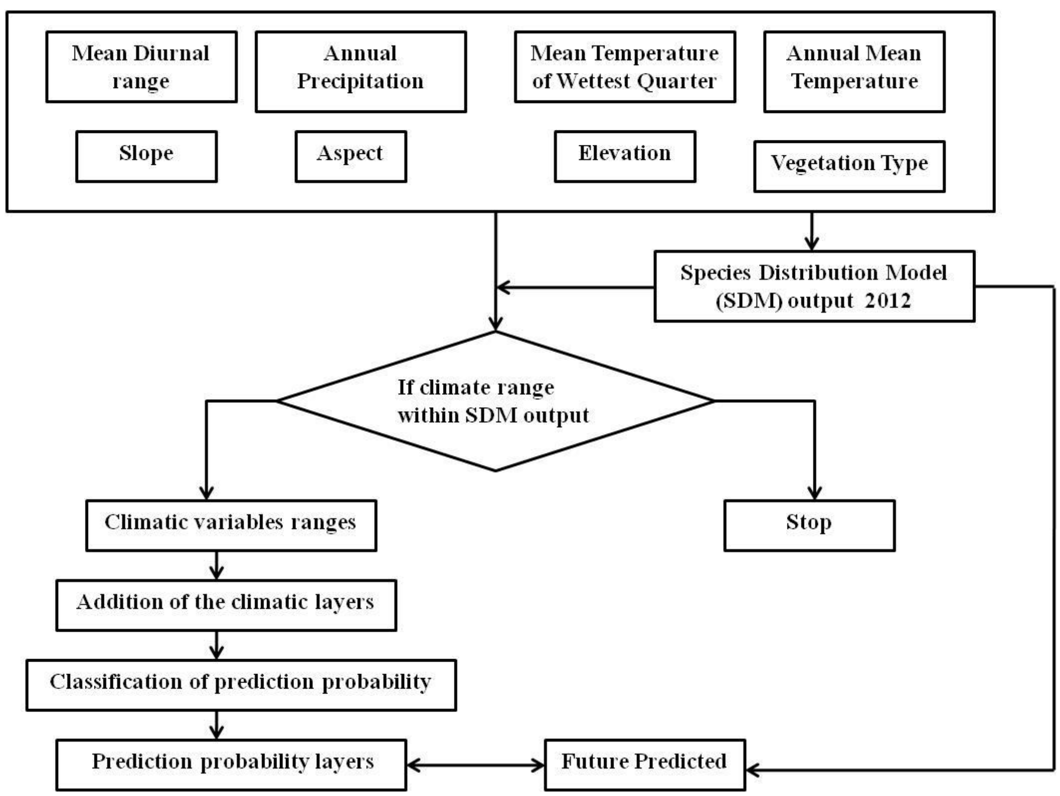

Fig. 5.16. Model for future prediction.

5.4.2 Model validation

The model validation was done for the result which produced from the developed model for future prediction 2050 A2a and B2a.The results generated validated for 2012 with the current niche generated through existing niche model outputs. Further analysis was done and the result was compared on the visual basis of other model result for the same year means 2012. This process has been done for the three endemic species such as *Aconitum napellus* , *Agapetes serpens and Rhododendron edgeworthii* and map were generated for all three species year 2012 , using the future model for current data whose presence location was matched with both the model and so, the validation was confirmed Appendix 26-28. By this model understanding of the probability level became easier than the other two models. On the basis of field survey the model result were analyzed and it was very accurate for all species. And further this model was used for other future dataset.

5.4.3 Model prediction 2050 A2a

The climate change special Report on emission scenario for A2 is a regionally oriented economic development scenario with a temperature increase of 2.0 - 5.4 ºc. On the basis of the result of 2012 the probability level of 2050 A2a scenario decrease for the species which has been considered as an awful sign on the basis of economic development. For *Aconitum napellus* has an enormous medicinal value. It has huge demand in the pharmacy laboratory to prepare medicines and for *Agapetes serpens* has a little medicinal value. It has huge demand in the natural remedies to prepare medicines. But in case of *Rhododendron edgeworthii* on the basis of result 2012 the probability level of a 2050 A2a scenario increase for the species which has been considered as an excellent sign on the basis of economic development. *Rhododendron edgeworthii* has an enormous medicinal value. It has huge demand in the pharmacy laboratory to prepare medicines. Appendix 29-31.

5.4.4 Model prediction 50 B2a

The climate change special Report on emission scenario for B2a is a local environmental sustainability in 1.4- 3.8 ºc. On the basis of the result of 2012 the probability level of 2050 B2a scenario sustain for the species which has been considered as an excellent sign on the basis of environmental sustainability. For *Aconitum napellus* has an enormous medicinal value. It also helps in maintaining the sustainable environment for other species which are associated with it due to its poisonous nature, for *Agapetes Serpens* has a little medicinal value. It helps in maintaining the sustainable environment for other species with whom it associates. This species generally found on mature tree it helps in retaining the water capacity of the particular tree and for *Rhododendron edgeworthii* has an enormous medicinal value. It has huge demand in the pharmacy laboratory to prepare medicines. Appendix 32-34.

5.5 Potential niche of present IIPCC scenario

The potential niche of the three endemic species showed variable changes with the climate change (IPCC) scenarios. As expected *Agapetes serepens* and *Aconitum napellus* showed decrease in the potential area of spread for all the probability levels but surprisingly *Aconitum napellus* showed a slight increase in A2a scenario as compared to B2a. Most surprising is the trend seen in *Rhododendron edgeworthii* where in the A2a IPCC scenario the potential niche of the species is seen to increase.

Table 5.10 Potential areas of *Aconitum napellus*, *Agapetes serpens* and *Rhododendron edgeworthii* for the present and predicted IPCC scenarios.

		FUTURE PREDICTED NICHE (Area in Sq km)		
Sl.no.	**Probability level(%)**	**2012**	**2050_A2a**	**2050_B2a**
		Aconitum napellus		
1	50	3092.30	3085.53	3107.22
2	60	27.08	27.93	17.05
3	70	13.54	16.93	14.50
4	80	9.31	11.85	3.41
5	90	5.92	4.23	5.12
6	100	0.85	2.54	1.71
		Agapetes serepens		
1	50	2296.80	2341.65	2120.77
2	60	197.18	482.38	445.99
3	70	174.33	204.80	178.56
4	80	152.33	80.40	94.78
5	90	146.41	21.16	141.33
6	100	181.95	18.62	167.56
		Rhododendron edgeworthii		
1	50	2893.40	2130.08	2695.78
2	60	155.71	214.11	281.40
3	70	45.70	315.66	119.34
4	80	30.47	319.89	30.47
5	90	18.62	149.79	16.08
6	100	5.10	19.46	5.92

Chapter -6

DISCUSSION

6.1 Prediction of species niche

In most of the studies, the effects of climate and potential niche of the species have been generally considered separately. In this study the relation of climate change, LULC and changes in the potential niche has been considered together to model the changes in the potential of the species due to climate change. Here the relationship between the elevation and ecological niche in Darjeeling hills of important endemic species has been explored. It was observed that the species which survive in cold temperature or more rainfall are showing shift in its niche, some are moving toward higher elevation and some species towards lower elevation (Koleff, P., and Gaston,K.J., 2001) . Results suggest that the relationships between the climate and habitat components of the niche have to be taken into account to understand and predict changes in species' distributions. Best way to understand the climate change impact on the species and consider this for further prediction particular species.

6.2 Controlling factors of target Species' survival

6.2.1 Niche selection/Identification

The niche selection of *Aconitum napellus*, *Agapetes serpens and Rhododendron edgeworthii* has been analyzed considering all the environmental factors. For *Aconitum napellus niche* has been modeled using climatic variables such as annual mean temperature, minimum temperature of the coldest month, mean temperature of wettest quarter, annual precipitation, precipitation of wettest month, precipitation of driest month, precipitation of driest quarter , Precipitation of coldest quarter, elevation, aspect, fragmentation and land use / land cover (Srivastava, U. C., 2001, The Plant List, 2010) . The potential niche of *Agapetes Serpens niche* has been modeled on the basis of all the climatic variables used in *Aconitum napellus* accept for such as mean diurnal range, isothermality, maximum temperature of the warmest month, a minimum , temperature annual range, mean temperature of driest quarter, mean temperature of warmest quarter, mean temperature of coldest quarter, precipitation of driest month, precipitation seasonality, slope (Singh P, Chauhan AS. 1997, The Plant List, 2010) and the potential niche of *Rhododendron edgeworthii* niche has been analyzed on the basis of all the climatic variables use in *Aconitum napellus* and *Agapetes serpens* accept for temperature seasonality. (Polunin, O. and Stainton, A. 2003, The Plant List, 2010).

The elevation range of *Aconitum napellus*, *Agapetes serpens and Rhododendron edgeworthii* generally overlap to sub tropical broad leaved and temperate broad leaved. Sub tropical broad leaved and Temperate broad leaved regions generally have a cooler temperature than the adjacent lowland regions. Good separation of temperature data, precipitation data, elevation and land use/ land cover between absence and presence confirm it. Considering the all sixteen vegetation types the summary of more accurate and frequent vegetation type was decided on the basis for both models and both probability levels (80-90% and 90- 100%) show that niche loss due to LULC change is the reason for the niche shifts. The result confirmed that *Aconitum napellus ´* potential niche at present in to Sub tropical broad leaved and temperate broad leaved forests but is shifting towards the temperate coniferous. In case of *Agapetes serpens* range of presence records was observed in temperate broad leaved, temperate coniferous, tree clad area, scrub, tea, sub tropical broad leaved, agriculture, shrub land and built up. The result confirmed that *Agapetes Serpens ´*s potential niche at present insub tropical broad leaved and temperate broad leaved forest but is shifting towards the temperate coniferous and other non forest type such as mostly built up. For *Rhododendron edgeworthii ´*s potential niche belongs to temperate broad leaved but it is moreover shifting towards the temperate coniferous other non forest type such as mostly scrub , shrub land and built up due to the influence of climate and land use and land cover changes.

6.2.2 Influence of variables: Ecological Basis

Jackknife test of MaxEnt´s final model for *Aconitum napellus* , *Agapetes serpens and Rhododendron edgeworthii* .In case of *Aconitum napellus* ranked the minimum temperature of coldest month as first, the precipitation of driest month as the second, the precipitation of the coldest quarter as third and elevation as fourth. From existing literature variables such elevation is known as the important niche for *Aconitum napellus* (http://en.wikipedia. org/wiki/ Aconitum_napellus, Behera,et al., 2002). However this result can be interpreted that the minimum temperature of coldest month is more important than the elevation. In case of *Agapetes serpens* jackknife test of MaxEnt´s final model ranked the isothermality as first, the mean diurnal range as the second, elevation as third, slope and LULC both as fourth. From existing literature variables such as elevation and LULC is known as the important niche for *Agapetes serpens* . However this result can be interpreted that the isothermality and mean diurnal range important than the elevation and LULC. For *Rhododendron edgeworthii* jackknife test of MaxEnt´s final model ranked the temperature seasonality as first, the minimum temperature of coldest month as the second, the precipitation of the wettest month as third and land use/land cover as fourth. From existing literature variables such as land use/ land cover is known as the important niche for *Rhododendron edgeworthii*. However this result can be interpreted that the temperature seasonality important than the land use / land cover. Till now there was no study for investigating the relative importance of elevation and land use/land cover for species distribution. One possible interpretation is that, considering the variables both temperature and precipitation are important factors in climate change, these results suggest that climate disturbance have a more considerable negative influence on species distribution than it is currently perceived. For *Aconitum napellus* it was suggested that even for the minimum temperature of coldest month, for *Agapetes serpens* isothermality and mean diurnal range and for *Rhododendron edgeworthii* temperature seasonality and minimum temperature of coldest month,which look close to nature, the negative impact on the its distribution should not be neglected.

6.3 Distributional patterns

Potential niche for *Aconitum napellus, Agapetes serpens and Rhododendron edgeworthii* in Darjeeling hills has been predicted by two approaches. The two modeling algorithms predict *Aconitum napellus* ´s presence in the north west region of Darjeeling hills where Singalila national park and pattern were similar. But map which was produced by GARP provides additional pattern in north east region and central regions of Darjeeling hills where Neora valley national park and Senchal wildlife sanctuary respectively. (http://www. icimod.org/hkhc onservationportal/PA.aspx?ID=18). The potential niche was correct in both the model but more accurate was in the case of GARP. *Agapetes Serpens* ´s shows presence in North West, northeast and central region of Darjeeling hills where Singalila national park, Neora valley national park and Senchal wildlife sanctuary respectively and pattern wsimilar, the potential niche was correct in both the model and also accurate in both the case. *Rhododendron edgeworthii* ´s presence in the North West region of Darjeeling hills where Singalila national park and pattern were similar. But map which was produced by GARP provides additional pattern in north east region and central regions of Darjeeling hills where Neora valley national park and Senchal wildlife sanctuary respectively. The potential niche was correct in both the model but more accurate was in the case of GARP. The trend observed potential niche for both the model showed decreasing trend and also range shift from forest to non forest. This analysis was based on the study of temporal data sets of 1977, 1985, 1997, 2005 and 2012.

6.3.1 Role of LULC on species niche

It is well-known that habitats composed of spatially heterogeneous abiotic conditions provide a great diversity of suitable niches for plant species (Elith J., Leathwick J.R., 2009). Land use / Land cover changes play a very important role on species niche (Sala et al 2000). Darjeeling Natural vegetation has been transformed from dense vegetation cover to, more and more managed ecosystems. These changes are associated with the process of removing the trees from an area of land, loss in biodiversity and reduction in land. A synthesis of results from five temporal data such as 1977, 1985, 1997, 2005 and 2012 land use / land cover. The results indicate that as local vegetation is lost, native plant and animal biodiversity and plant cover are lost. Due to a loss in biodiversity and plant cover many species were lost their niche. As per model result it was observed the shift of species niche from forest type to non-forest type.

6.4 Different performances of modeling algorithm

The analysis revealed that performance of modeling algorithms differs for different kind of species with respect to probability as cut off, and test data or train data. GARP algorithm produced the most accurate map among two chosen algorithms for the *Aconitum napellus* with Kappa value = 0.7076 at p= 0.5 and AUC = 0.996. Similarly, MaxEnt algorithm produced the most accurate maps were produced for *Agapetes serpens* with Kappa value = 0.786 at p = 0.5 and AUC = 0.970. For species *Rhododendron edgeworthii* both models produced almost same kappa value such as 0.726 and 0.729 at p= 0.5 and AUC = 0.997 and 0.962, the most accurate map generated from the GARP algorithm. These results suggest that the performance of modeling algorithm depends on the kinds of species distribution (Segurado *et al*., 2004). There is a difference between the accuracy of the maps generated by different modeling algorithms. This is the first attempt to investigate appropriate modeling methods for the chosen species: *Aconitum napellus*, *Agapetes serpens* and *Rhododendron edgeworthii*. A suggestion is made that the GARP algorithm may be useful to model *Aconitum napellus*´s distribution, and the MaxEnt algorithm may be appropriate to the model the *Agapetes serpens*´s distribution. However, *Rhododendron edgeworthii* perform better with both the model algorithm.

6.4.1 Probability cuts off

Generally, indices, such as Kappa coefficient, proportion agreement, sensitivity and specificity, showed better scores at an optimum cut off than the ones at a probability cutoff 0.5. First of all; the above mentioned indices are highly dependent on a threshold value (Bonn et. al., 2001 ,Hosmer et. al.,1989 ,Fielding, A. H, and Bell, J.F., 1997) . Bonn (2001)stated that but even when optimum probability is examined, possible evaluation of niche model transfers based on confusion matrices might lead to seemingly unsatisfactory results, merely because of differences for optimum within comparative datasets. However, this opinion is based on the transferability of niche model. At the current moment, no validation technique was superior in all circumstances. The result indicates that the accuracy of the models can be maximized by implementing an optimum cut off threshold. On the other hand, ROC plots and AUC have their own advantage that they are independent of the threshold value probability and AUC provides a single quantitative index of diagnostic accuracy of the model. In general, recommend employing multi- evaluation techniques, such as Kappa statistics at an optimum cut off value of probability, ROC plots, and AUC.

6.4.2 Test data and train data

Basically, the accuracy of the test data was lower than the train data. In case of MaxEnt, there was not a big difference in the performance between the test and train data for all the three species the AUC range is approximately 1. In case of GARP there was little difference in the value of AUC for all the three species. It can be due to the area capacity, for larger area MaxEnt performs better and for small area GARP perform best. There can be one more reason such as for low occurrence data GARP gives fine result and for large occurrence data MaxEnt performs best. While considering these all, suggested that the precision of GARP´s predictive map was sufficiently and accurate for smaller area than MaxEnt. In comparison with GARP, the important disadvantage of MaxEnt was the continuous and its range was more with respect vegetation type class which shows the overestimation for the species (Phillips et al., 2006 and Gracía, J.R.M., 2006). Considering the accurate assessment and Kappa value of MaxEnt model potential distribution of all the three species was lower than GARP model. The reason for this result may be due to the GARP characteristics. The difference in the value of test and train data to GARP´s capacity to detect accurate probability of species occurrences. But with respect to the value of Area under curve the MaxEnt was a continuous and precise prediction.

6.5 Applicability

6.5.1 Applicability of the methodology

It was prepared a set of simple criteria and assesses suitable study area and species. Which was considered widely applicable for similar research because of its generality? To be more scientific, it is recommended to test whether the target species truly hold a potential niche or not (Bonn et. al., 2001).

The data source used to create a Geo – database is mainly freely available through websites. This approach is more cost effective than the actual measurement of each environmental variable in fieldwork. Especially, if the study area is large and if many variables should be prepared. It has advantages for replication of research. Our method, species´ record extraction, is only applicable when the similar data – point observation in maps – is available, but is quite effective to extract the species´ occurrences with coordinates in space. The method adopted for the data compilation and preparation for test and train data is widely used techniques (Botanical Survey of India, 1983).

The statistical analysis is extremely important to justify our selection of predictors. It was highly recommended the statistical technique adopted in this thesis especially for the main objective niche analysis. The multi-evaluation techniques, such as kappa statistics at an optimum cut off value of probability, ROC plots, and AUC. These techniques are widely used and applied techniques for validation. To compute an optimum cut off probability is highly recommended. It was found that the software (Institut für Geoökologie, 2007) did not function well, when the prediction is perfect (such as Kappa = 1 and AUC = 1) and the opposite situation (such as Kappa = 0 and AUC = 0.5). If such case happens we suggest using R version 2.4.0 (Gentleman, R.I. a.R., 1996 and R Development Core Team 2006) to compute optimum cutoff values. Method to estimate the local population is applicable when the area and species occurrence data is known. Such estimation is more cost – more effective than the actual count of individuals in the field. However it is important to know that this approach heavily relies on the reliability of area and species occurrence data.

6.5.2 Applicability of the predictive models

As modeling techniques were adopted both widely applicable modeling algorithms, namely MaxEnt (Maximum Entropy) and GARP (Genetic Algorithm for Rule-set Production). If which algorithm fits the target species' distribution best is not known, such as model comparison is useful(Peavey, L., 2010).Output revealed that two chosen modeling algorithms perform much better than a random prediction for all the three species. In case of GARP it generates more accurate potential spatial distribution maps of the target species. MaxEnt is also the best algorithm to predict the distribution of all the species. MaxEnt drawback is that it's not able to predict for the same range whose point coordinates are unknown. In order to apply these findings, required input data for GARP and MaxEnt is the species' presence points and spatial predictors which satisfy (same window size – extent to study area, same coordinate system, and same cell size.

6.5.3 Applicability of the predictive maps

Utilizing GARP and MaxEnt modeled geographic distribution of *Aconitun napellus* , *Agapetes Serpens* and *Rhododendron edgeworthii* at a resolution of 60 m by 60 min Darjeeling hills west Bengal . In general, the two chosen modeling algorithm performed much better than a random prediction for all species. The accuracy of map assessed by kappa statistics at the optimum threshold of probability and ROC and AUC plots. The first application is contributing to the preparation of a local level conservation plan in Darjeeling. For example, analysis of fragmentation, identification of suitable niche patches can be carried out. For further analysis, Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), and design of ecological networks for the endemic species. As an analytical tool, integration of GIS into Multiple criteria evaluation (Sadler, B., and Verheem, R., 1996) techniques are recommended. It also contributes to the preparation for the appropriate zoning plan which can help the local community and board to decide at which level the conservation of species to be done and where.

6.6 Distributional patterns of Future scenario

Models and scenarios for future climate in Darjeeling predict significant changes by 2050 in the distributions of nearly all of the three species examined. Reduction in the area of distribution according to a majority of models/scenarios is predicted for 1species, whereas the distribution areas of 2 species are predicted to expand; contraction versus expansion is equivalent for 2 species (Midgley, et. al., 2003). However, expansion versus contraction is by no means the only response. Many species, both those exhibiting expansion and contraction, also manifest significant shifts in their predicted distribution areas in comparison to their known (historical and contemporary primary occurrence points) and predicted the current (= 2012) distributions. Significant shifts in distribution areas will thus require dispersal in order to track suitable niche during the next 37years. A number of robust patterns of congruent response among species emerge with respect to vegetation types, bioclimatic zones, and geographic areas. Among the 2 species (*Agapetes serpens and Rhododendron edgeworthii*) for which expansion was predicted from 2012 to 2050, for 1 species (*Aconitum napellus*) contraction was predicted. The future scenario for 2050 A2a and B2a itself a predicted result of climate model and on the basis of this the result was generated and these all were decided for particular species and particular region for their sustainable environment. But if there were some change was predicted due to natural environment the prediction may get changed.

The changes in the potential niche distribution and area of the three endemic species i.e. *Aconitum napellus*, *Agapetes serpens* and *Rhododendron edgeworthii* in climate change scenarios (i.e. IPCC, A2a and B2) have thrown up some interesting trends. From the results it is obvious that the potential niche of Agapetis and Aconitum will decrease and is under threat due to climate change. But surprisingly *Rhododendron edgeworthii* which is reported to be under threat mainly due to LULC change and overexploitation in climate change scenario especially IPCC-A2a is expected to have a increase in its potential niche due to the climate change scenarios.

6.7 Vulnerability of Species to Climate Change

Potential effects of climate change are different depending on the species. For *Aconitum napellus*, climate change tends to extent the suitable habitat of the species towards Nort-West of Darjeeling. Aconitum is adapted to very high altitude with a strong climatic variation. Thus,the predicted increase in temperature for 2050 A2a and B2a scenario. (Hannah et al; 2008) tends to extend the suitable habitat of this species. In case of *Agapetes serpens* the potential suitable sites disappearing due to fragmentation area is also reducing. But it remains in two part of Darjeeling hills North West and North East on the basis of present scenario. *Agapetes serpens* , showed most changes in climate change scenario A2a in 2050 which has lead to a sharp decline in niche. For *Rhododendron edgeworthii* for both the scenario 2050 A2a and B2a area shows an increase so, for this species it is still not clear whether the climate change is going to be favourable or un favourable. (Vieilledent et al; 2013).

Chapter-7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The uniqueness of this study is to model shifts in the potential niche of selected endemic species in Darjeeling hills as a result of land use/ land cover and climate change. The distribution and concentration of endemic plants in a particular region are an index of the overall biogeography of the area. It has been observed that endemic plants occur in a mosaic of climatic, hydrological, topographical and edaphic features. Wherever climate, topography and rain fall shifts suddenly occur over time and space, then there are chances of a change in patterns of endemic elements favouring particular ecological niche. To know about the potential of endemic centers, it is necessary to look for such variables like climate shifts, topographical discontinuities and rainfall changes. Considering that the Darjeeling hills have a high diversity of medicinal plants that should be care and most of them are endemic which are more useful in building the biodiversity of the region. Additional studies are also necessary to identify possible links between a plant´s chemical composition and its niche. To determine how human population in Darjeeling hills select and use these plants for daily purpose. The participation of public and private association in the management and utilization of medicinal plants in sustainable approach is indispensable to content human pressure on these valuable natural resources.

The effect of global climate change on the areas and distribution patterns of wild relatives of cultivated plants will be assessed. Eastern Himalayas of which Darjeeling hill is a part of, is the center of origin of several plant species (Vavilov, 1937) that have been domesticated and played an important role for humans. Endemic species of some families such as the Ericaceae and Ranunculaceae had an important role in conserving the genetic traits that can mitigate reduction in their distribution and avoid extinction by ex situ conservation. The results are useful for present scenario while, considering the result and the importance of particular endemic species should be decided. And conservation techniques should be identified according to the demand of the species.

The maps was generated from the models should be considered as a base line data for all three species. Because it has all presence and absence record of the particular species and also validate from multi evaluation techniques. So, that all those results can be used as inputs for conservation and prioritization. Based on the most accurate predictive map for each species, potentially suitable niche was identified as the core area.

It was observed that Aconitum *napellus* ranges has decreased considerably and is found in the Singalila national park and to some extent in Neora valley national park. This species is an important medicinal plant extensively used. Considering its medicinal value this is an urgent need to conserve it. But scenario shows that its niche will show a continuous decrease. In case of *Agapetes serpens* the distribution also shows a decrease due to development in and around Darjeeling.

This species is mainly found on mature trees and due to excessive deforestation and logging its number has reduced considerably. In case of *Rhododendron edgeworthii*, it shows that its number is expected to increase due to climate change scenario.

7.2 Recommendations

Ecological niche is now generally regarded as essential not only for conserving biodiversity but also for promoting economic development and sustainable livelihoods, particularly in the developing countries (SER 2004b). Likewise, a potential niche within and around degraded ecosystems provides a powerful tool for maintaining or increasing resilience and connectivity in natural environments, thereby reducing the vulnerability of these ecosystems and their resident biodiversity to the projected consequences of climate change. This is especially important in ecosystems with strong and steep ecological gradients, as these areas are particularly at risk.

Impacts of climate change are likely to be particularly severe, governments, communities, corporations and NGOs can increase the chances of conserving endemic species and biotic communities. It is essential that reserves are increased in size and connected to other reserves within the context of increased ecosystem function and structural complexity at the landscape scale in order to safeguard biodiversity against the uncertainties of climate change. The loss of niche and biodiversity at the local level is due to ecosystem degradation as such it needs global society’s response to the ecological management and economic activities.

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URLS

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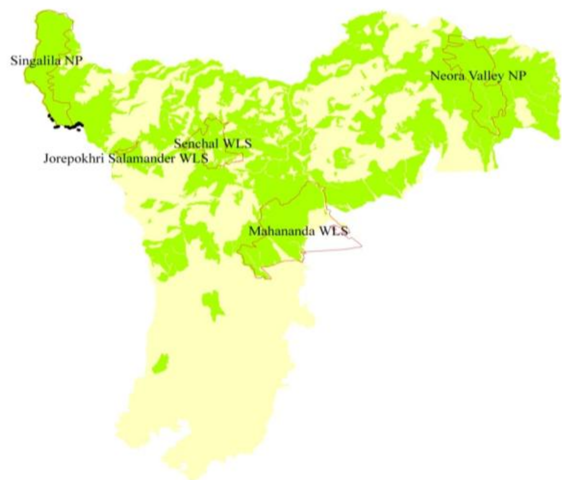
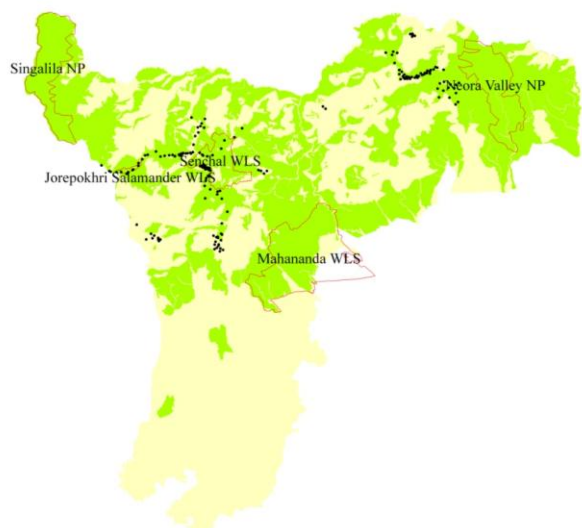
APPENDICES

Appendix 1. Species Location point of *Aconitum napellus* in Darjeeling hills.



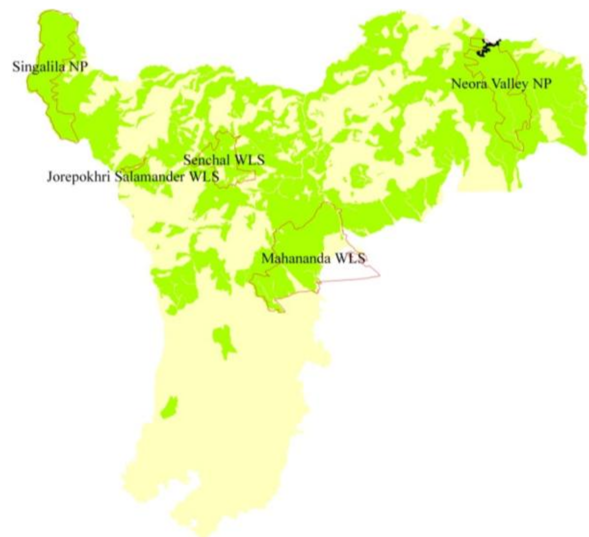
Green color shows forest area, Yellow color Non-forest area and Red colors protected area and Black Occurrence point of species.

Appendix 2. Species Location point of *Agapetes serpens* in Darjeeling hills.



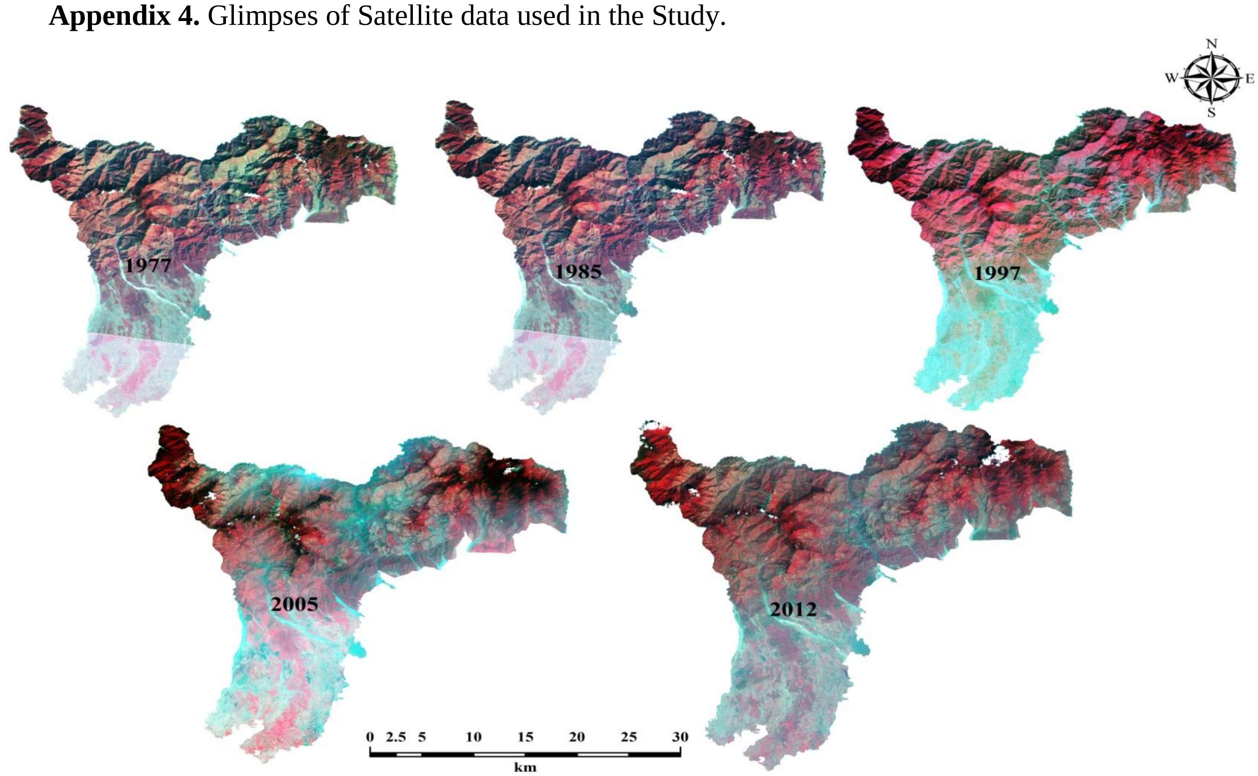
Green color shows forest area, Yellow color Non-forest area and Red colors protected area and Black Occurrence point of species.

Appendix 3. Species Location point of *Rhododendron edgeworthii* in Darjeeling hills.



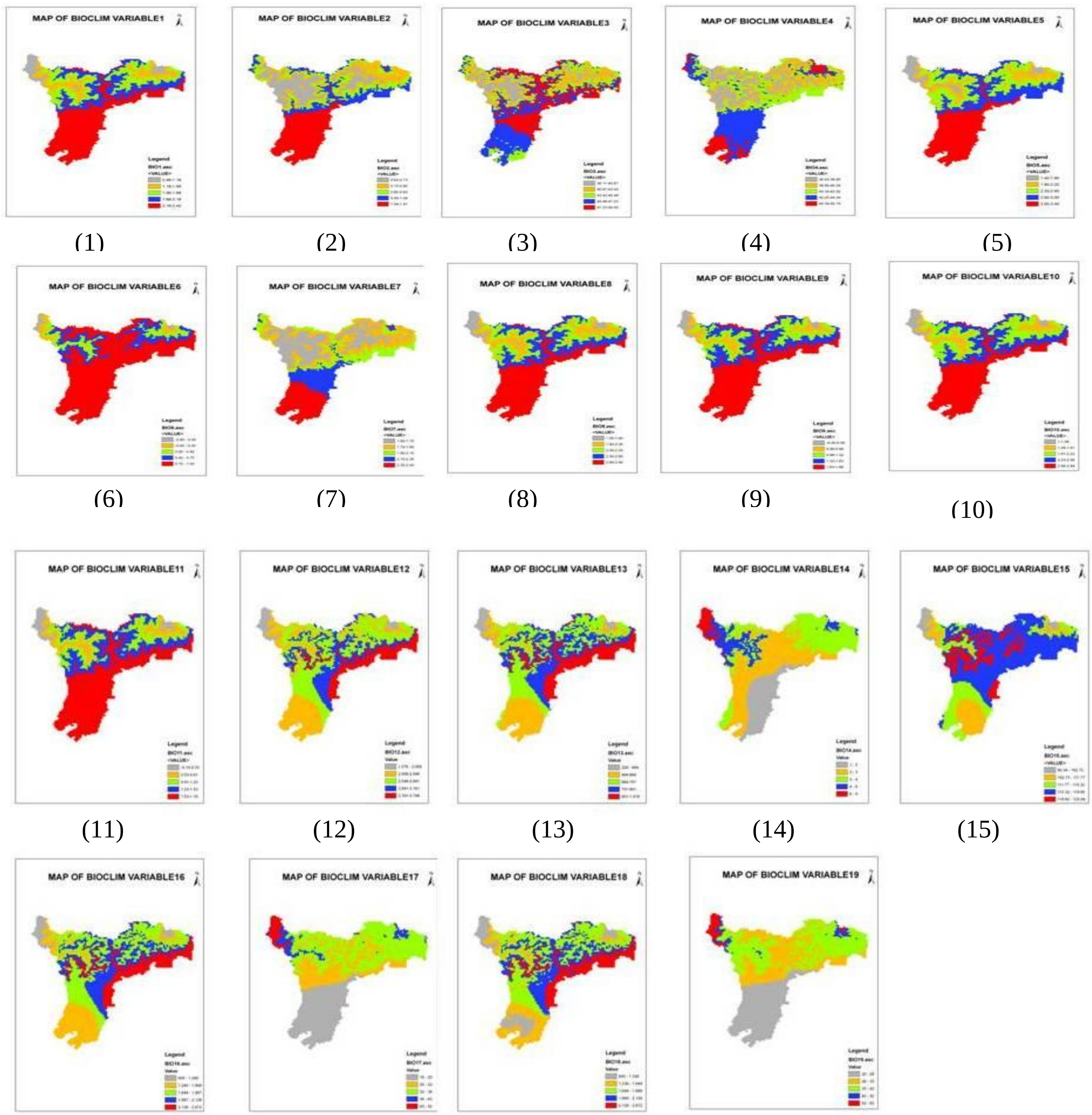
Green color shows forest area, Yellow color Non-forest area and Red colors protected area and Black Occurrence point of species.

Appendix 4. Glimpses of Satellite data used in the Study.



Imagery of satellite data used (a) 1977, (b) 1985, (c) 1997, (d) 2005, (e) 2012.

Appendix 5. Nineteen Bioclimatic Variables Prepared from DIVA-GIS.

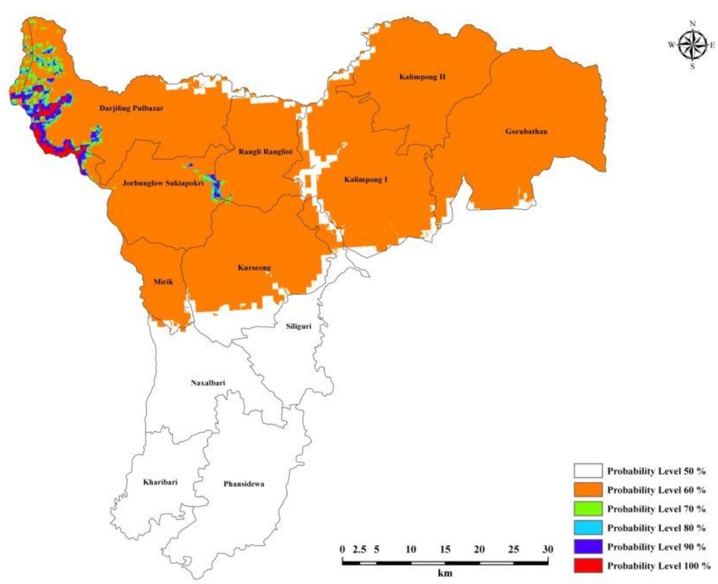


(1) Annual mean temperature (2) Mean diurnal range, (3) Isothermality, (4) Temperature seasonality, (5) Maximum temperature of warmest month, (6) Minimum temperature of coldest month, (7) Temperature annual range, (8) Mean temperature of the wettest quarter, (9) Mean temperature of the driest quarter, (10) Mean temperature of the warmest quarter, (11) Mean temperature of the coldest quarter (12)annual precipitation ,(13)Precipitation of wettest month, (14) Precipitation of driest month, (15) Precipitation seasonality, (16) Precipitation of wettest quarter, (17) Precipitation of driest quarter, (18) Precipitation of warmest quarter, (19) Precipitation of coldest quarter.

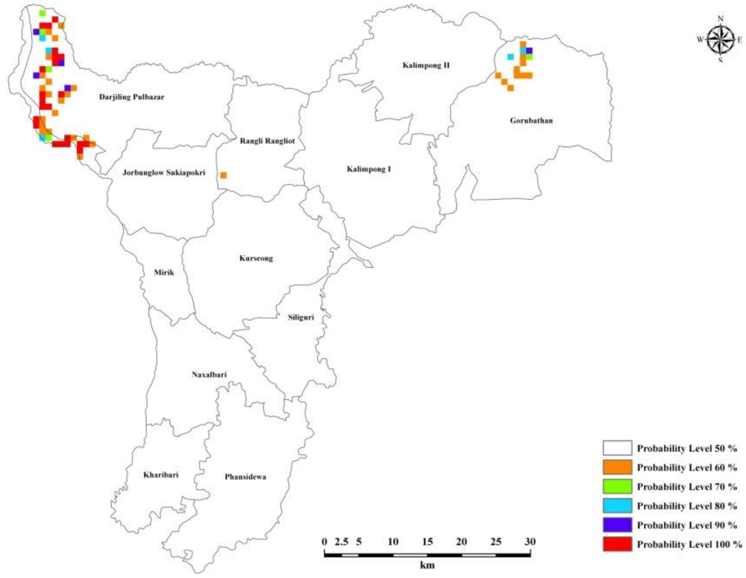
Appendix 6. Characteristics of the modeling algorithms.

Sl.no.		GARP	MaxEnt
1	Input	Species' presence data Environmental predictors	Species' presence data Environmental predictors
2	Output	Binomial predictive distributional map A summary of all tasks Error messages Result parameters Preliminary statistical test Accuracy	Probabilistic predictive distributional map AUC Response curve Jackknife analysis
3	Advantages	Specialized in making distributional maps	Specialized in making distributional maps Indicates the variable importance Compatible with categorical data
4	Disadvantages	No indicators of predictor importance No statistical analysis of the environmental predictors No predictive equation Not very compatible with categorical data	No statistical analysis of the environmental predictors No predictive equation

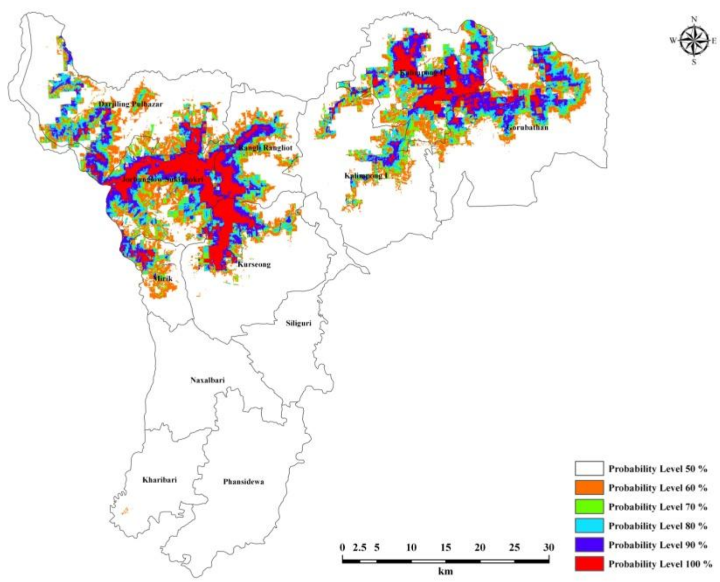
Appendix 7. Potential niche map of *Aconitum napellus* 2012 using MaxEnt model.



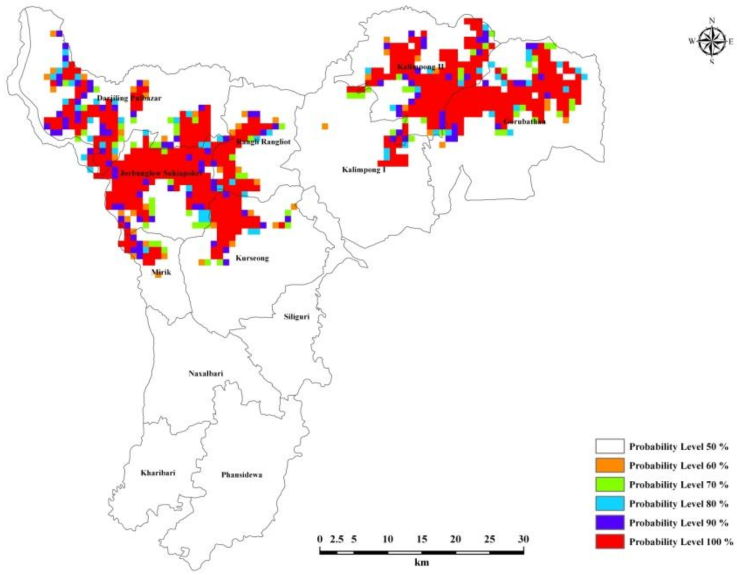
Appendix 8. Potential niche map of *Aconitum napellus* 2012 using GARP model.



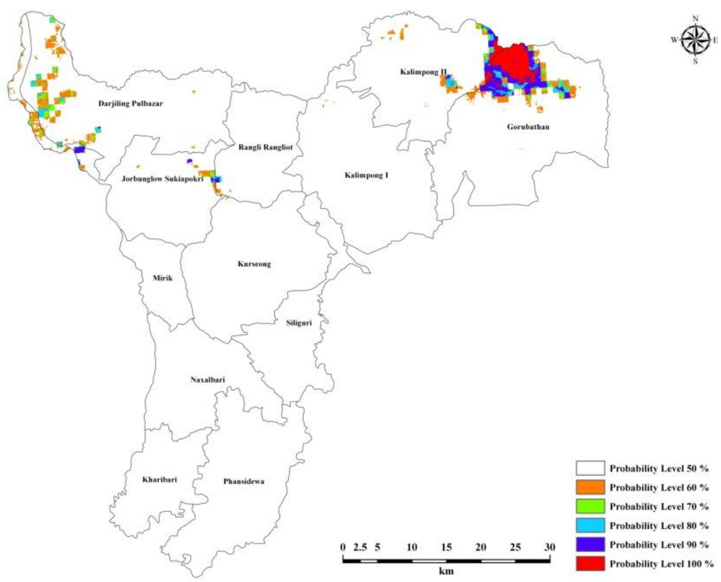
Appendix 9. Potential niche map of *Agapetes serpens* 2012using MaxEnt model.



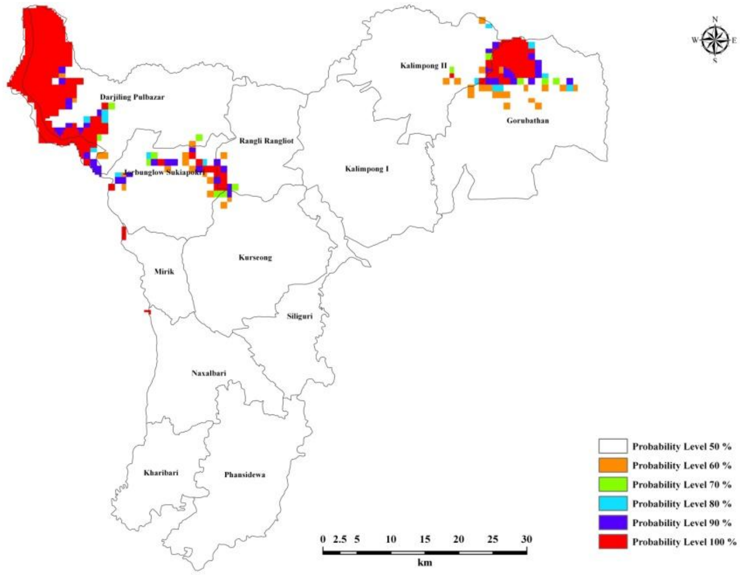
Appendix 10. Potential niche map of *Agapetes serpens* 2012 using GARP model.



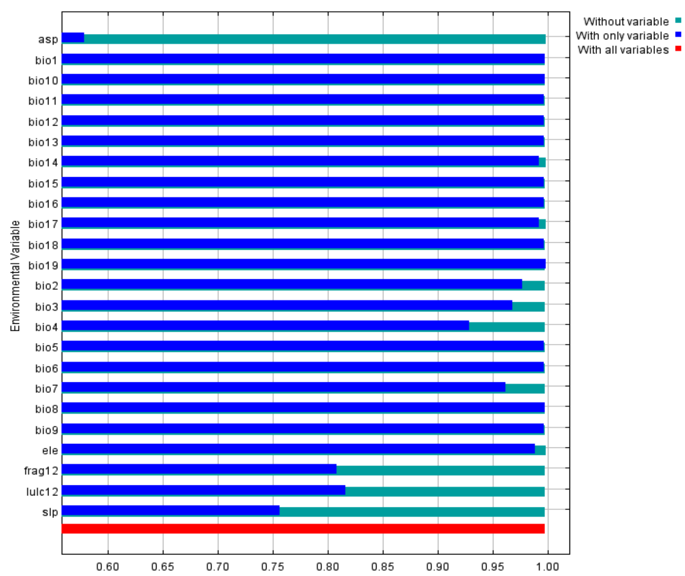
Appendix 11. Potential niche map of *Rhododendron edgeworthii* 2012 using MaxEnt model.



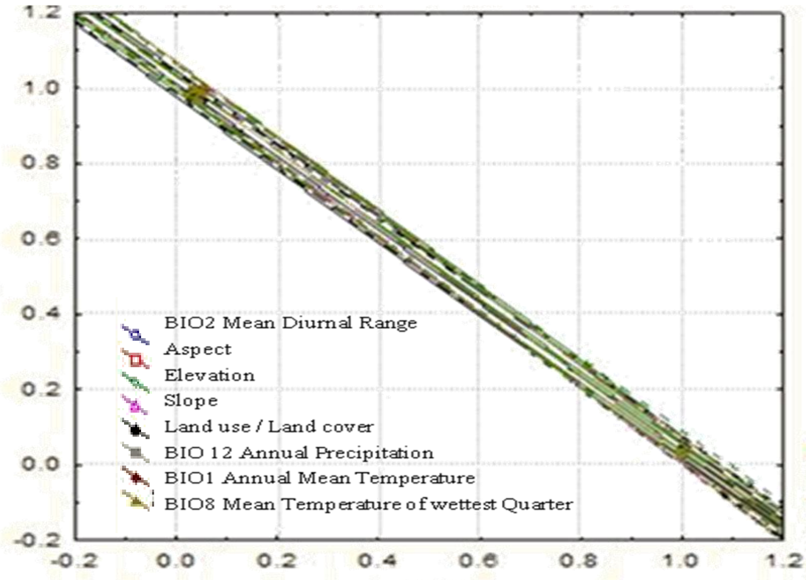
Appendix 12. Potential niche map of *Rhododendron edgeworthii* 2012using GARP model.



Appendix 13. Sensitivity analysis of *Aconitum napellus*.

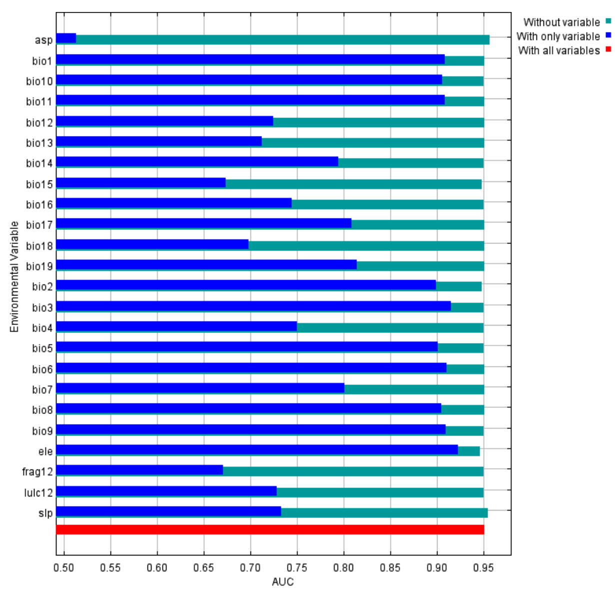


Sensitivity analysis – Jackknife for *Aconitum napellus* obtained from MaxEnt model. The red color line indicates the sensitivity analysis output while considering all variables. Blue color lines indicate the sensitivity analysis of single variance. Green color lines indicate the sensitivity of single variable excluding the other variables.

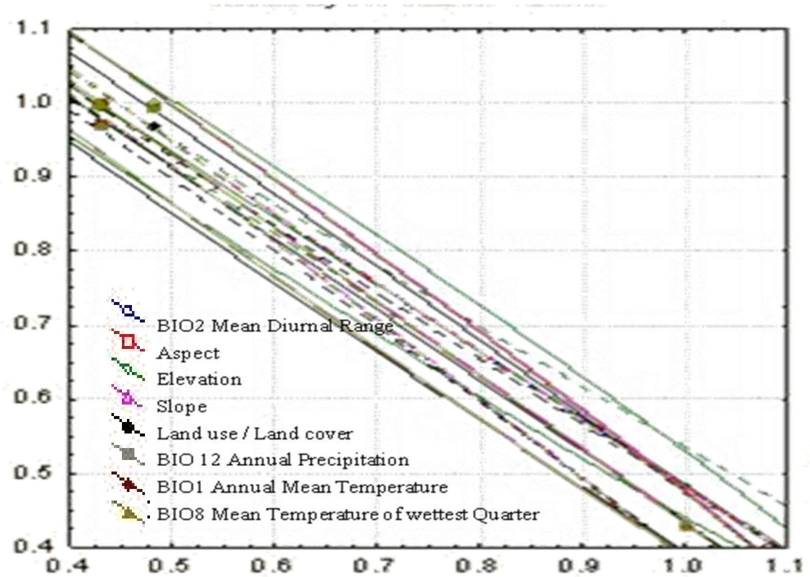


Scatterplot for *Aconitum napellus* and climatic varaiables from GARP model

Appendix 14. Sensitivity analysis of *Agapetes serpens.*

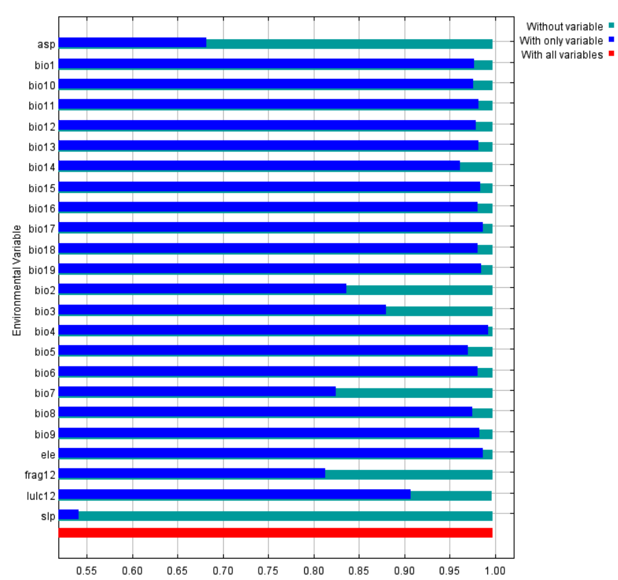


Sensitivity analysis – Jackknife for *Agapetes serpens* obtained from MaxEnt model. The red color line indicates the sensitivity analysis output while considering all variables. Blue color lines indicate the sensitivity analysis of single variable. Green color lines indicate the sensitivity of single variable excluding the other variables.

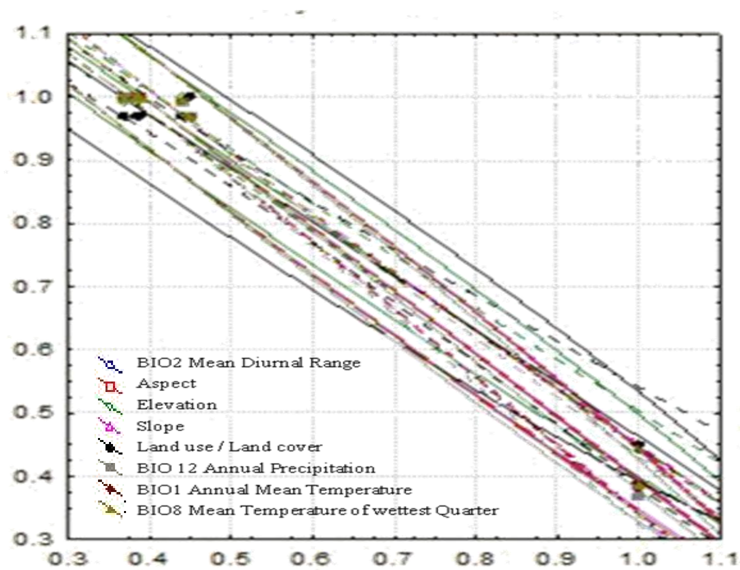


Scatterplot for *Agapetes serpens* and climatic varaiables from GARP model.

Appendix 15. Sensitivity analysis of *Rhododendron edgeworthii*.

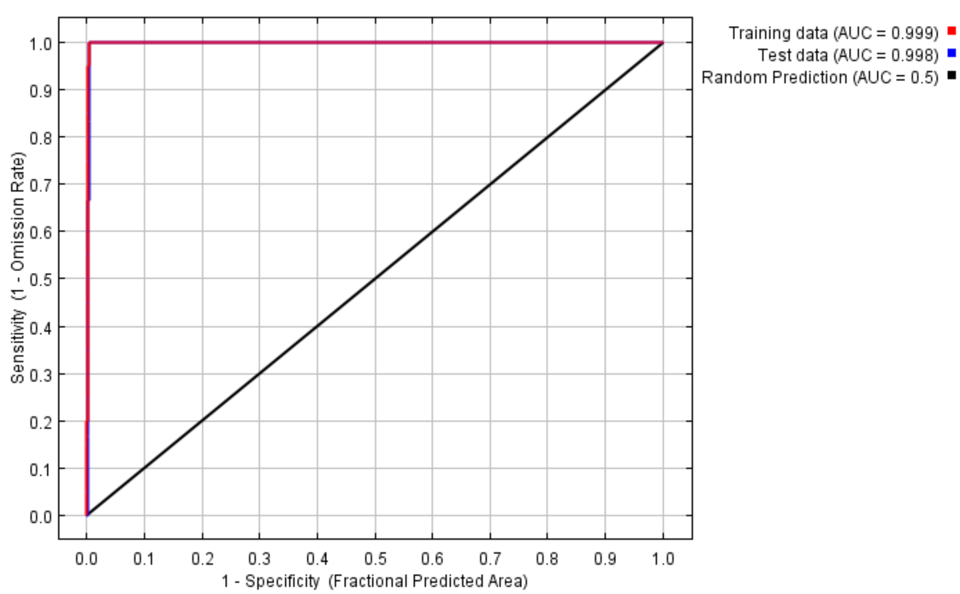


Sensitivity analysis – Jackknife for *Rhododendron edgeworthii* obtained from MaxEnt model. The red color line indicates the sensitivity analysis output while considering all variables. Blue color lines indicate the sensitivity analysis of single variable. Green color lines indicate the sensitivity of single variable excluding the other variables.

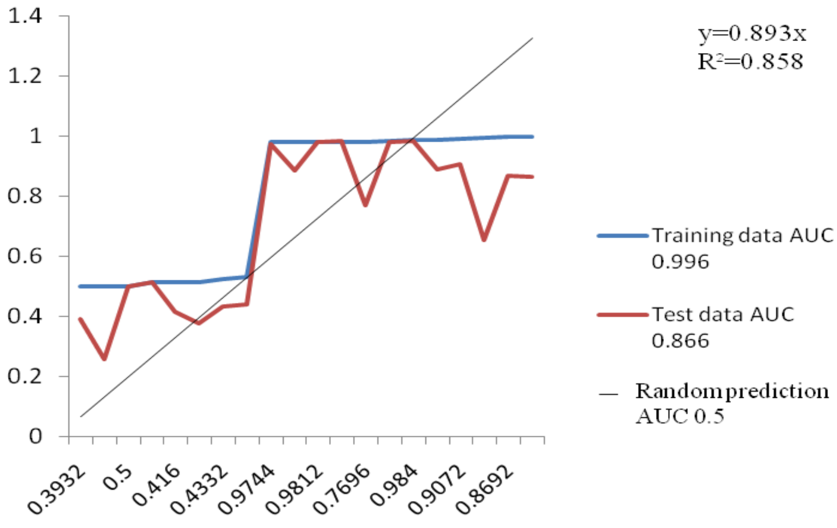


Scatterplot for *Rhododendron edgeworthii* and climatic variables from GARP model.

Appendix 16. Receiver Operating Characteristics for *Aconitum napellus*.

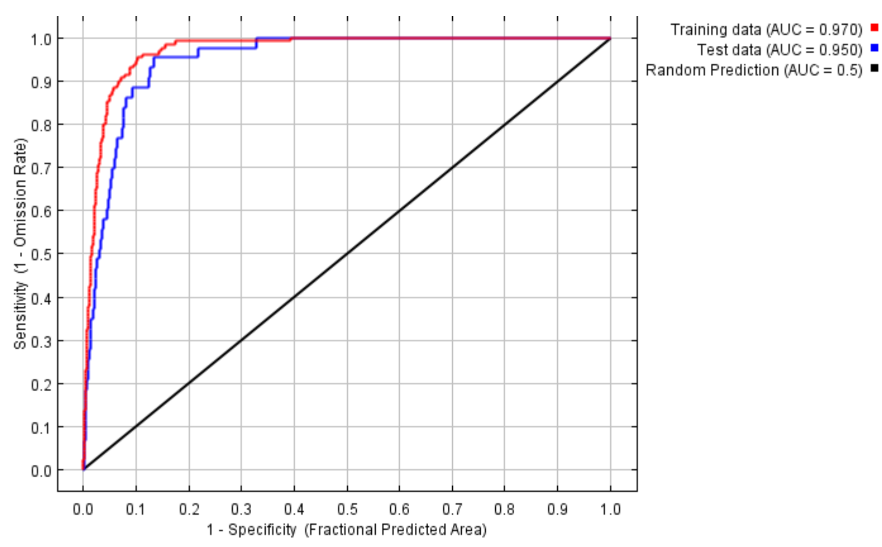


Area under the curve of *Aconitum napellus* for MaxEnt model.

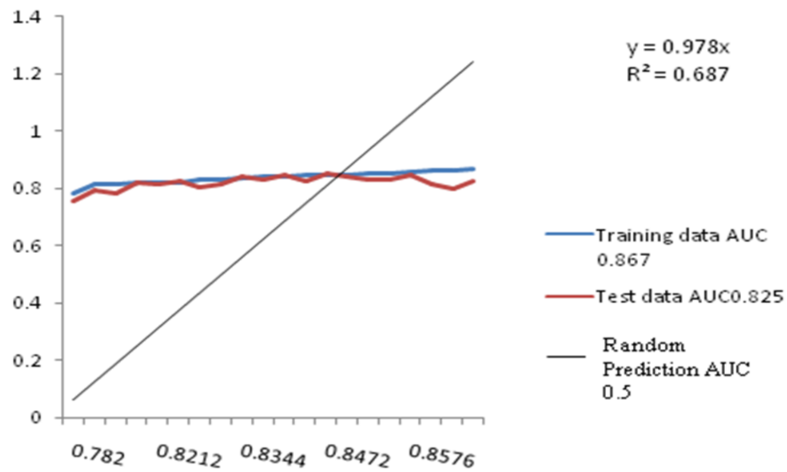


Area under the curve *of Aconitum napellus* for GARP model.

Appendix 17. Receiver Operating Characteristics for *Agapetes serpens* .

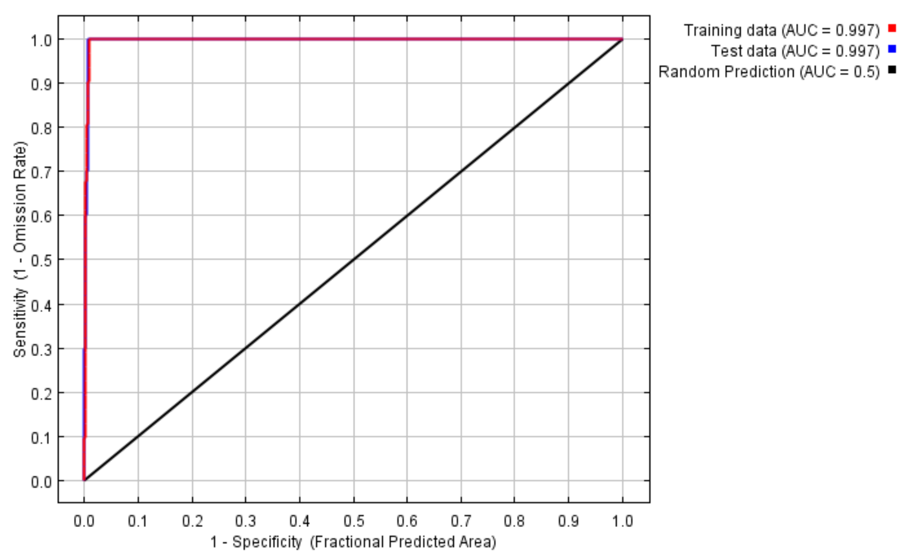


Area under the curve of *Agapetes serpens* for MaxEnt model.

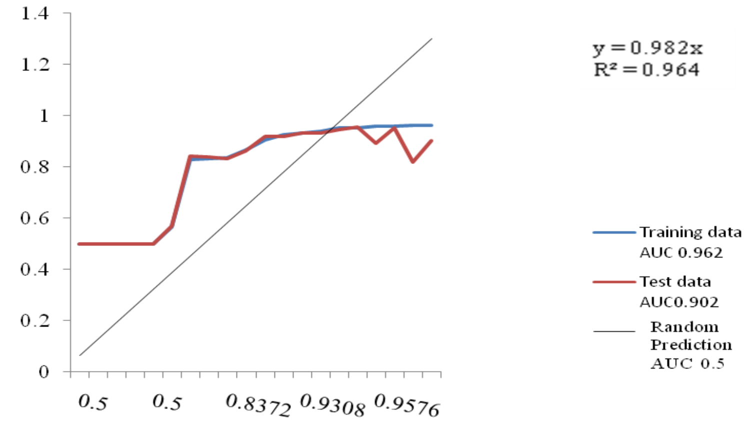


Area under the curve *of Aconitum napellus* for GARP model.

Appendix 18. Receiver Operating Characteristics for *Rhododendron edgeworthii*.

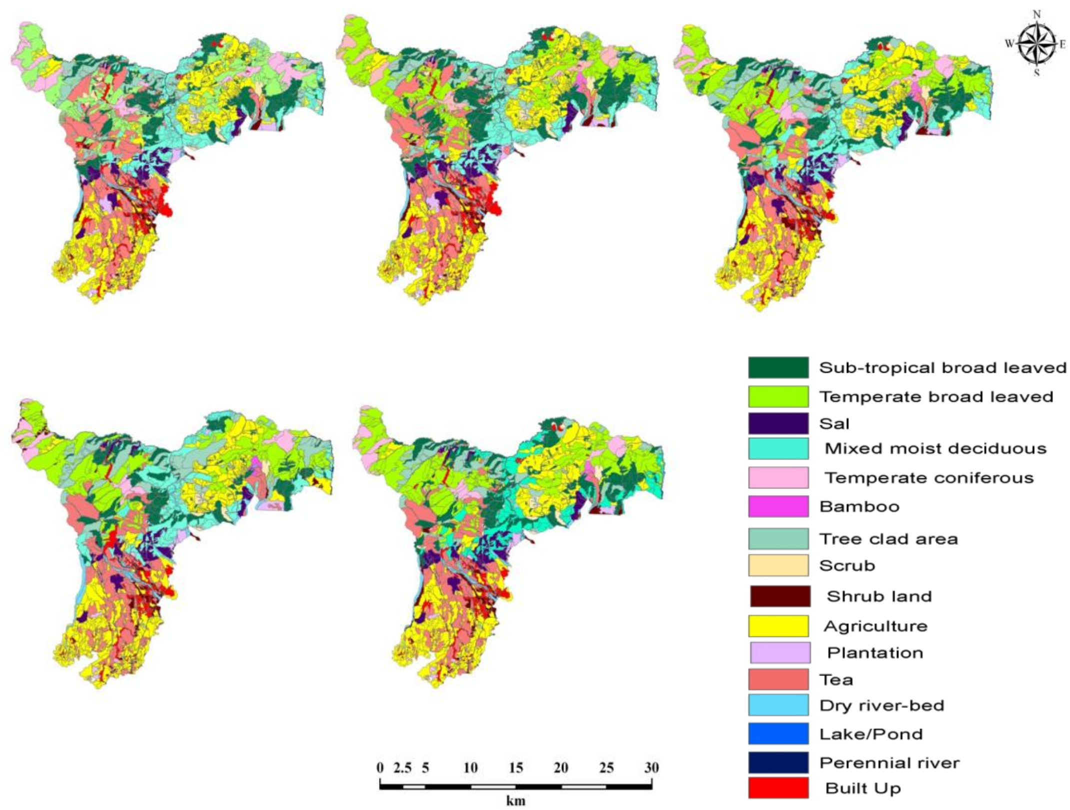


Area under the curve of *Rhododendron edgeworthii* for MaxEnt model.

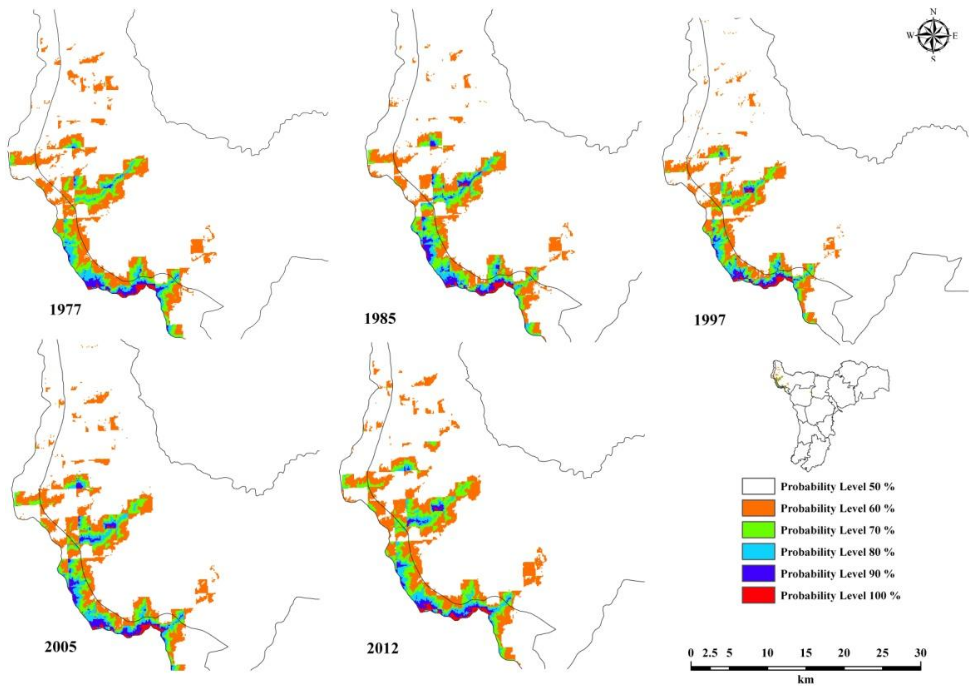


Area under curve *of Rhododendron edgeworthii* for GARP model.

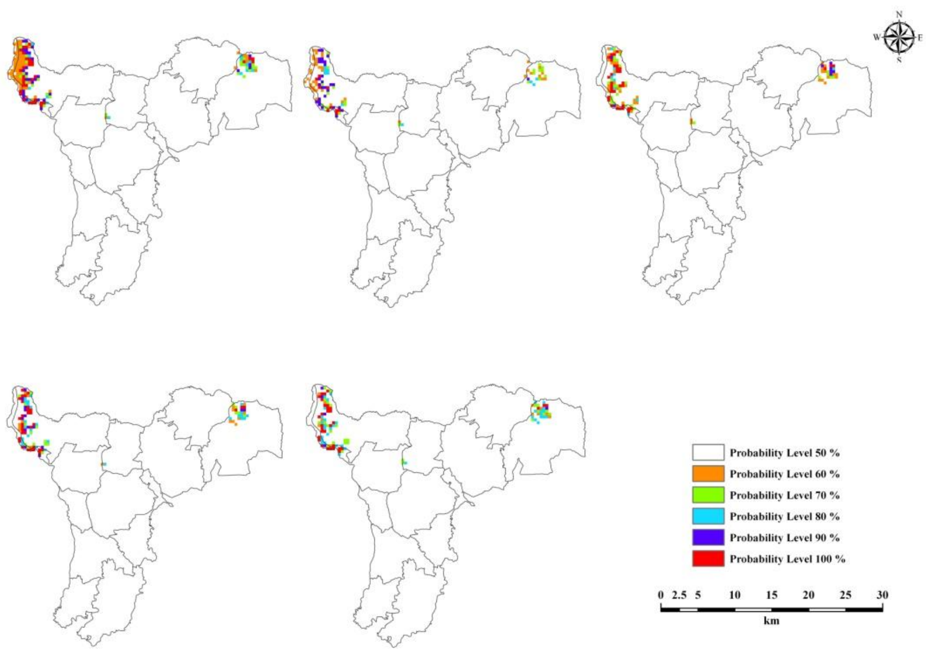
Appendix 19. Land use/Land cover for five different years.



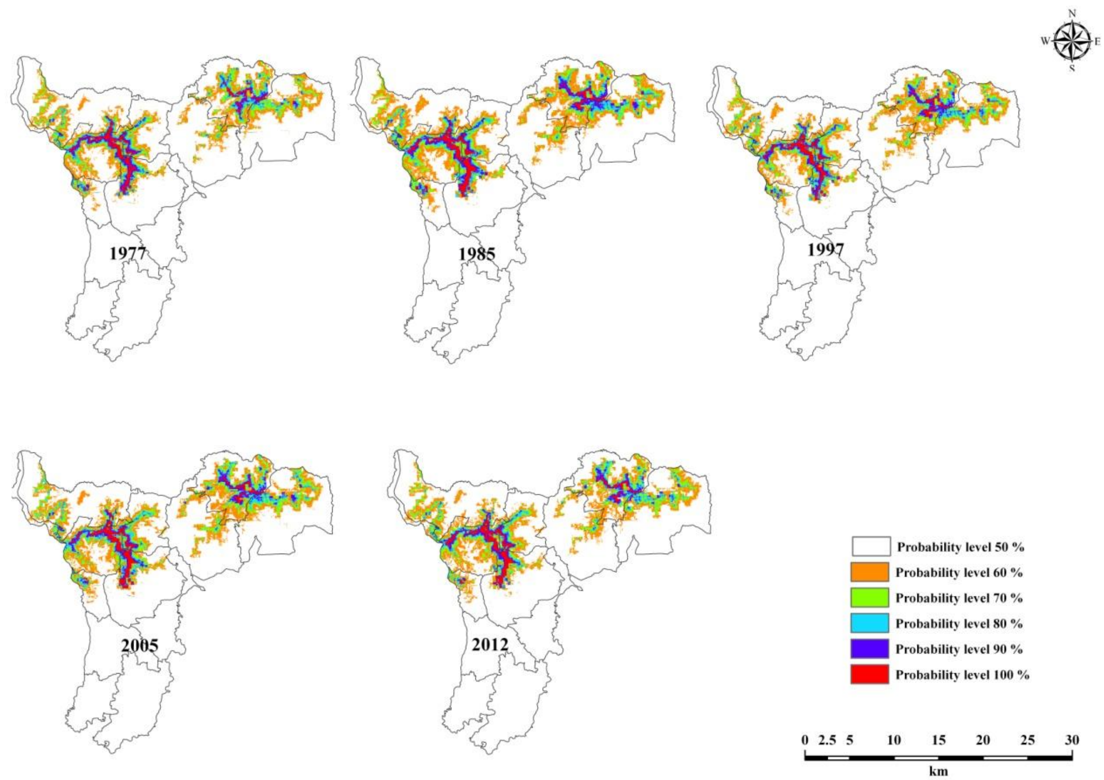
Appendix 20. Influence of LULC on MaxEnt model for *Aconitum napellus* (1977 – 2012).



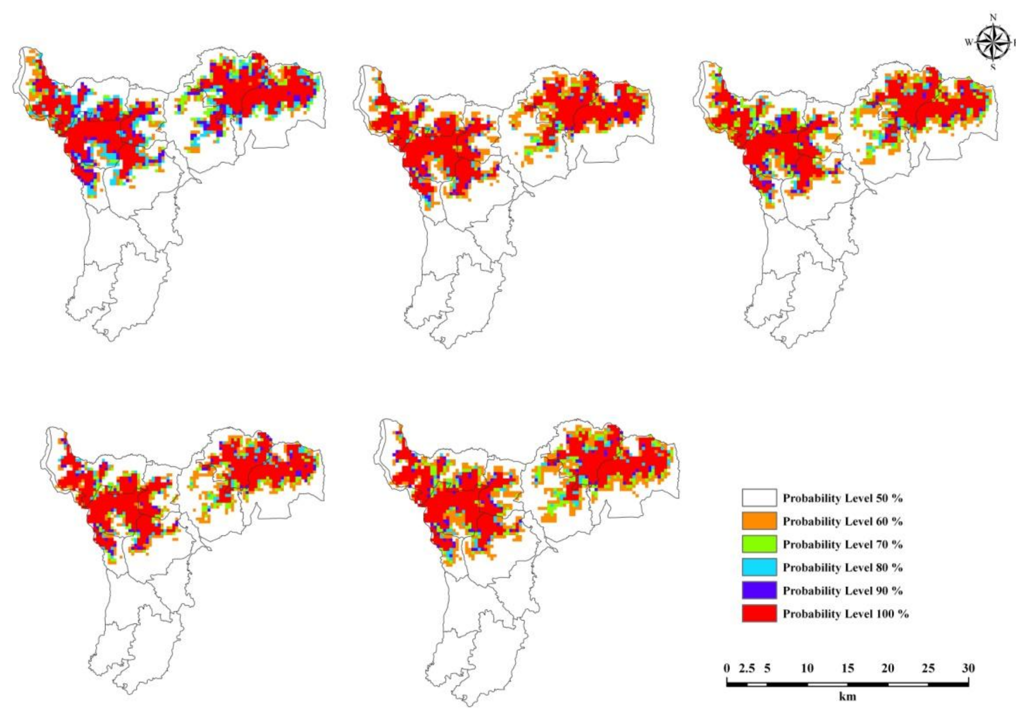
Appendix 21. Influence of LULC on GARP model for *Aconitum napellus* (1977 – 2012).



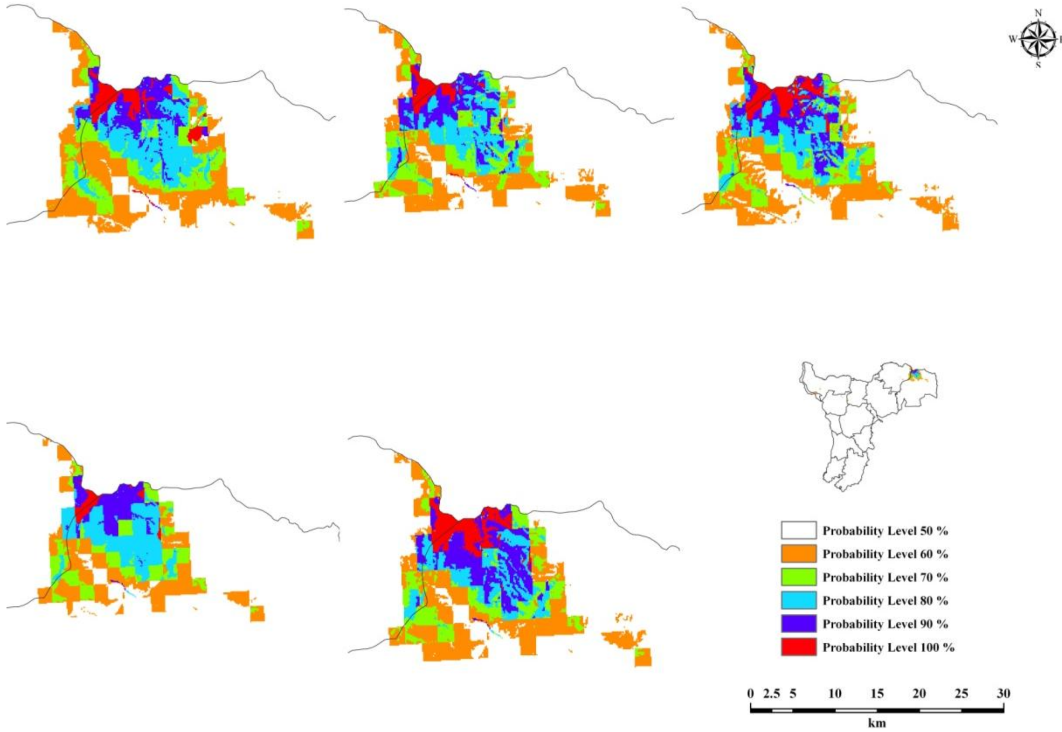
Appendix 22. Influence of LULC on MaxEnt model for *Agapetes serpens* (1977 – 2012).



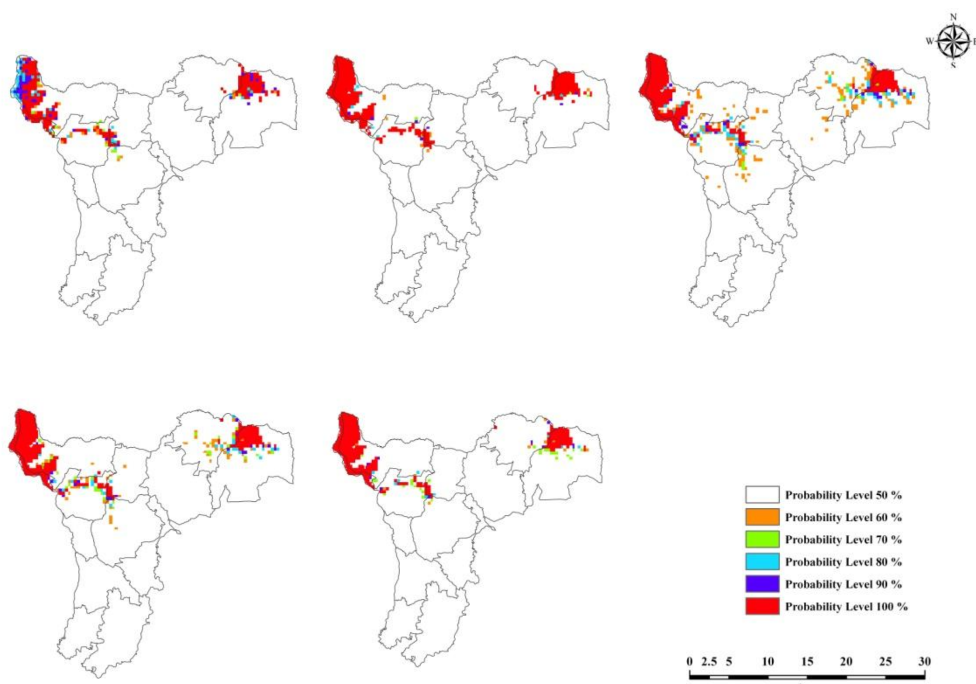
Appendix 23. Influence of LULC on GARP model for *Agapetes serpens* (1977 – 2012).



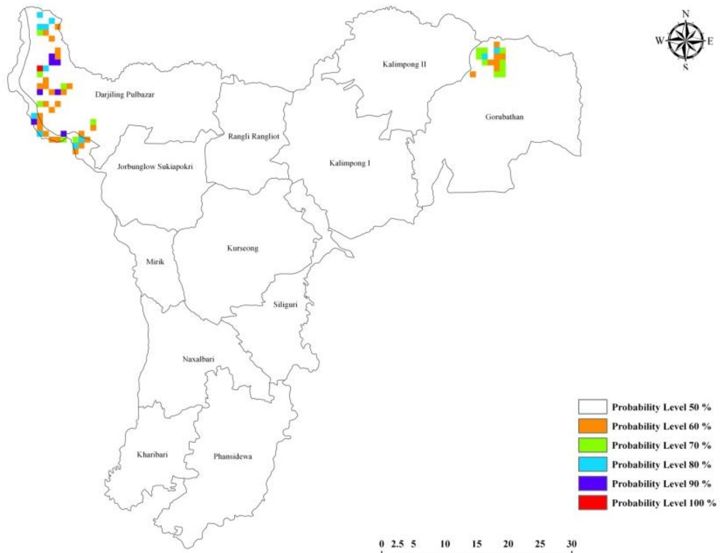
Appendix 24 Influence of LULC on MaxEnt model for *Rhododendron edgeworthii* (1977 – 2012).



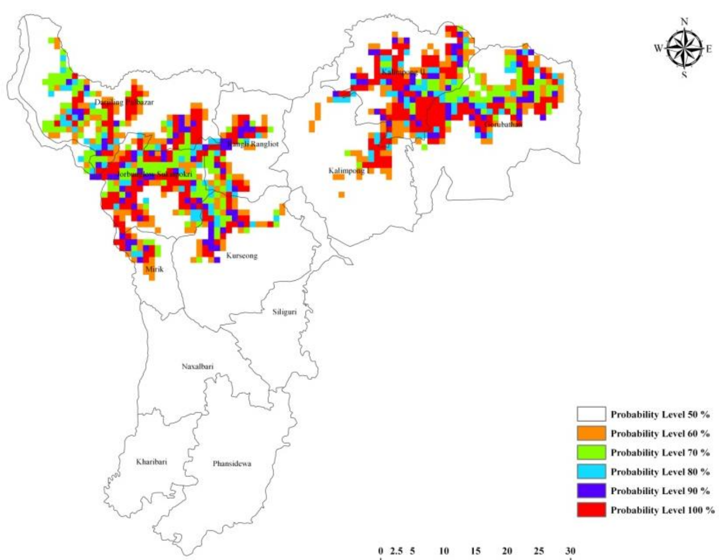
Appendix 25 Influence of LULC on GARP model for *Rhododendron edgeworthii* (1977 – 2012).



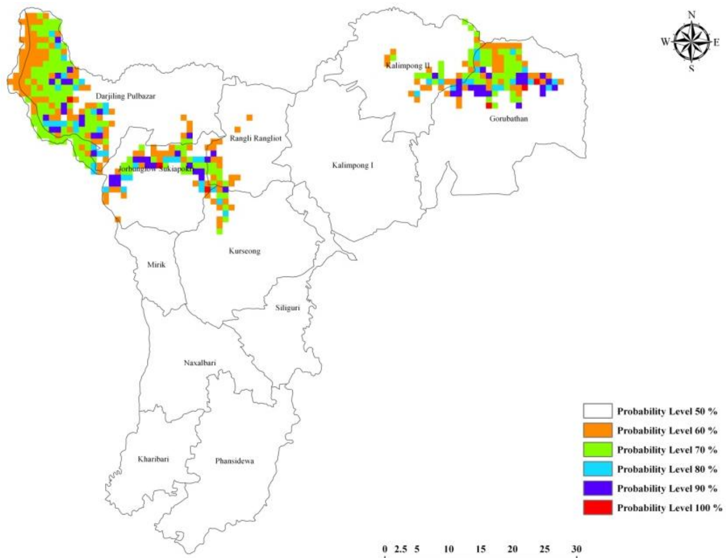
Appendix26 . Map generated from the model developed future prediction of *Aconitum napellus* (2012).



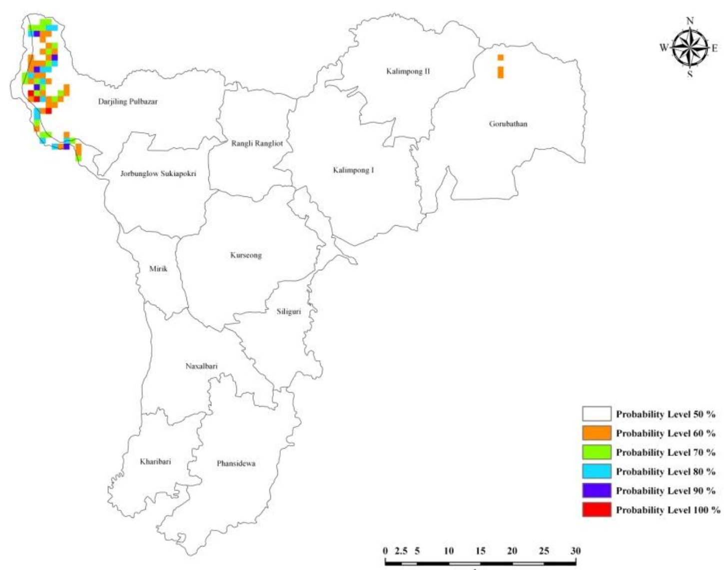
Appendix27 . Map generated from the model developed future prediction of *Agapetes serpens* (2012).



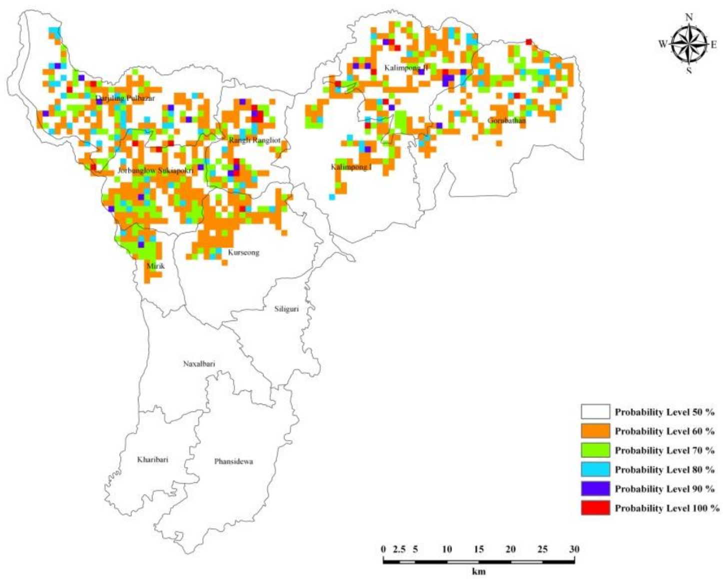
Appendix28. Map generated from the model developed future prediction of *Rhododendron edgeworthii* (2012).



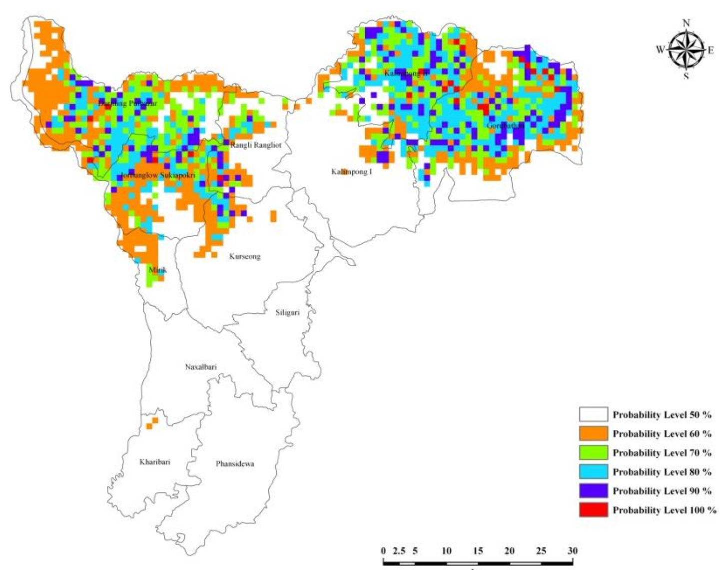
Appendix 29. Map generated from the model developed future prediction of *Aconitum napellus* (2050 A2a.).



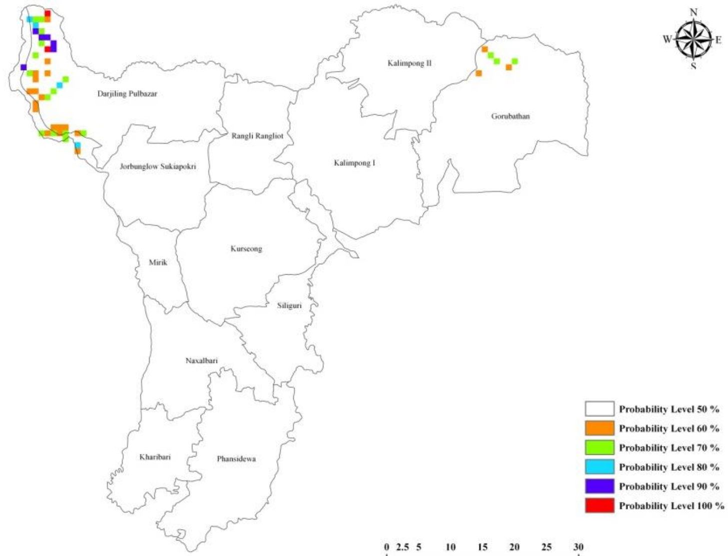
Appendix 30. Map generated from the model developed future prediction of *Agapetes serpens* (2050 A2a.).



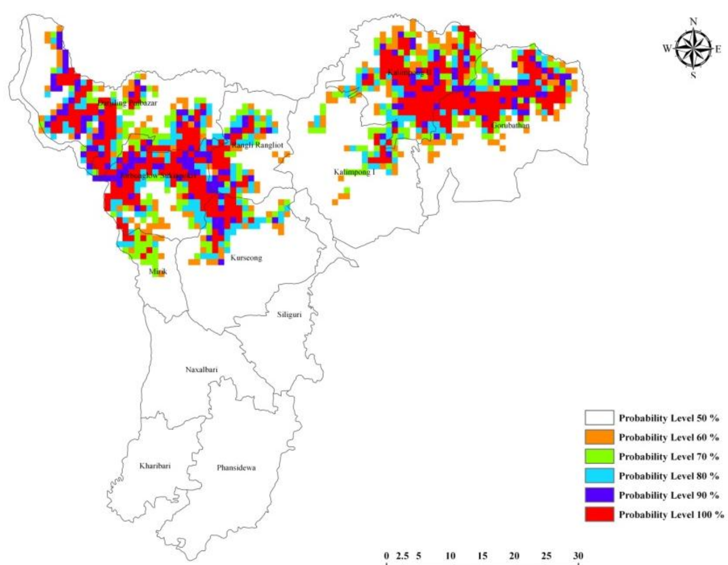
Appendix 31. Map generated from the model developed future prediction of *Rhododendron edgeworthii* (2050 A2a.).



Appendix 32. Map generated from the model developed future prediction of *Aconitum napellus* (2050 B2a.).



Appendix 33. Map generated from the model developed future prediction of *Agapetes serpens* (2050 B2a).



Appendix 34. Map generated from the model developed future prediction of *Rhododendron edgeworthii* (2050 B2a).