Classification of urban area vegetation in Islamabadusing high-resolution satellite data

BY

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Classification of urban area vegetation in Islamabadusing high-resolution satellite data

A thesis submitted in partial fulfillment of the requirements for the degree of
Master of Studies (MS) in Environmental Science

by

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TO MY DEAR PARENTS

CERTIFICATE

This thesis entitled **"Classification of urban area vegetation in Islamabad using high-resolution satellite data"** submitted by **Muhammad Atif** in partial fulfillment of MS degree in Environmental Science, has been completed under my guidance and supervision. I am satisfied with the quality of student's research work and allow him to submit this thesis for further process as per rules and regulations of the International Islamic University, Islamabad.

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FINAL APPROVAL

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DEDICATION

It is great honour for me to dedicate this work my late father Muhammad Ashraf who encouraged me always and was a source of great motivation for me. It is because of his tireless efforts and sacrifices that made my dream of having this degree a reality. Words cannot adequately express my deep gratitude to you. May his soul rest in peace. Besides, I dedicate this work to my loving mother...... who prays and support me at every walk of my life. Last but not the least, to my sweet brothers and sisters who remain a great source of inspiration for me to achieve my goal to pursue-MS degree.

DECLARATION

The material contained in this thesis is my original work, except where acknowledged. No part of this thesis has been previously presented elsewhere for any other degree.

Muhammad Atif

Date 02-03-2017

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All glory and praise to the Almighty ALLAH, the most merciful and beneficent, Who taught the man which he does not know, He bestowed him with internal intuition and curiosity to know and search out how several phenomena happening around him. May Allah, the almighty bless His beloved messenger, Hazrat Muhammad (PBUH), with his countless grace and blessings, He (S.A.W.W) a symbol of inspiration and guidance for all mankind.

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List of abbreviations and acronyms

ARVI........................Atmospherically Resistant Vegetation Index

AUC........................Area Under Curve

ECP........................European Copernicus Program

EO.........................Earth Observation

ESA...................... European Space Agency

EVI........................Enhanced Vegetation Index

GAM......................Generalized Linear Models

GAM......................Generalized Additive Models

ICT........................Islamabad Capital Territory

LAI........................Leaf Area Index

LULC ....Landuse and Landcover

MSI...................... Multispectral Imager

NDVI.................... Normalized Difference Vegetation Index

NIR........................Near Infrared

OOB ....Out of Box

RF........................ Random Forest

ROC.................. .... Receiver Operating Characteristic

SAVI......................Soil-adjusted Vegetation Index

SDM...................... Species Distribution Modeling

SWIR.................... Short Wave Infrared

TCB............... ....Tasseled Cap Brightness

TCV...................... Tasseled Cap vegetation

TCW...................... Tasseled Cap Wetness

VHR.............. ....Very High Resolution

VNIR.:................... Visible and Near-Infrared

ABSTRACT

The assessment of landuse landcover (LULC) and selected trees species distribution modeling in the urban areas of Islamabad capital territory (ICT) was carried out for tree species prediction and assessment of their spatial distribution by using recent Sentinel-2 satellite data (2016). For the purpose high resolution spectral bands of 10 meter resolution were used to extract the land cover classes.

The random forest classifier method was applied to classify the land cover into major five classes including, agriculture, grasses and weeds, shrubs, trees and urban built up. For the purpose of accuracy assessment land cover Out of Bag (OOB) error technique produced 90 percent classes accuracy.

Each land cover classes area was calculated by using map algebra process for results and estimations. It shows urban built up area as the largest class of the study area (4753 hectare) followed by grasses/weeds (2839 hectare), trees (2402 hectare), agriculture (1287 hectare) and shrubs/scattered trees (350 hectare) area. MAXENT model was used to predict the maximum entropy regarding individual tree species. Species prediction about their occurrence was calculated at different level of suitability.

Receiver operating characteristic (ROC) show the range of accuracy for different species, the findings varies from 83 to 99 percent. Species like *Bischofia javanica, Citharexylum spinosum, Cedrela serrata and Sapium sebiferum* shows 99 percent accuracy. While, ROC result for *Acacia sp.* was 89 percent (AUC = 0.89) and 83 percent (AUC = 0.83) for *Terminalia arjuna*. The results are satisfactory for the selected species, Species distribution in the study area were mapped. Also, the results of species prediction of occurrence assessed *Acacia sp.*, *Albizia lebbeck* and *Broussonetia papyrifera* as the most dominating species with significant cover in the study area.

The results of this study will be useful for further management and planning initiatives to improve the ecological assets of Islamabad. Also, it will be helpful for the identification of environmental variables which influence species richness and diversity.

1. INTRODUCTION

Land cover classification maps are easily accessible at a variety of scales and classification types, but are rarely available with high spatial resolution (Hansen *et al.*, 2000), that necessitate the creation of site-specific maps for various mapping modelling studies. (Hicke & Logan, 2009) are of view that high spatial resolution land cover maps are characteristically created for local areas with the help of Ikonos or Quickbird data sets. (Jacobsen *et al.*, 2003) stated high costs of these data sets prohibit their use for research and management from moderate to large spatial areas.

The prior knowledge of correlation between the vegetation and the contextual environment is a prerequisite to map vegetation for conservation planning and/or management of any of its element. It is opined that identified classification units and established processes in depicting and estimating landscapes in terms of their vegetation patterns make the task more reliable and successful for vegetation mapping (Hirzel & Le Lay, 2008; Parolo & Rossi, 2008). In this regard tree species are used as a benchmark in the forest (Dalponte *et al.*, 2012).

Trees are the most prominent and important component of urban vegetation which perform a variety of important ecosystem functions and resultant ecosystem services are considered critical for urban areas.

Microclimatic enhancement of urban areas such as abnormal temperature fluctuations, and moisture in the atmosphere are regulated / modified from vegetation. It is also opined that surface albedo and solar radiation are also influenced by vegetation (Oke, 1990; Sukopp & Werner, 1982). Human activities in urban areas have a direct and significant impact on floristic species (Hope, 2003). Species richness and distribution in an urban ecosystem is regulated and determined by environmental conditions and the species pool (Lepš, 2004). The aspects are less weighted and considered by decision makers and planners due to lack of knowledge about the benefits provided by natural vegetation.

Urbanization through conversion of land into built up structures and other man made habitats stimulate the destruction of natural ecosystems (Honu *et al.*, 2009). The increase in human population and demand of land for infrastructure is met by vertical and horizontal urban sprawl, which results in the form of land fragmentation (Ewing, 2008; Jim & Chen, 2008). It stresses the natural capital and adversely disturbs environmental and ecological functions and processes (Benedict & Mc Mahon, 2002). The poor resource base and lack of planning further aggravates the situation for the developing economies of the world.

Greenway concept in Islamabad traces its roots back in the 1960's when the city planners were dealing with strategies for beautifying roads of the federal capital to improve Its landscape quality. The city is considered one of the fastest growing urban settlements distinctly characterized by park areas and large green spaces (Ali & Malik, 2010). This rapid expansion of Islamabad has resulted in shrinkage of green spaces.

The scholars such as (PySek, 1995) have a valued opinion that knowledge and awareness of urban vegetation is a prerequisite for better decision making about the urban environment. There is a growing consensus of opinion that knowledge about eco-capital is essential for the improvement and management of urban ecosystem resources. Also quality is important for natural resource conservation.

In Pakistan, to best of our knowledge, no studies have been carried out where prevailing distribution of urban vegetation is correlated with land use types. Unfortunately, there is not much awareness about this issue in the general public and issue is also absent in policy discourses.

The current study is aimed to provide detailed landuse information of urban Islamabad. The specific objectives are to assess the vegetation related diversity of Islamabad city, to provide much needed information about trees species of green spaces and along water courses located in the inner city and identification of tree species with the help of machine learning method. The present study will also help researchers and urban planners who are interested in land cover maps with higher spatial resolution.

The results of this research will be useful for further management and planning initiatives to improve the ecological assets of Islamabad.

1.2 Statement of the Problem

Islamabad being a capital city has witnessed extraordinary expansion, growth and developmental such as infrastructure development activities which includes building, road construction, deforestation and many other anthropogenic activities since its inauguration in 1959. Since the shifting of capital to Islamabad, the process of urbanization is still in progress and in recent years the appearance of Islamabad city has extensively been changed, as the land has been cleared for housing and developmental projects.

As a result, an influx of people is moving from rural areas. This would have critical impact on the surrounding ecosystem of Islamabad, loss of agricultural land, destruction of forest cover and on the benefits produced from the land. Pre 1959 Islamabad, was a forested landscape, but now the signs of ecological degradation are observable. The impacts of this uncontrolled urbanization are visible and negative for natural vegetation of the capital. Therefore, the landuse/landcover (LULC) maps of high resolution are essential for making more accurate decisions.

1.3 Significance of the Study

The main objective of the study was to assess the suitability of Sentinel-2 data for typical land cover classifications in agriculture and forestry using a supervised random forest (RF) classifier. As part of the case studies, we were also interested to see that which Sentinel 2 spectral band contribute most to the different tree species prediction.

The present study has been carried out with the help of random forest classifier for image classification. The technique is considered an appropriate and highly accurate method of classifying land cover, when remotely sensed spectral imagery and ancillary data are combined. The first level deals with broad structural categories such as built up areas, agricultural land, trees, weeds or grasses and shrubs or scattered trees; the second level introduces, generally concerns more detailed species-based class differentiation, and is specifically used for major trees species.

The accurate mapping of significant trees species in urban areas of Islamabad can provide numerous benefits for the managerial authorities like capital development authority (CDA). Such benefits include the mapping of valuable tree species, which are a key source of fuel and food, invasive, allergic and bush encroaching species, which can be destructive for environment and livelihoods of the local communities.

The other important intention of the current study was to create a GIS based database of the vegetation of urban Islamabad that will be helpful in refined search of locations where urbanization impacts on different vegetation pattern are found. Through creation of georeferenced data on landcover and species occurrence, the present study will contribute towards effectiveness of natural resource management actions and conservation initiatives, mobilization of the data, climate change impact studies on biodiversity, biological reserve design, community and ecosystem modeling, Species and habitat conservation plans, invasive species monitoring, basic research and predicting the effects of global environmental change on species and ecosystems of Islamabad. To achieve these goals, the different type of vegetation occurrence data was collected from the field, georeferenced, mapped and evaluated for assessment of suitability trends.

1.4 Objectives

The general objectives of the study were to evaluate the classification of vegetation of urban areas of Islamabad.

The specific objectives of the study were

- To assess the potential of multi-temporal data of sentinel-2 for landcover classification accuracy.
- To calculate the area of different landcover classes.
- To map the significant tree species suitable habitat in urban Islamabad.
- To find the most abundance tree species in the urban areas of Islamabad.

2. LITERATURE REVIEW

Landuse and Landcover (LULC) mapping is commonly carried out by planning agencies, and land cover data are becoming increasingly important for land surface characterization required for modeling global and environmental change (Foley et al., 2005).

2.1 Landcover classification and mapping

Land-cover information at global, continental, and regional scales is an essential product for use in scientific research, economic and government planning. This information is essential for governments to overcome the problems of uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitat (Anderson, 1976).

If living conditions and standards are to be improved or maintained at current levels, land-use data are needed in the analysis of environmental processes (Anderson, 1976). Knowledge of the present distribution and area of agricultural, recreational, and urban lands, as well as information on their changing relative proportions, is needed to determine better land-use policy, to project transportation and utility demand, to identify future development pressure areas and to implement effective plans for regional development (Anderson, 1976).

The Coordination of Information on the Environment (CORINE) land-cover mapping scheme was developed between 1985 and 1990 by the European Commission to collect and store environmental information. The CORINE scheme has been used with multiple types of remote sensing systems including the Landsat, and SPOT series (See & Fritz, 2006). It has three tiers of classes with 5, 13 and 44 classes, respectively. This class system is primarily used in Europe. It can also use ancillary data that is not necessarily derived from remotely sensed data to aid in the classification process (Bossard *et al.*, 2000).

2.2 Sentinel-2 data

The Sentinel-2 MSI is a multispectral sensor with 13 different bands and wavelength range lies between 443 nm and 2190 nm. The band centers and spectral widths are also presented in (Table 2. 1).

Table 2. 1: Spectral characteristics of sentinel-2 satellite data

Band #	Wavelength(nm)	Ground Sampling Size(m)	Spectral width Δλ at FWHM(nm)
1	443	60	20
2	490	10	65
3	560	10	35
4	665	10	30
5	705	20	15
6	740	20	15
7	783	20	20
8	842	10	115
8a	865	20	20
9	945	60	20
10	1375	60	30
11	1610	20	90
12	2190	20	180

Sentinel-2 MSI will use three different spatial ground sampling sizes, 10 m, 20 m, and 60 m. The 10 m bands are to ensure compatibility with SPOT 4 and 5 in addition to meet user requirements for land cover classification (Drusch et al., 2012). The 60 m bands will be used for atmospheric correction (443 nm for aerosols retrieval, 940 nm for water vapour correction and 1375 nm for cirrus cloud detection).

(TOPALOĞLU *et al.*, 2016) recently compared classification accuracies of landuse and land cover (LULC) maps created from Sentinel-2 and Landsat-8 data for the study area, Istanbul metropolitan city of Turkey, with a population of around 14 million, having heterogeneous and diverse landscape characteristics. Major landuse and landcover (LULC) classes selected to identify were water, forest, agricultural areas, grasslands, transport network, urban, airport-industrial units and barren land- mine land. They employed image pre-processing steps like atmospheric correction and geometric correction as well. They concluded that low resolution bands of Sentinel-2 which were resampled to 30m dataset produced better results than Landsat-8 dataset and overall classification accuracies of Sentinel-2 were much higher than Landsat-8.

In a recent study (Immitzer *et al.*, 2016) used Sentinel-2 data for mapping crop types and tree species in different parts of Europe. They used random forest (RF) classifier for landcover classifications. Also, they used pixel-based and object-based approaches for crop land and concluded that the pixel-based classification gave a somewhat lower overall accuracy. The concluded that the achieved classifications result for the pixel- and the object-based approach were satisfactory but not extremely high.

2.3 Significance tree species of Islamabad and species distribution models (SDM)

Species Distribution Models (SDM) are generally utilized techniques that take numerical tools and join them with perceptions of species occurrence or abundance and environmental parameters to distinguish reasonable or accessible habitats.

Broussonetia papyrifera and *Dalbergia sissoo* are abundantly separated in different communities of Islamabad (AH & Kauser, 2006).

(Ali & Malik, 2010) conducted a study in Islamabad focusing on vegetation community prevailing along the drain sides and their relationship to the underlying soil properties. The two-way indicator species analysis (TWINSPAN) identified the different vegetation communities in Islamabad, in plants they recorded 113 pant species with *Broussonetia, Dalbergia, Eucalyptus* and *Populus as a* most widely spread and dominant genera in the study area.

Species distribution models can be used to provide an understanding of the ecology in specific landscapes and/or to predict the species' distribution across one or more landscapes. However, generally speaking, SDMs combine concepts from natural history with more recent developments in statistics and information technology. Generalized linear models (GLM) were originally used in early analyses of presence-absence and count data whereas generalized additive models (GAM)(Bolker et al., 2009), which are similar, can be used to describe nonlinear responses.

A study was carried out in the savanna ecosystem by (Naidoo *et al.*, 2012) to classify and map the important eight tree species by using a combination of hyperspectral and LiDAR data through random forest approach. Random forest model developed classification shows satisfactory results with 87.68% accuracy.

However, in recent years MAXENT has become the new norm for simulating the spatial distributions of many different species. Maximum entropy (MAXENT) is very sophisticated, machine-learning method of modeling a species' geographic distribution. Using data points of observed species (presence-only), and environmental conditions, MAXENT can estimate the environmental requirements of a species. MAXENT produces habitat suitability analyses addressing the spatial extent of a species. It has become the frequently used software for inferring species distributions and environmental tolerances, and It allows users to fit models of varying complication (Warren & Seifert, 2011).

3. RESEARCH METHODS

3.1 Study Area

The present assessment was carried out in urban areas (sectors) of Islamabad consisting of almost entire residential sectors within the administrative jurisdiction of Islamabad capital territory (sectors E-7 to E-13, F-6 to F-13, G-6 to G-13, H-8 to H-13 and I-8 to I-13 and the area around D-Chowk). Sensitive areas such as parliament building and diplomatic areas were not considered due to security reasons, as well as, inaccessibility. The study area is located in foothills of Margalla Range in Potowar plateau with an aerial extension ranging between 33.61°N – 33.74°N latitudes and 72.93°E -73.11° E longitude and an approximate area of 11633 hectare (Figure 3. 1).

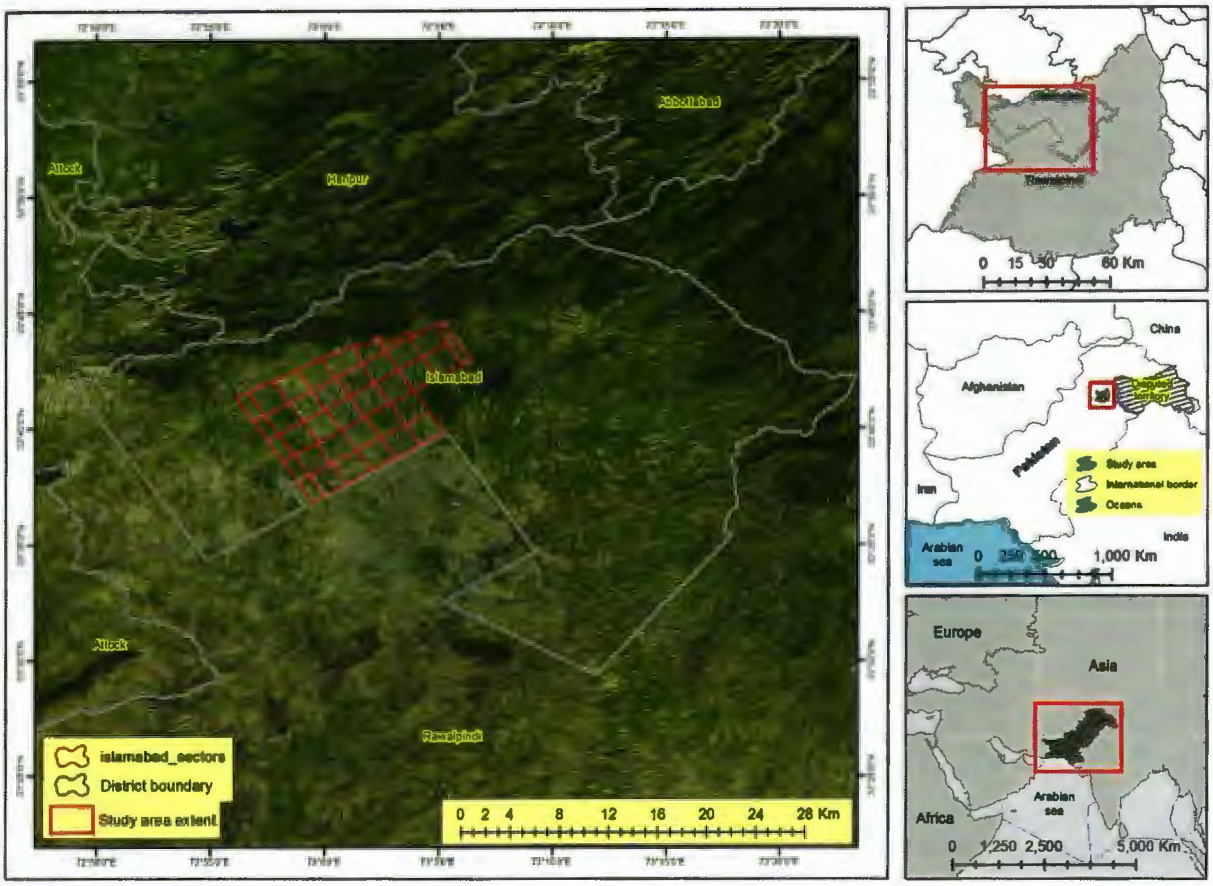


Figure 3. 1: The study area in context of its location in Pakistan

With marked exception to E series the original master plan of Islamabad envisaged the division of the city into equal sized sectors, each of which is further subdivided into four sub-sectors separated by green belts. In case of E-7 there is no subdivision of sector while from E-8 to E-10 sectoral series are under the control of armed forces of Pakistan which utilized the allotted land to meet their purpose specific needs. The total area of each sector is approximately 4 km square. Each sector is facilitated with Its own shopping area, public and recreational parks (Islamabad Census Report, 1998).

Its population in 1961 was approximately 117,669 which increased to 805,235 according to the 1998 census report (Butt *et al.*, 2012). Due to this enormous population growth urban land cover changes are quite visible at present. Man-made landscape and infrastructure is replacing natural ecology of the area. Keeping in view the human impacts upon the landscape, there is a need to establish spatially explicit baseline data to comprehend the scale and orientation of these changes.

Since the current assessment focused mainly on mapping vegetation in the study area through high resolution satellite data, a systematic approach was adopted to achieve this goal. Initially the main landcover types including agriculture, grasses and weeds, shrubs and scattered trees, tree cover and urban area were extracted from satellite based data and then frequently occurring tree species were mapped using predictive modelling techniques (Figure 3. 2).

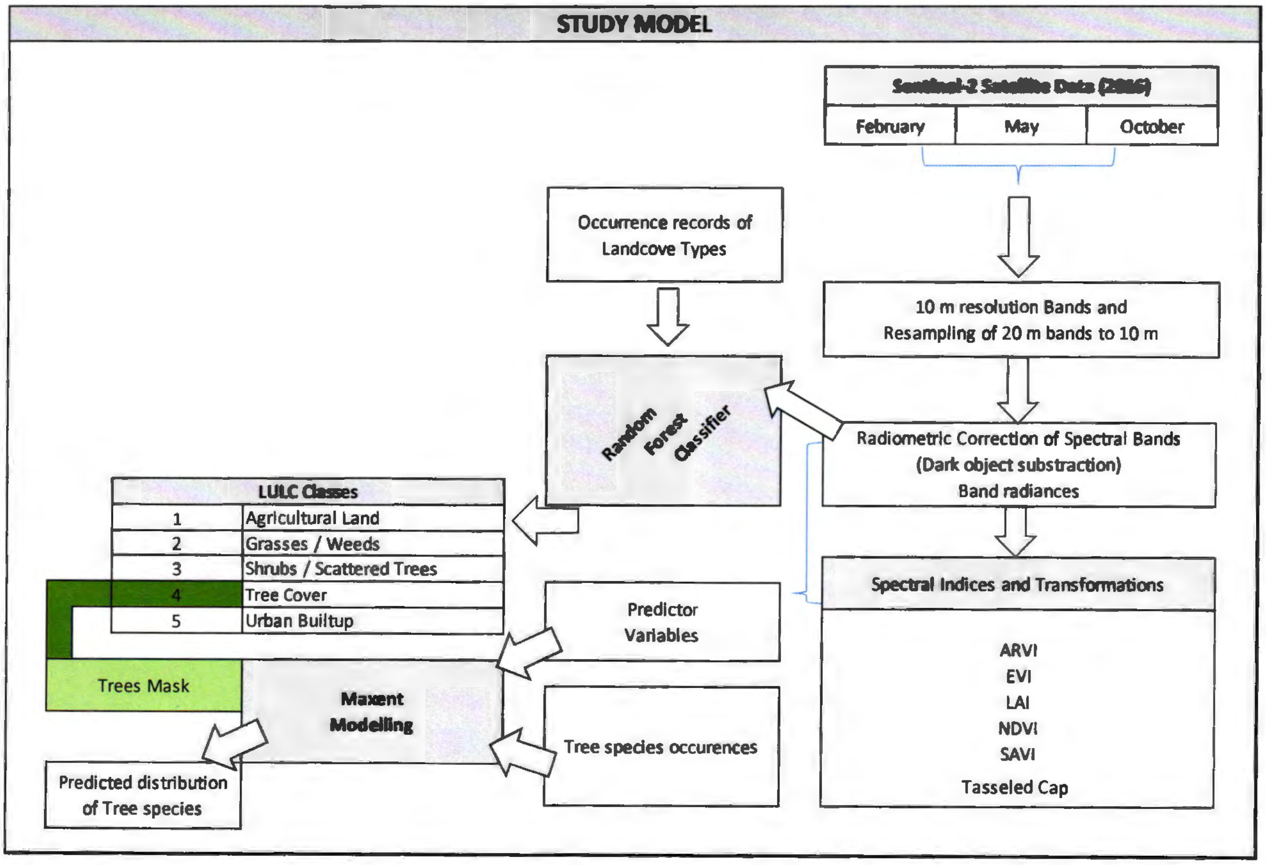


Figure 3. 2: Present Study Model

3.2 Extraction of major landuse/landcover

The major landcover/landuse types that were inferred for the study area are detailed in section 3.2.2.

3.2.1 Satellite Imagery

In order to incorporate various seasonal characteristics of major landcover/landuse types, multi-temporal imagery was used that consisted of Sentinel-2 images acquired during various dates of year 2016 i.e., (1) 21st February (2) 10th May and (3) 22nd October. The data chosen were 100% cloud free for the study area (Tiling grid ID: 43/S/CT) and downloaded from Sentinels Scientific Data Hub (SciHub; https://scihub.copernicus.eu/dhus/).

Sentinel 2 data comprises of 13 different spectral bands including B1 (443 nm/60m), B2 (490nm/10m) B3 (560nm/10m) and B4 (665nm/10m) falls in visible spectrum B5 (705nm/20m), B6 (740nm/20m), B7 (783nm/20m), B8 (842 nm/10m), B8a (865nm/20m) and B9 (940nm/60m) include in VNIR, while, the rest B10 (1375nm/60m), B11 (1610nm/20m) and B12 (2190nm/20m) belong to SWIR spectrum (Figure 3. 3).

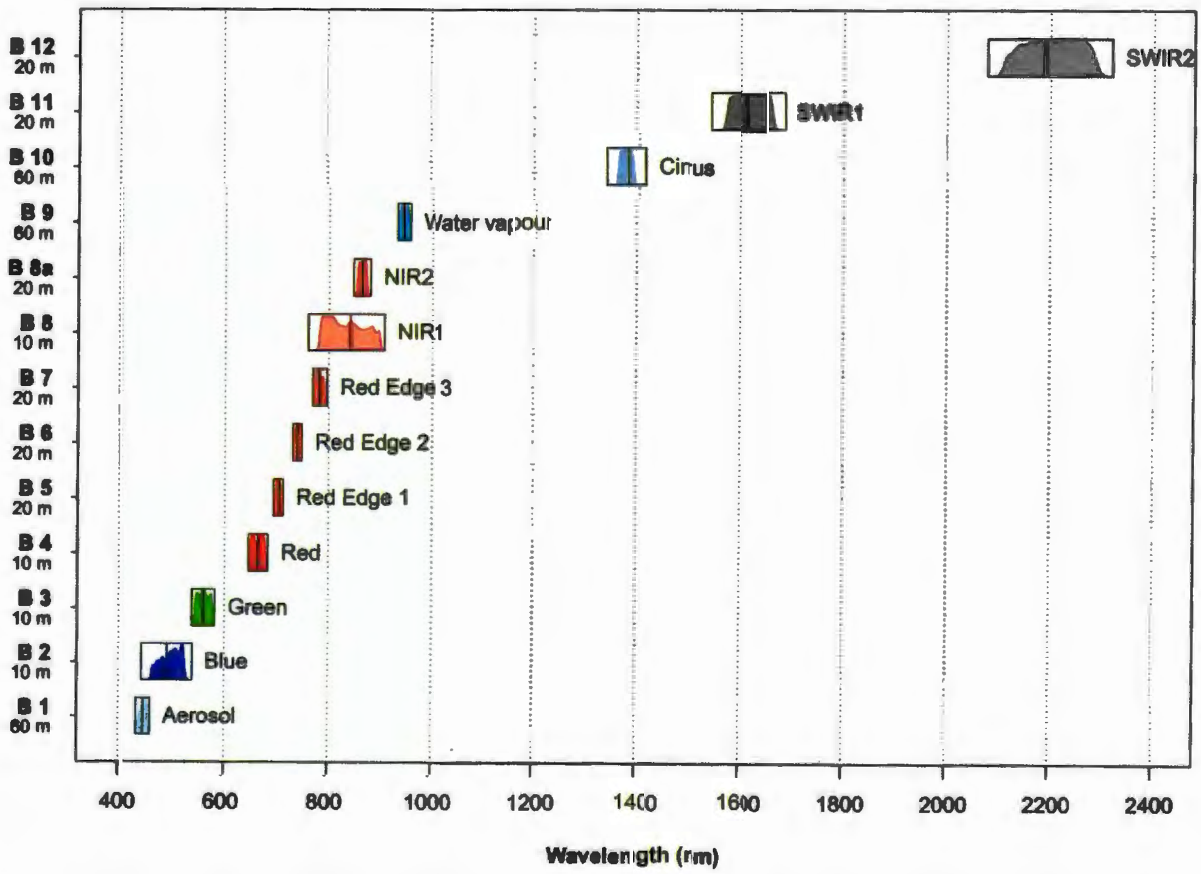


Figure 3. 3: Spectral bands of sentinel 2 satellite data and their spatial resolution

3.2.2 Land Cover Classification

I. Agricultural land

II. Grasses and weeds

III. Shrubs and scattered trees

IV. Trees

V. Urban built up area

Table 3. 1: Landcover types of the study area (Urban Islamabad)

Sr #	Landcover Type	Description	Pictures
I.	Agricultural land	It includes all arable farming land present in the study area.	
II.	Grasses and weeds	This class includes all kind of grasses (maintained or undisturbed) and weeds (*Canabus*, *Partinium* and *Silybum* etc) patches.	
III.	Shrubs and scattered trees	This land cover contains herbaceous, epiphyte, climber and specific ornamental plants in the study area.	
IV.	Trees	It includes all broad leaved, coniferous and mixed broad-leaved/coniferous trees present in the study area.	

V.	Urban built up	It contains all kind of urban infrastructures like buildings, paved areas, roads and walls etc.	

Random Forest Classifier (Breiman, 2001) that is a machine learning technique was applied to multi-temporal satellite data (section 3.2.1) in order to derive information on landuse and landcover (LULC) of urban Islamabad. The classifier was applied to the data in software R version 3.2.4; 64 bit (R Core Team 2016; https://www.R-project.org/) within package randomForest version 4.6-12 (Liaw & Wiener, 2002).

Random Forest Classifier is relatively unknown in land remote sensing and has not been evaluated thoroughly by the remote sensors compared to more conventional pattern recognition techniques (Rodriguez-Galiano *et al.*, 2012). The major advantages of RF include: their non-parametric nature; high classification accuracy; and capability to determine variable importance. The Random Forest Classifier was chosen because it is much quicker in training and testing than traditional classifiers such as Support Vector Machine(SVM) (Bosch *et al.*, 2007).

A field survey was conducted to identify landcover types on ground and location of a homogeneous patch of a given landcover/landuse type was recorded using handheld global positioning system (GPS) device. Many supplementary locations were inferred from visual interpretation of satellite images mainly for classes such as urban areas, open grassy patches and trees as well.

Random Forest Classification accuracy assessment shows satisfactory results for landuse and landcover classes. The out-of-bag error or out-of-bag estimate method was used to measure the prediction error of Random Forest. The results out of bag error shows that February 2016 image has 14.08 percent error. Moreover, 13.09 percent (May image) and 17.03 percent (October image) error area measured. This error is reduced to 9.05 percent for a composite image. So, in this study we used composite image of different time periods to reduce the out of bag error (OOB).

Finally, sector-wise extent of each LULC class was determined using map algebra. Out of bag (OOB) estimation result for combine (composite) imagery is given in table 3. 2.

Table 3. 2: Out of bag (OOB) error calculation of combine image of Sentinel-2

Combine Image	Agriculture	Urban Builtup	Grasses/Shrubs	Shrubs/Scattered trees	Trees	class error
Agriculture	1034	1	10	2	25	0.042
Urban Builtup	3	198	4	0	0	0.205
Grasses/Shrubs	26	1	157	6	6	0.276
Shrubs/Scattered trees	9	0	13	26	25	0.667
Trees	25	0	4	3	1220	0.029
OOB Error = 9.05%						

3.4 Tree Species Distribution Mapping

Maps of species distribution or habitat sustainability are required for various aspects of environmental research, resource management and conversation planning. Species distribution modeling represents a scientifically important area that deserves the attention of the machine learning community while presenting it with some interesting challenges (Phillips *et al.*, 2004). Spatial prediction of Species Distribution Model (SDM) relies on the availability of different predictors in the form of maps or, more precisely, digital spatial data (Goodchild *et al.*, 1996).

Eighteen different tree species were analyzed to observe the spatial distribution in urban areas of Islamabad through Maximum Entropy Model. Further, predicted probability of presence of each species is divided into four classes from unsuitable to highly suitable areas. Detail of each class is given below,

Class	Predication Range (threshold)
• Unsuitable area	< 0.2
• Less suitable area	0.2 to 0.4
• Moderately suitable area	0.4 to 0.6
• Highly Suitable area	> 0.6

Maximum entropy (MAXENT) is very sophisticated, machine-learning method of modeling a species' geographic distribution. Using data points of observed species (presence-only), and environmental conditions, MAXENT can estimate the environmental requirements of a species. MAXENT produces habitat suitability analyses addressing the spatial extent of a species. It has become the frequently used software for inferring species distributions and environmental tolerances, and It allows users to fit models of varying complication (Warren & Seifert, 2011). MAXENT is a broadly useful method for making forecasts or predictions from inadequate data. Its sources lie in statistical mechanics (Ratnaparkhi, 1997) and MAXENT is now a common species distribution modeling (SDM) tool used by conservation practitioners for predicting the distribution of a species from a set of records and environmental predictors. The idea of MAXENT is to estimate a target probability distribution by finding the probability distribution of maximum entropy (i.e., most spread out, or close to uniform), When MAXENT is applied to presence-only species distribution modeling, the pixels of the study area make up the space on which the MAXENT probability distribution is defined, pixels with known species occurrence records constitute the sample points, and the features are climatic variables, vegetation type or other environmental variables, and functions thereof (Phillips, 2005).

Ground reference data were collected from the randomly chosen sites within the study area in 2016. Sites were required to be an urban forest in nature. In this case some random patches have been selected of the same species of about 20x20m area because the used images were at 10m spectral resolution. Tree species parameters measured include the position or location of occurrence and species diversity, the position of the field plots was assessed with the help of a GPS. Latitude and longitudes of all points were noted in an inventory. Additionally, pictures were taken for species identification and in the laboratory with the help of Botanist these species were identified. There were species for which no or very few sample points were collected during the field visits. Those species were neglected, due to lack of sample size and less significance.

Also, a ground survey was conducted using a Google satellite image. The positions of the trees were directly marked on images, ensuring a precise matching between ground and aerial observations. The final position of each point was the centroid of all polygons which were marked on the shape file. A differential correction was also applied to the acquired points. By using MAXENT version 3.3.3k we run the analysis of different species. Two types of variables were used in this study which include, predictive variables (individual bands) and environmental variables (bands transformation and ratios).

Sector-wise area of all species was computed with different classes of suitability and mentioned in the tables, which shows the area of relevant species in hectare. Also, maps were generated by using MAXENT prediction of species spatial distribution. Moreover, the jackknife test of variable importance and curves of different significant variable are shown, that how the variables affect the MAXENT prediction.

3.5 Explanatory variables

The explanatory variables to be used in the Maximum Entropy Models for the respective study were divided into two categories,

I. individual bands of the imagery

II. Indices (calculated from the individual bands)

A summary of these variables has been given in table below.

Table 3. 3: Different variables used in present study (*conventions*: _x = _f (February); _m (May); _o (October)

No	Predictor variables	Description
Individual Bands		
1	bi02_x	Band 2 radiance
2	bi03_x	Band 3 radiance
3	bi04_x	Band 4 radiance
4	bi05_x	Band 5 radiance
5	bi06_x	Band 6 radiance
6	bi07_x	Band 7 radiance
7	bi08_x	Band 8 radiance
8	bi08a_x	Band 8a radiance
9	bi09_x	Band 9 radiance
10	bi11_x	Band 11 radiance
11	bi12_x	Band 12 radiance
Bands Transformation and Ratios		
1	arvi_m	Atmospherically resistant vegetation index (May)
2	arvi_f	Atmospherically resistant vegetation index (February)
3	arvi_o	Atmospherically resistant vegetation index (October)
4	evi_m	Enhanced vegetation index (May)
5	evi_f	Enhanced vegetation index (February)
6	evi-o	Enhanced vegetation index (October)
7	lai_m	Leaf area index (May)
8	lai_f	Leaf area index (February)
9	lai_o	Leaf area index (October)
10	ndvi_m	Normalized difference vegetation index (May)
11	ndvi_f	Normalized difference vegetation index (February)
12	ndvi_o	Normalized difference vegetation index (October)
13	savi_m	Soil-adjusted vegetation index (May)
14	savi_f	Soil-adjusted vegetation index (February)
15	savi_o	Soil-adjusted vegetation index (October)
16	tcb_m	Tasseled cap brightness (May)
17	tcb_f	Tasseled cap brightness (February)

No	Predictor variables	Description
18	tcb_o	Tasseled cap brightness (October)
19	tcv_m	Tasseled cap vegetation (May)
20	tcv_f	Tasseled cap vegetation (February)
21	tcv_o	Tasseled cap vegetation (October)
22	tcw_m	Tasseled cap wetness (May)
23	tcw_f	Tasseled cap wetness (February)
24	tcw_o	Tasseled cap wetness (October)

3.6 Sentinel-2

The Sentinel-2A satellite launched on 23June 2015; It is an Earth observation mission developed by ESA (European Space Agency) as part of the European Copernicus Program (ECP) to accomplish terrestrial observations in support of services such as forest monitoring, land cover change detection and natural disaster management etc. The first scenes were delivered a few days later. Santinel-2 carries an innovative wide-swath, high-resolution, Multispectral imager (MSI) with 13 spectral bands in the visible, near infrared (NIR), and short wave infrared (SWIR) part of the spectrum which include 3 atmospheric bands, this is going to offer unprecedented perspectives on our land vegetation.

Earlier satellite sensors (Landsat MSS, TM), having a spectral band in the near infrared part of the spectrum, had good spectral resolution, however, they had too coarse a spatial resolution to produce detailed maps in urban areas. Today very high resolution (VHR) satellites are capable of providing spatial details compatible with urban mapping (Treitz *et al.*, 1992). The combination of high resolution (up to 10 m), novel spectral capabilities (e.g., three bands in the red-edge plus two bands in the SWIR), wide coverage (swath width of 290 km) and minimum five-day global revisit time (with twin satellites in orbit) is expected to provide extremely useful information for a wide range of land (and coastal) applications (Malenovský et al., 2012).

In preparation for this new satellite mission, the scientific community has been working to provide feedback to system developers to define the best algorithms and data exploitation strategies. This activity resulted in several experiments based on simulated Sentinel-2 datasets (Hill, 2013). These studies reported that Sentinel-2 have high potential in various fields of application. This potential in Earth observation (EO), however, needs to be confirmed by real data.

Actual Sentinel-2 data are now available and ready for exploitation for scientific and commercial purposes. In the present study, an assessment of the Sentinel-2 landcover mapping capabilities are undertaken by using February, May and October 2016 images, Sentinel-2 images acquired over study area the Islamabad Capital Territory (ICT). The preliminary assessment focuses on landuse classification and species distribution modelling of some prominent tree species of urban Islamabad, both are important for remote sensing applications.

3.6.1 Characteristics and details of different spectral bands of SENTINEL-2

The SENTINEL-2 spatial resolution depends on the particular spectral band. Spectral resolution, wavelength and purpose of all 13 bands are given.

Band 1 (b1)

The spectral resolution of this band is 60 meter. Its wavelength is 443 nanometers A typical human eye can respond to wavelengths from about 390 to 700 nm, so it is a visible light. This band works much better for aerosol detection.

Band 2 (b2)

The Spectral resolution of band 2 is 10 meter and its wavelength is 490 nanometers. Band 2 falls in the visible spectrum and also capable of differentiating soil and rock surface from vegetation.

Band 3 (b3)

It is also a 10 meter spectral resolution band with 560 nanometer wavelength. It is green band and sensitive to water turbidity differences. Because it covers the green reflectance peak from leaf surfaces. It can separate vegetation (forest, croplands with standing crops) from soil or urban landscape that may have brighter (lighter tone), but all types of vegetation appear as dark tone.

Band 4 (b4)

Band 4 is 665 nanometers red band with a 10 meter spectral resolution. It senses in a strong chlorophyll absorption region and strong reflectance region for most soils. It can discriminate vegetation and soil as well.

Band 5 (b5), Band 6 (b6), Band 7 (b7) and Band 8a (b8a)

These all bands have a 20 meter spectral resolution and 05 nm to 865 nm wavelength. These all bands lie in visible and near-infrared (VNIR) spectra. These bands are more effective for classification of vegetation and tree species identification.

Band 8 (b8)

Band 8 is a 10 meter spectral resolution band with 842 nanometers wavelength. It is NIR (near infrared), and can distinguish a variety of conditions. Because water is a strong absorber of NIR, this band is important in delineating water bodies, distinguishing dry and moist soils, barren areas and crop lands.

Band 9 (b9) and Band 10 (b10)

These both are 60 meter spectral resolution bands with atmospheric characteristics. Band 9 is useful for water vapors and similarly band 10 is useful for cirrus. Due to the high spectral resolution these were found less significant in the current study.

Band 11 and Band 12

The band 11 and 12 both are Short-wave infrared (SWIR) or non-visible light. It is adjacent to NIR and both bands have 20 meter spectral resolution. These bands are sensitive to snow, ice or clouds because snow has maximum reflectance.

The significance of individual bands has been discussed as above and their representations of the respective months of 2016 have been shown in the figures 3. 4 to 3. 6.

3.6.2 Image of study area with different spectral bands

February 2016 Image:

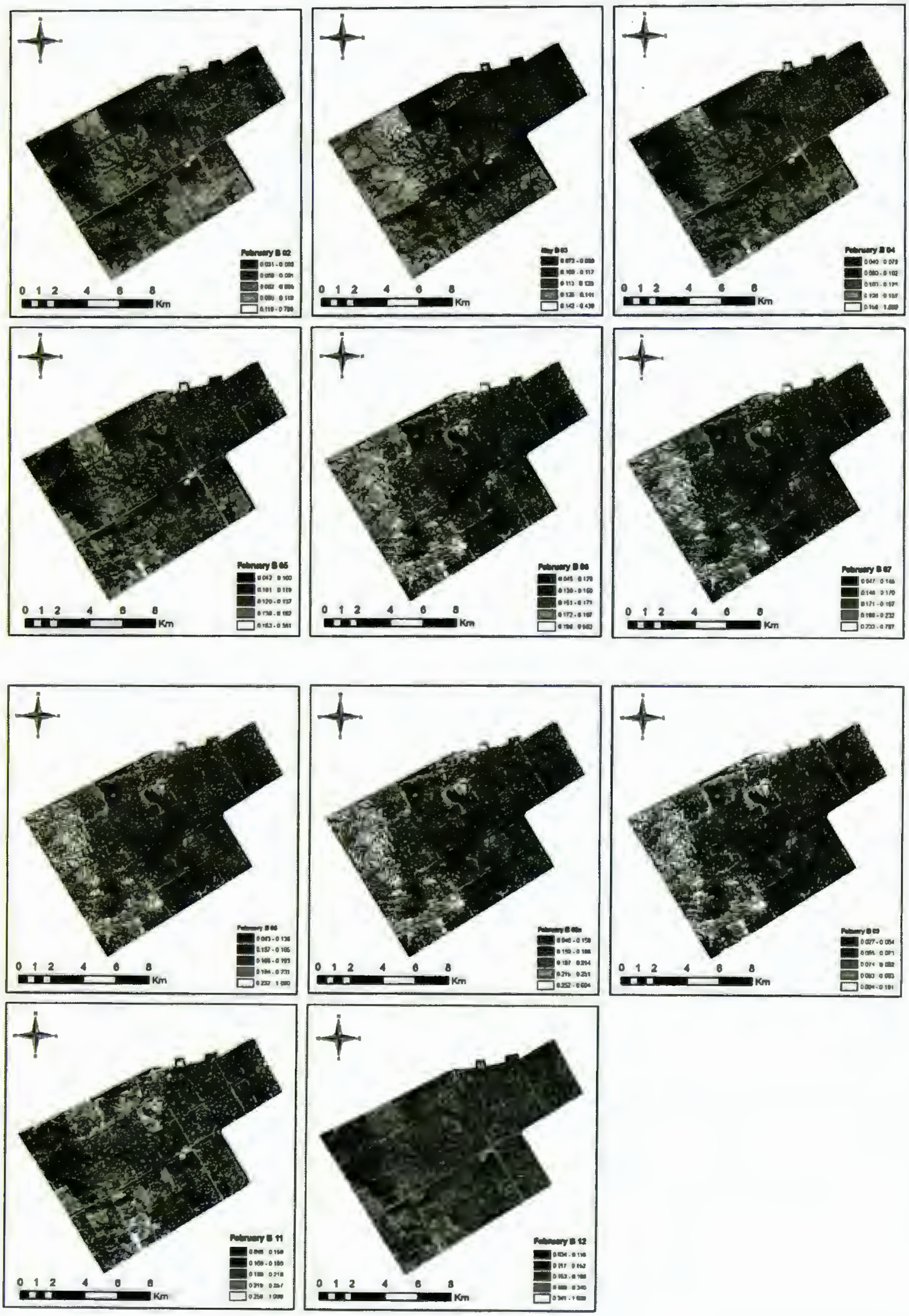


Figure 3. 4: A representation of different bands of February imagery

May 2016 Image:

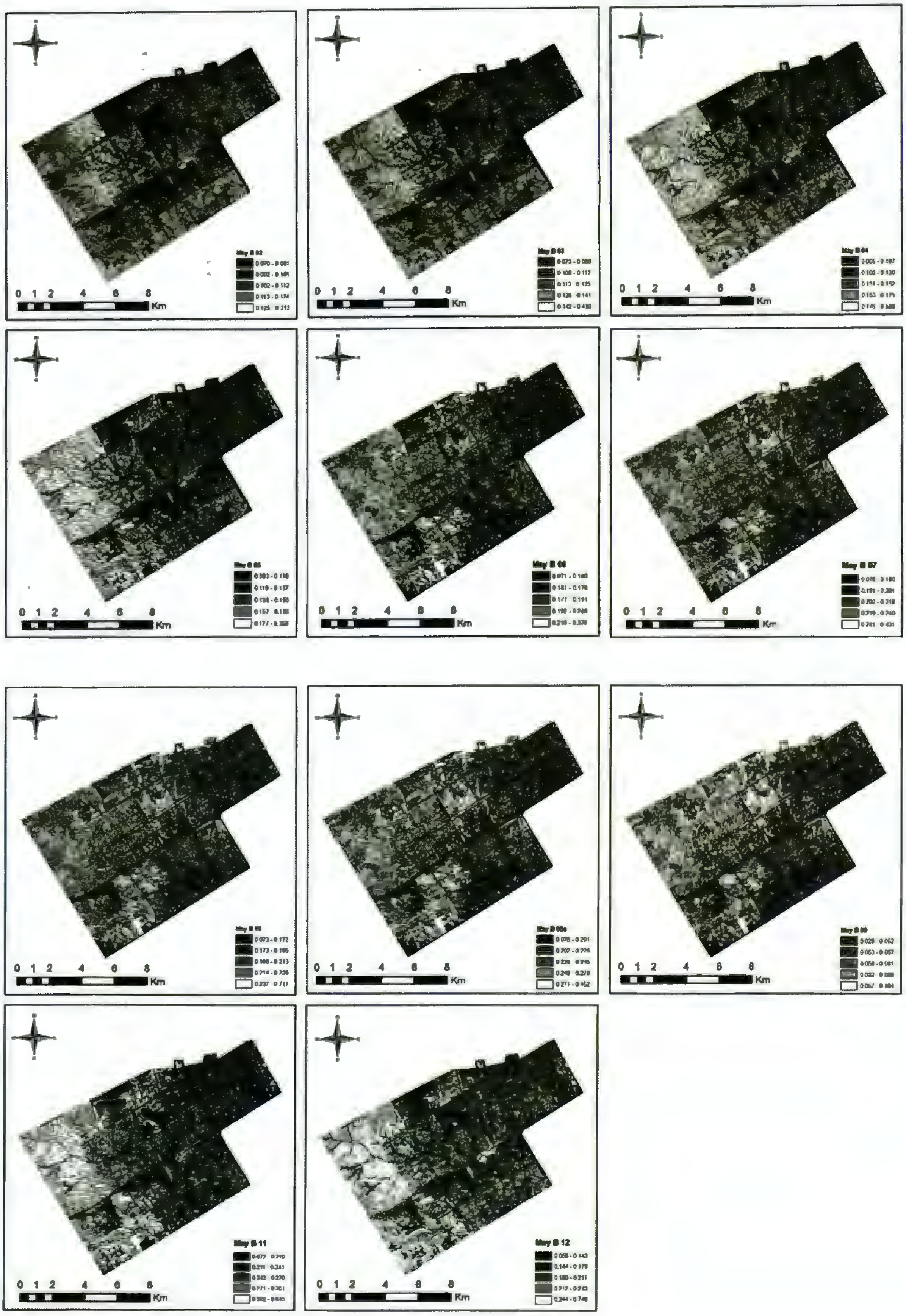


Figure 3. 5: Representation of different bands of May imagery

October 2016 Image:

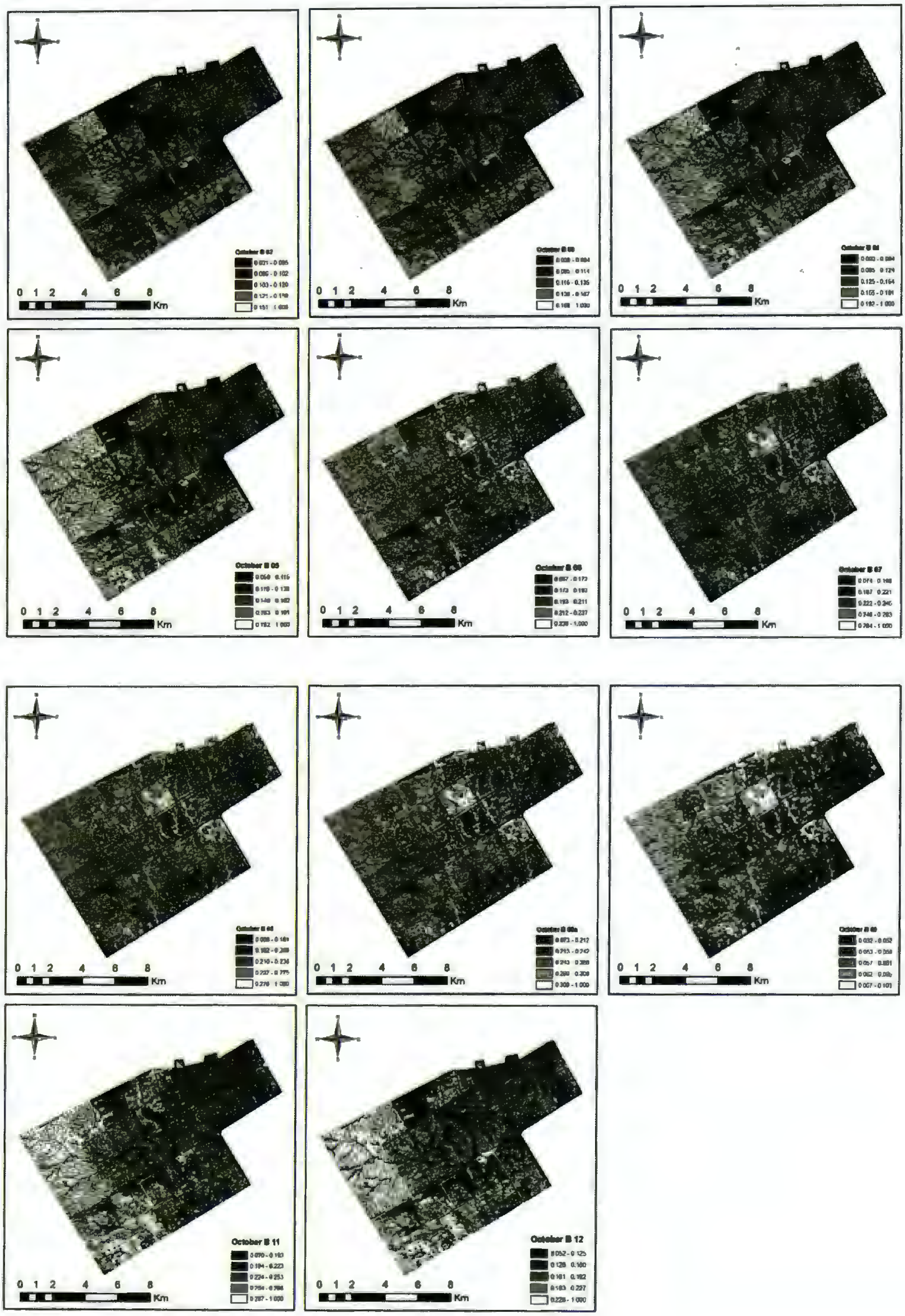


Figure 3. 6 : A representation of different bands of October imagery

3.7 Individual vegetation indices

3.7.1 Normalized difference vegetation index (NDVI)

NDVI is widely used vegetation index (Tucker, 1979) which is a band ratio technique. The purpose of this technique is to reduce the multiple bands of data down to a single band that accesses the vegetative ground cover. The NDVI (sum and differences between spectral bands), as given is applied to each satellite image.

$$NDVI = \frac{(NIR-RED)}{(NIR+RED)}$$

where Red is band 3 and band 4 is NIR of Sentinel-2 satellite system.

The NDVI techniques are useful to extract the vegetation cover and prediction of tree species (Butt, *et al.*, 2012) from each satellite image. In the current study , this technique is found to be very useful to improve the results.

3.7.2 Soil adjusted vegetation index (SAVI)

SAVI is an alternative for NDVI, because It is less sensitive to variate in the reflectance of the sol background. The SAVI allows better green vegetation monitoring paticularly with unsuitable areas or low plant cover (e.i., < 20%) and the soil surface is exposed, the reflectance of light in the red and near infrared spectra can influence vegetation index value. This is especially biometric when comparisons are being made across different soil types that may reflect different amounts of light in the red and near infrared wavelengths. SAVI is calculated by using following equation:

$$SAVI = \frac{NIR-RED}{NIR+RED+L} \times (1+L)$$

L= Soil brightness correction factor

The Value of L varies by the amount or cover of green vegetation: in very high vegeation regions, L=0; and in areas with no green vegetation, L=1. Generally, L=0.5 works well in most situations and is the default value used. When L=0, then SAVI=NDVI.

3.7.3 Enhanced vegetation index (EVI)

This index is designed to improve the vegetation signal with better sensitivity in high biomass areas and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences (Huete *et al.*, 1997).

The formula of EVI is given below,

$$EVI = \frac{2.5 \times (\text{nirchan} - \text{redchan})}{\text{nirchan} + 6.0 \times \text{redchan} - 7.5 \times \text{bluechan} + 1.0}$$

3.7.4 Atmospherically resistant visible index (ARVI)

Positive values of ARVI generally indicate the presence of vegetation (with greater values indicating healthier vegetation) and negative values usually indicate a lack/defeiciency of vegetation (water, rock, soil, etc.).

$$ARVI = \frac{(NIR - (2 \times Red) + Blue)}{(NIR + (2 \times Red) + Blue)}$$

3.7.5 Leaf area index (LAI)

It is a dimensionless quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area (Myneni *et al.*, 1997). Forumua for calculating LAI is,

$$LAI = \text{leaf area} / \text{ground area}$$

(Unit of the leaf and ground area is "m^2")

3.7.6 Tasseled cap

Tasseled Cap fits all the criteria for a good vegetation index and almost as widely used as the NDVI. It defines a new coordinate system to represent soil line and vegetation and It creates three band image. Three of the six tasseled caps transform bands are often used:

Band 1 (brightness, measure of soil)

Band 2 (greenness, measure of vegetation)

Band 3 (wetness, interrelationships of soil and canopy moisture)

4. RESULTS AND DISCUSSION

The present study examined the application of recently developed global satellite data products in modeling land use/land cover (LULC) types and potential distribution of selected tree species in urban areas of Islamabad. Initially, land use/land cover (LULC) were extracted by using random forest classifier leading into identification of five major landcover classes (Figure 4. 1). The results are presented in the form of maps, graphs and statistical tables.

The land cover classification shows result of 90.95 percent accuracy through out-of-bag (OOB) error technique. The urban built up structure occupies the highest class with approximately 4753 hectares (40 percent) area. Grasses and weed forms the second largest class, covering approximately 2839 hectares (25 percent) of the study area. Shrubs and scattered trees covers approximately 350 hectares which makes it the least significant land cover class. Besides, farming seems to be practiced moderately occupying 1287 hectares (11 percent) of all classes. The trees or urban forest covers 2402 hectares or 20 percent of the whole study area. Sectors-wise area of each land cover class is tabulated in table 4. 1.

Tree species prediction results are presented in maps of predicted probability of presence with suitability for selected eighteen tree species. Predicted suitability of the species are categories into four classes: ranging from highly suitable to unsuitable sector-wise probability of occurrence is calculated. Further, assessment of significant variables is carried out through Jackknife test of regularize training gain from MAXENT and response curves are discussed.

4.1 Land Cover Classification

Landcover of urban Islamabad is classified into five major categories.

I. Agricultural land
II. Grasses and weeds
III. Shrubs and scattered trees
IV. Trees
V. Urban built up area

Random forest created land cover classes includes; agricultural land, grasses or weeds, shrubs or scattered trees, trees and urban built up area are shown in the figure 4. 1.

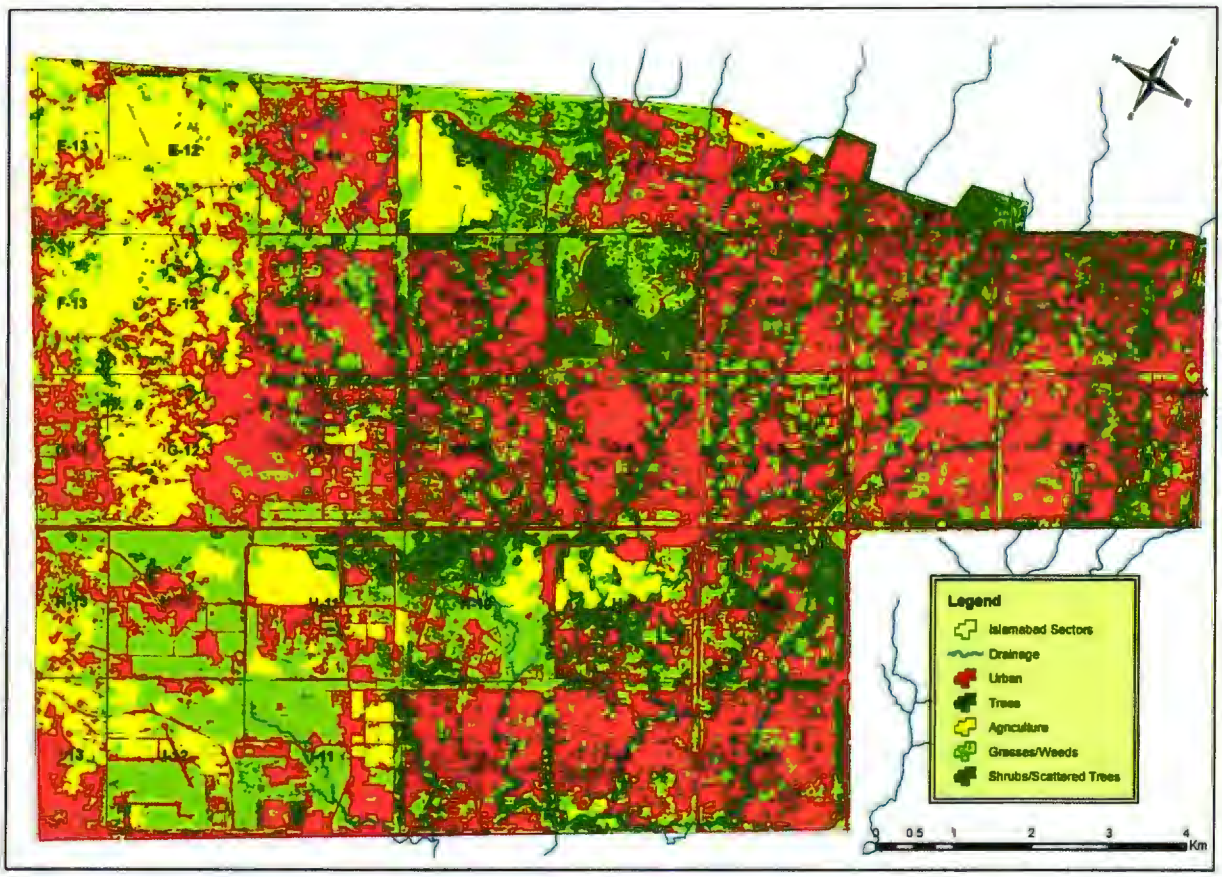


Figure 4. 1: Spatial distribution of major landcover classes in urban (sectoral) Islamabad

4.1.1 Agricultural land

About 1287 hectares (11 percent of the total study area) consist of agriculture land, due to urbanization process mostly residential sectors don't have significant agriculture. Mostly, agriculture carried out in the slums or peri-urban areas. Sectors like E-7, F-6, F-7, F-8, F-9, F-10, G-6, G-7, G-8, G-9, G-10, H-8, I-8 and I-10 do not have enough significant agriculture land. Maximum agriculture land is found in the sector E-12 which is about 252.61 hectare or the 61.7 percent of the total sector (Table 4. 1).

4.1.2 Grasses and weeds

The land cover type grass or weeds are mostly found in the green belts along the major Highways and road in almost all sectors. The most significant areas are remnant vegetation patches grasses and weeds almost occupy 2839 hectare (24.4 percent) land cover of the total study area. In sector H-12, 215 hectare area is covered with above mentioned land cover class which makes about 62.8 percent of the total sector. Other important sectors having significant with grasses and weeds covers are I-12, I-11, H-10, H-11 and E-9. Sector-wise land cover type area of each class is given in table 4. 1.

4.1.3 Shrubs and scattered trees

The land cover type (Shrubs or scattered trees) makes approximately 3 percent of the total study area which is almost 350 hectares. This land cover class dominantly found in E-10, F-9 and H-10 with 64.9, 56.3 and 41.8 hectare area respectively. Further details of each class are given in table 4. 1.

4.1.4 Trees

Trees address distinctive issues of food, safe house, vitality and stylish in the city. Urban forests and backwoods range, past the city offer relief if just for a while, from the pressure of the daily life. In Urbanized area the Public parks, along the all drainage or water channels and along the both sides of main roads, dense tree canopy are found, which is about 2402 hectares or 20.4 percent of the total study area. Sector F-6 is having maximum tree cover area which is about 172 hectare land cover. It is about 47.8 percent of the whole sector F-6. Beside this, F-9 and H-8 are the second and third largest sectors having the maximum trees cover 167 hectare and 158 hectare area. While, I-13 is covered just 0.5 hectare or 0.3 percent of the total area of I-13 which makes it prominent sector with very less tree cover (Table 4. 1).

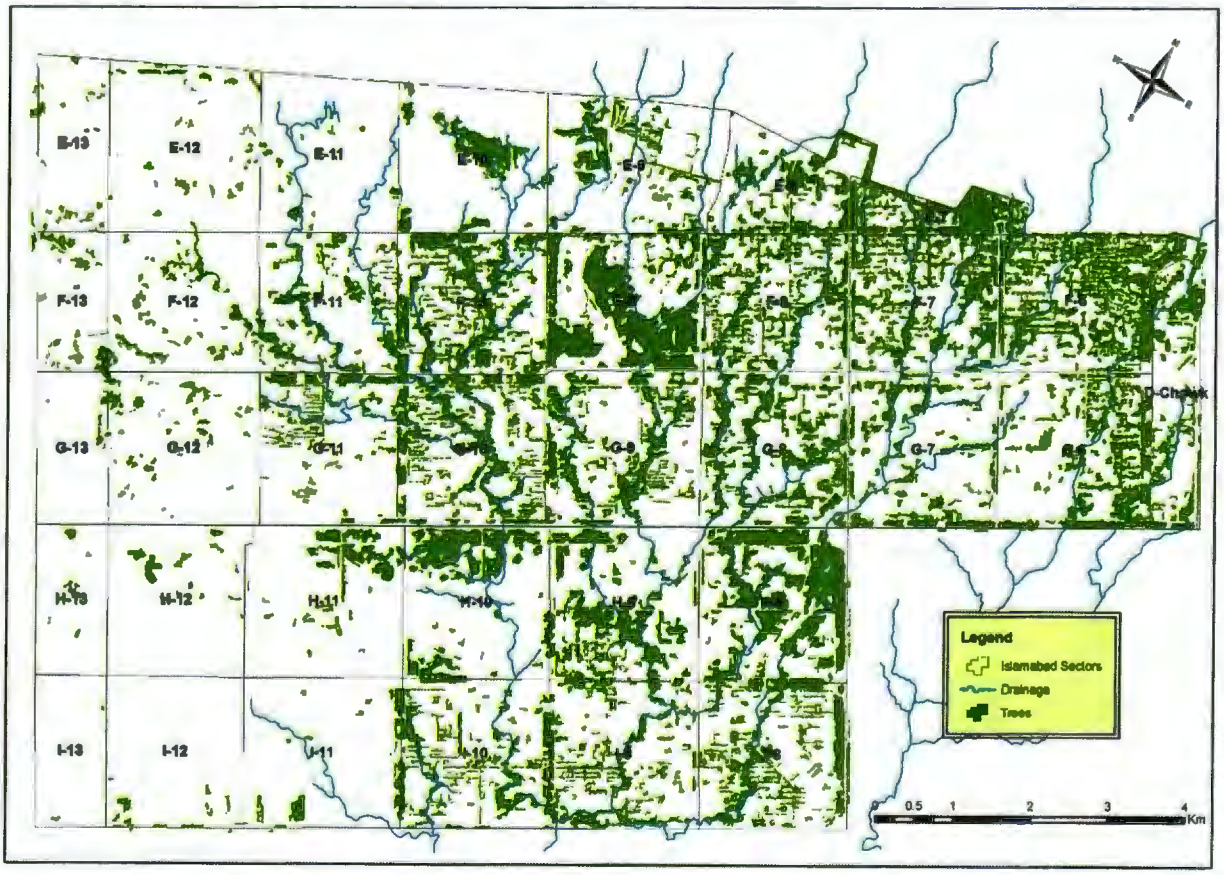


Figure 4. 2: Map of the urban Islamabad showing trees along with Drainage pattern

In vegetation map of the study area is shown in figure 4. 2, It can be observed that the most tree cover of urban Islamabad is found in undisturbed or protected areas especially, green belts or along the drainage sides due to availability of water and suitable habitat.

4.1.5 Urban built up

In the present study, urban built up area which includes all man-made infrastructure like roads, buildings and all other relevant phenomena makes up about 40.8 percent of the total area which makes it the dominant land cover type of the present study area. Urban built up area comprises about 4753 hectare of the whole study area (11633hectare). Among all major residential sectors G-7 is having about 237 hectare built up area which is about 63 percent of the total sector area, followed by Sectors G-9 and G-6 which are having 233 hectare and 227 hectare area respectively (Table 4. 1). While, sectors E-10 is having minimum built up cover 23 hectare, because this sector is under-developed. So, the built up area is about 6.65 percent of the sector E-10. The urban landscape of Islamabad is shown in figure 4. 3.

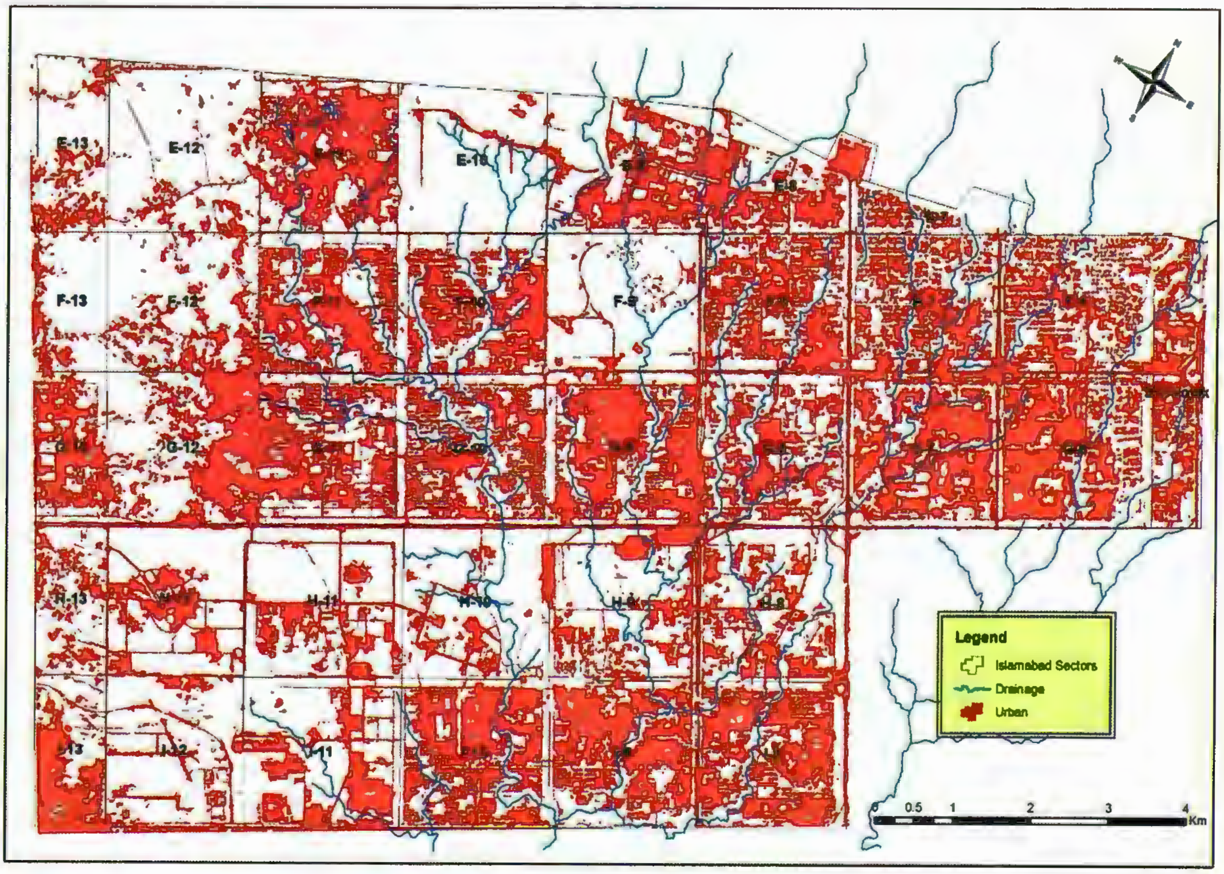


Figure 4. 3: Urban built up land cover of the Study area

Sector wise area of all five landcover types are listed in table 4. 1.

Table 4. 1: Sector-wise area of different land cover type in the study area (hectare)

Land Cover ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7
Urban	50.12	49.88	214.66	23.19	161.97	105.19	29.32
Trees	7.26	15.07	8.59	42.52	58.36	64.04	74
Agriculture	93.65	252.61	5.66	107.16	0.98	20.25	0
Grasses/weeds	51.18	91.43	118.8	111.28	122.11	24.07	8.04
Shrubs/scattered trees	0.52	0.38	1.02	64.94	29.63	10.29	3

Land Cover ↓ Sector →	F-13	F-12	F-11	F-10	F-9	F-8	F-7	F-6	D-Chowk
Urban	25.89	81.24	169.77	163.4	42.21	182.57	167	161.66	121.15
Trees	14.39	28.27	61.34	125.83	166.85	108.1	121.86	172.87	62.4
Agriculture	85.44	189.12	0.47	0	0	0	0	0	0
Grasses/weeds	35.64	48.96	79.87	43.52	91.96	30.99	44.42	25.95	30.46
Shrubs/scattered trees	0.52	0.38	1.02	10.25	[illegible]	5.62	4.51	1.89	1.81

Land Cover ↓ Sector →	G-13	G-12	G-11	G-10	G-9	G-8	G-7	G-6
Urban	100.19	171.98	182.32	165.84	233.22	168.67	237.66	227.51
Trees	3.39	16.57	45.3	119.04	106.19	118.93	75.85	112.88
Agriculture	8.74	145.71	6.52	0	0	0	0	0
Grasses/weeds	64.38	42.23	104.5	68.55	45.28	75.94	60.31	46.59
Shrubs/scattered trees	0.95	0.83	3.98	12.74	10.64	10.4	3.83	2.09

Land Cover ↓ Sector →	H-13	H-12	H-11	H-10	H-9	H-8
Urban	54.06	96.97	112.2	64.61	118.97	138.13
Trees	3.62	10.45	37.4	78.49	106.24	158.75
Agriculture	39.84	17.16	87.21	27.26	51.17	0
Grasses/weeds	78.88	215.54	133.12	155.9	91.45	73.84
Shrubs/scattered trees	0.43	3.08	23.99	41.81	9.44	8.25

Satistic	
Min:	0
Max:	252.61

Land Cover ↓ Sector →	I-13	I-12	I-11	I-10	I-9	I-8
Urban	92.33	65.12	128.95	213.63	212.24	219.21
Trees	0.51	6.55	18.05	80.18	79.04	93.8
Agriculture	46.85	68.44	28.7	0	4.44	0
Grasses/weeds	32.91	202.9	201.96	72.69	69.35	44.4
Shrubs/scattered trees	1.32	4.51	15.01	3.47	0.72	1.06

Total	Total	Min	Max
Urban	4753.03	23.19	237.66
Trees	2402.98	0.51	172.87
Agriculture	1287.38	0	252.61
Grasses/weeds	2839.4	8.04	215.54
Shrubs/scattered trees	350.67	0.38	64.94

4.2 Significant variables for different tree species

The table given below shows the variables with significant contribution in MAXENT. These variables show significant contribution in MAXENT model.

No.	Species	Used Significant Variables for MAXENT
1	*Acacia sp.*	bi07, boc.02, evif, ndvio
2	*Albizia lebbeck*	ndvi, evi, fb.08, bio4, savi, ndvif, savio, fb.08a, ndvio, bi08
3	*Alstonia scholaris*	arvi, fb.05, boc.04, laif, boc.12
4	*Bischofia javanica*	fb.08, fb.09, tewo, fb.08a, tevf, fb.04, fb.12
5	*Broussonetia papyrifera*	boc.05, tevf, bi12, boc.09, bi03, boc.08, boc.06, boc.03, fb.07
6	*Callistemon citrinus*	bio07, tewo, bi09, bi08, fb.07, tew, evio, fb.02, fb.12
7	*Cedrela serrata*	boc.09, bi.05, laio, bi09, bi08a, arvi, fb.07, fb.04, boc.06, teb
8	*Celtis australis*	fb.05, boc.11, fb.07, boc.06, boc.09, boc.07, tew, bi09, bi04
9	*Citharexylum spinosum*	bi09, boc.09, savio, fb.06, boc.11, laio, arvif, bi11, fb.12, ndvif
10	*Dalbergia sissoo*	evio, tewf, tev, fb.02, boc.09, fb.08, bi09, savio, boc.03
11	*Eucalyptus camaldulensis*	bi08, evio, tevf, boc.02, fb.08, tewo, bi12, fb.08a, fb.12, bi06
12	*Ficus elastica*	fb.05, tewo, fb.11, boc.05, bi12, fb.12
13	*Jackaranda mimosifolia*	bi11, bi02, bi04, ndvif, bi12, tewf, lai, laif, boc.09, fb.02
14	*Pinus roxburghii*	bi08, lai, boc.09, savio, arvio, fb.08, evif, bi12, bi05, boc.06
15	*Pongamia pinnata*	boc.02, fb.07, boc.09, tevf, bi02
16	*Populus ciliate*	boc.08, fb.09, fb.08a, fb04, boc08a, ndvio, ndvif, bi06, fb.12
17	*Sapium sebiferum*	tevo, savi, evio, fb.09, tewo, ndvio, laif, boc08a, boc09
18	*Terminalia arjuna*	fb.08, fb.09, bi08a, fb.02

4.3 Predicted distribution of tree species

4.3.1 *Acacia sp* (Phulai / Kikar / Babul)

Acacia modesta and *Acacia nilotica* are one of the most commonly occurring species in this study area. *Acacia modesta* is a medium size decidous tree locally called "phulai". Its flowering time is in April to May. *Acacia nilotica* locally called "kikar" or "babul" and June to July is the flowering time. It is observed that mostly *Acacia sp* is found along the drainage sides and in the green belts. Spatial distribution of *Acacia* sp in the study area is given in the figure 4. 4, and dark values indicate higher probability of occurrence.

Prediction distribution of *Acacia* with suitability classes (sector-wise)

Sector wise area of *Acacia sp* indicates that, It covers 275 hactares (11 percent of total tree class) with highest suitability class. Some prominent sectors which have a significant land cover are H-8, H-10, F-6, F-9 and G-6. Sector H-8 have 27.46 hectares cover with a highest suitability range, which makes sector H-8, the most suitable sector with maximum *Acacia sp* cover. Also with moderately suitable class, It is predicted to be found on 686 hectare (28.5 percent of the tree class) area. Sector H-8 is the biggest sector with 67.26 hectare cover. Further, details of each sector is given in table 4. 2.

Jackknife of regularized training gain for *Acacia sp*

The results of the jackknife test of variable importance show that the variable bi06 (band 6 of May imagery) contributes 26.2 percent with 0.23 regularized training gain, which makes it the most important variable. The other significant variables include, evif (Atmospherically resistant vegetation index_February), savif (Soil-adjusted vegetation index_February) and bi07 (band 7 of May). While, tcwo (Tasseled cap wetness_October) and bi09 (band 9 of May) is among the less significant variables (Figure 4. 5).

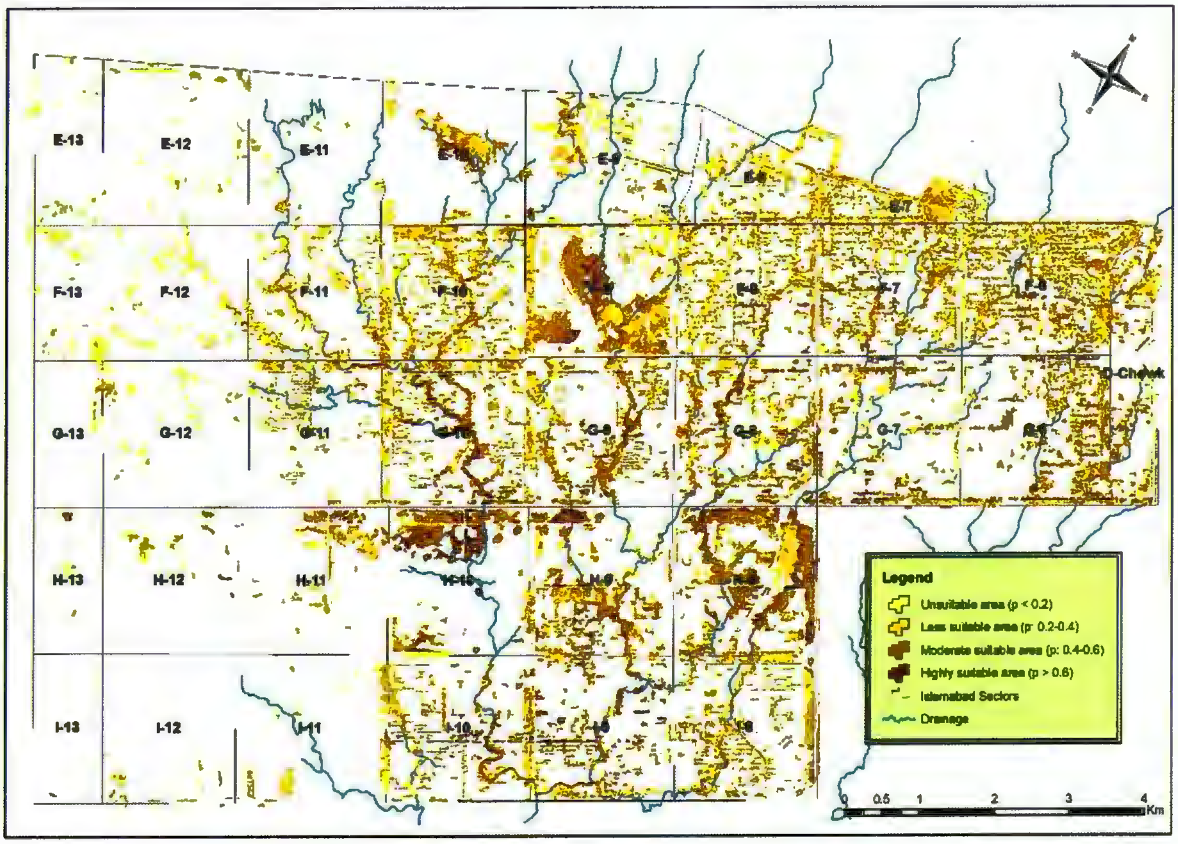


Figure 4. 4: Predicted probability of presence from MAXENT model for *Acacia sp.*

Table 4. 2: Suitability of *Acacia sp* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7
Unsuitable	2.62	5.25	1.65	2.17	10.05	11.06	9.71
Less suitable	4.36	8.41	5.36	24.08	34.49	41.83	48.32
Moderately suitable	0.27	1.28	1.25	14.64	10.9	9.1	13.72
Highly suitable	0.01	0.13	0.33	1.63	2.92	2.05	2.25

Suitability ↓ Sector →	F-13	F-12	F-11	F-10	F-9	F-8	F-7	F-6	D-Chowk
Unsuitable	6.9	13.97	6.91	11.09	10.92	10.9	11.27	18.76	4.43
Less suitable	7.29	13.11	42.83	82.36	83.66	60.49	62.66	90.3	30.58
Moderately suitable	0.16	0.89	9.44	27.76	58.75	26.1	33.01	42.13	17.85
Highly suitable	0.04	0.3	2.16	4.62	13.52	10.61	14.92	21.68	9.54

Suitability ↓ Sector →	G-13	G-12	G-11	G-10	G-9	G-8	G-7	G-6
Unsuitable	1.12	7.95	3.37	4.34	3.76	7.06	4.74	5.55
Less suitable	2.03	7.45	27.76	59.76	51.75	57.8	33.8	48.61
Moderately suitable	0.24	1.01	11.2	37.95	37.84	39.78	22.43	34.48
Highly suitable	0	0.16	2.97	16.99	12.84	14.29	14.88	24.24

Suitability ↓ Sector →	H-13	H-12	H-11	H-10	H-9	H-8
Unsuitable	1.27	2.49	2.84	2.44	3.01	3.88
Less suitable	1.15	4.02	20.88	20.42	47.01	60.15
Moderately suitable	0.69	2.79	11.95	35.44	40.54	67.26
Highly suitable	0.51	1.15	1.73	20.19	15.68	27.46

Suitability statistic	
Min:	0
Max:	90.3

Suitability ↓ Sector →	I-13	I-12	I-11	I-10	I-9	I-8
Unsuitable	0.2	0.73	3.19	6.67	3.22	6.58
Less suitable	0.05	4.58	12.65	40.18	34.79	53.9
Moderately suitable	0.15	1.07	1.9	21.84	24.24	26.04
Highly suitable	0.11	0.17	0.31	11.49	16.79	7.25

Total	Total	Min	Max
Unsuitable	212.1	0.2	18.76
Less suitable	1229	0.05	90.3
Moderately suitable	686.1	0.15	67.26
Highly suitable	275.9	0	27.46

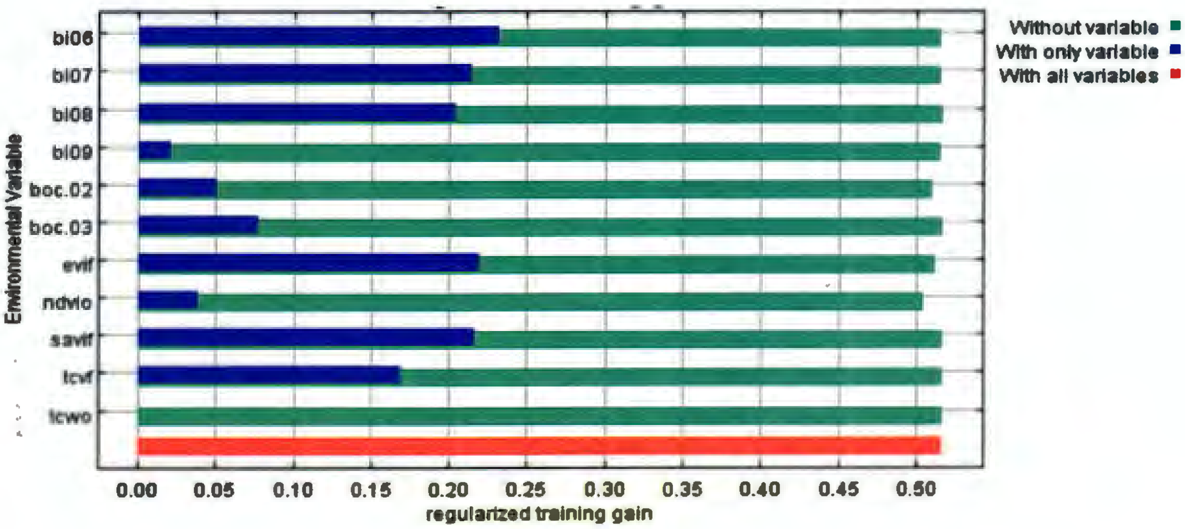
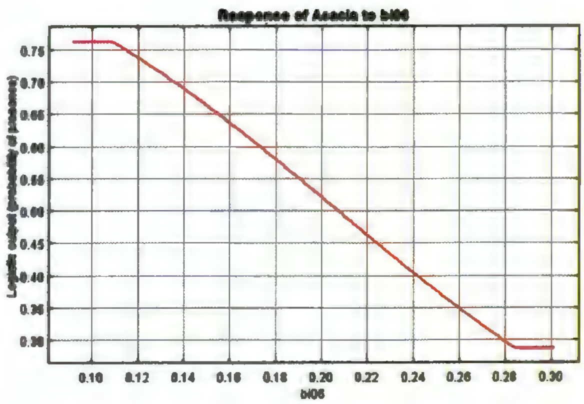
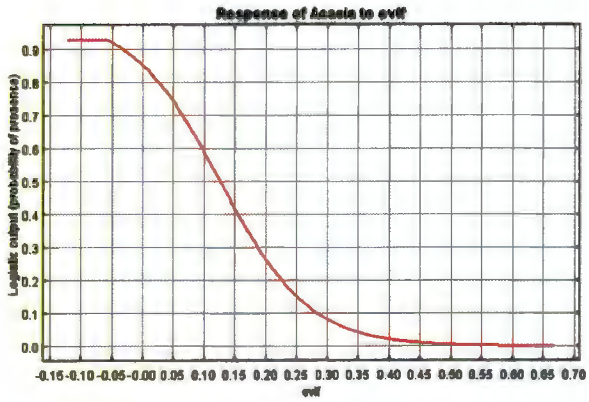


Figure 4. 5: *Jackknife of regularized training gain for Acacia sp.*

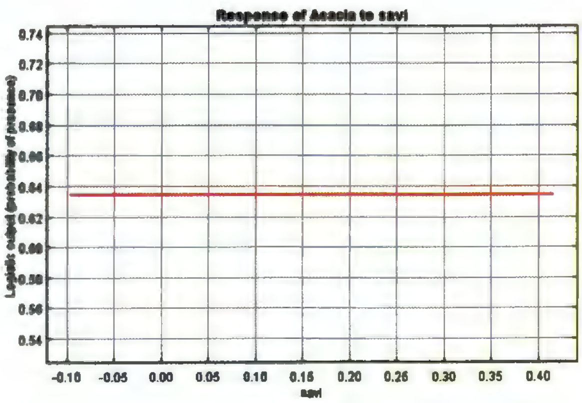
Response curves of important variables for *Acacia sp.*



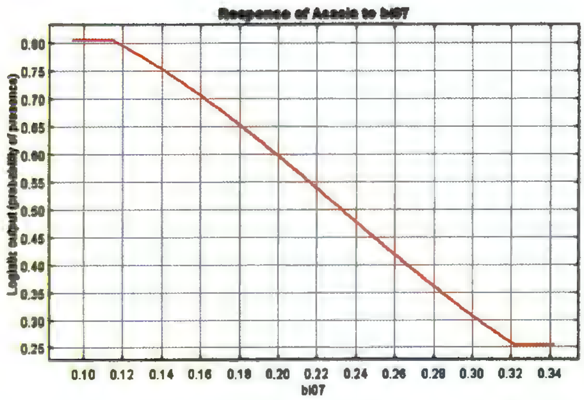
(a)



(b)



(c)



(d)

The values on y-axis shows the predicted probability of suitable conditions e.g., (a) Variable bi06 (band 6 of May image) is showing the negative correlation as the variable range is increasing the probability of presence is decreasing. (b) The variable evif, response curve shows negative correlation. (c) According to Jackknife of regularized training gain the variable savi is contributing significantly but it is not showing any trend. (d) The variable bi07 graph shows negative correlation.

4.3.2 *Albizia lebbeck* (Siris)

Albizia lebbeck is mostly fast-growing subtropical and tropical deciduous tree. It is often simply called "black siris". Dark values in the map (Figure 4. 6) indicates the highly suitable areas of the *Albizia lebbeck* which is about 243.6 (10.1 percent of the tree class). It is commonly spread in the urban green spaces and green belts in the study area. By area it is one of the most abundant tree species of urban Islamabad.

Prediction distribution of *Albizia lebbeck* with suitability classes (sector-wise)

Sector F-6 shows 33.63 hectares, the highest area with highly suitable class. While, *Albizia lebbeck* is predicted to be found on 360 hectare (15 percent of the tree class), the maximum area with a moderate suitability range is 34.8 hectare lies in sector F-6. Moreover, sectors G-6, G-7, F-7 and I-8 have significant cover. Distribution in other sectors with suitability range is also given in table 4. 3.

Jackknife of regularized training gain for *Albizia lebbeck*

The results of Jackknife test show that variable ndvi (normalized difference vegetation index_May) contribute 29.7 percent to the MAXENT model and shows highest gain in the Jackknife test, SAVI (Soil-adjusted vegetation index_May) just contribute 4.4 percent but show significant gain, EVI (Enhanced vegetation index_May) and bi04 (band 4 of May) both variables show significant gain (Figure 4. 7).

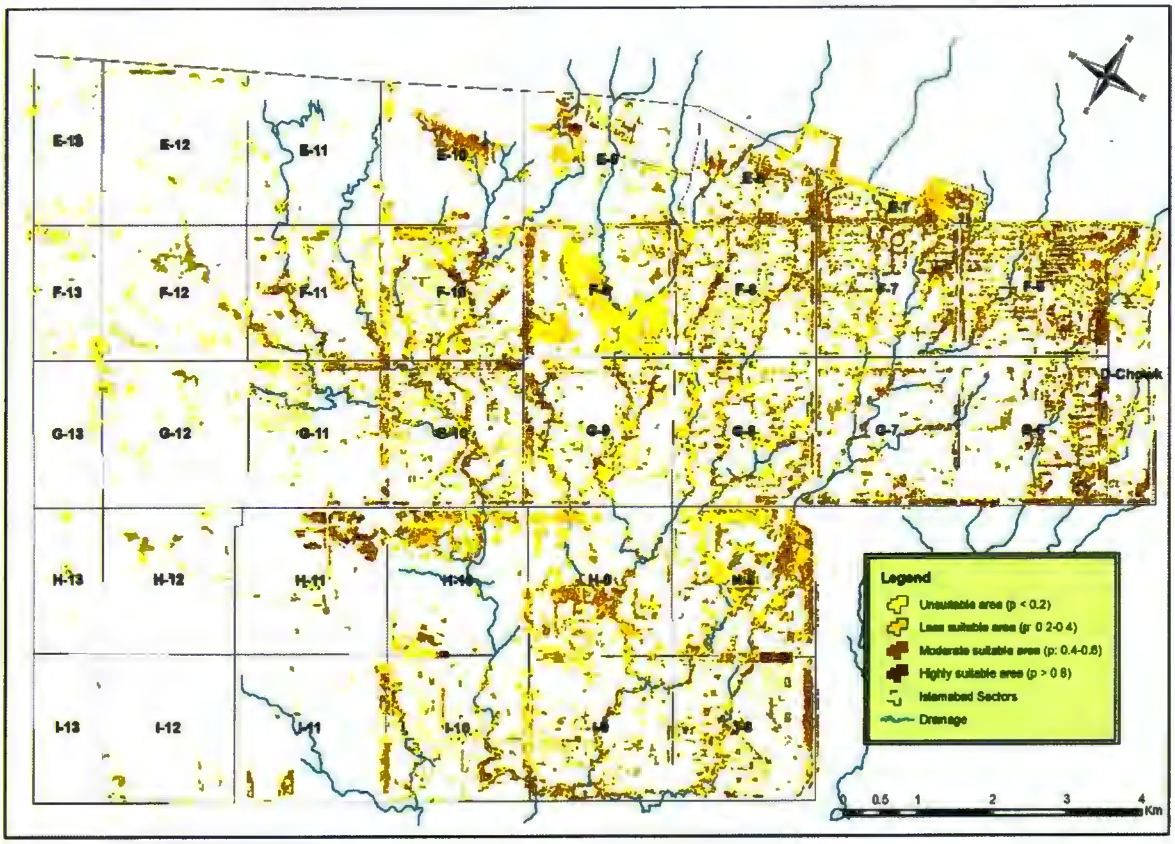


Figure 4. 6: Predicted probability of presence from MAXENT model for *Albizia lebbeck*

Table 4. 3: Suitability of *Albizia lebbeck* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7		
Unsuitable	6.18	10.19	4.36	6.85	15.91	12.38	15.23		
Less suitable	1.03	3.44	3.47	25.66	30.14	31.76	39.07		
Moderately suitable	0.05	1.15	0.49	7.78	7.35	12.62	10.99		
Highly suitable	0	0.29	0.27	2.23	4.96	7.28	8.71		
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**
Unsuitable	7.72	15.95	19.37	43.19	80.23	31.35	29.13	31.71	18.95
Less suitable	6.26	9.4	28.34	58.77	68.65	48.45	53.59	72.66	24.82
Moderately suitable	0.37	2.19	9.26	14.91	11.76	16.39	22.59	34.87	9.09
Highly suitable	0.04	0.73	4.37	8.96	6.21	11.91	16.55	33.63	9.54
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**	
Unsuitable	2.66	11.2	19.07	32.23	33.63	38.42	14.31	18.84	
Less suitable	0.72	4.27	18.68	53.05	47.24	54	32.41	44.85	
Moderately suitable	0.01	0.66	4.96	20.81	15.21	16.84	15.71	23.98	
Highly suitable	0	0.44	2.59	12.95	10.11	9.67	13.42	25.21	
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**			
Unsuitable	2.21	4.92	3.36	19.2	28.01	44.91			
Less suitable	1.26	4.18	16.74	45.69	60.36	77.39			
Moderately suitable	0.07	0.94	11.05	10.22	14.43	23.06			
Highly suitable	0.08	0.41	6.25	3.38	3.44	13.39			
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**			
Unsuitable	0.32	2.14	4.94	28.2	25.66	24.88			
Less suitable	0.16	3.65	8.62	36.51	36.4	39.27			
Moderately suitable	0	0.61	2.88	10.34	11.15	15.79			
Highly suitable	0.03	0.15	1.61	5.13	5.83	13.83			

Suitability statistic

Min:	0
Max:	80.23

Total	**Total**	**Min**	**Max**
Unsuitable	707.8	0.32	80.23
Less suitable	1091	0.16	77.39
Moderately suitable	360.6	0	34.87
Highly suitable	243.6	0	33.63

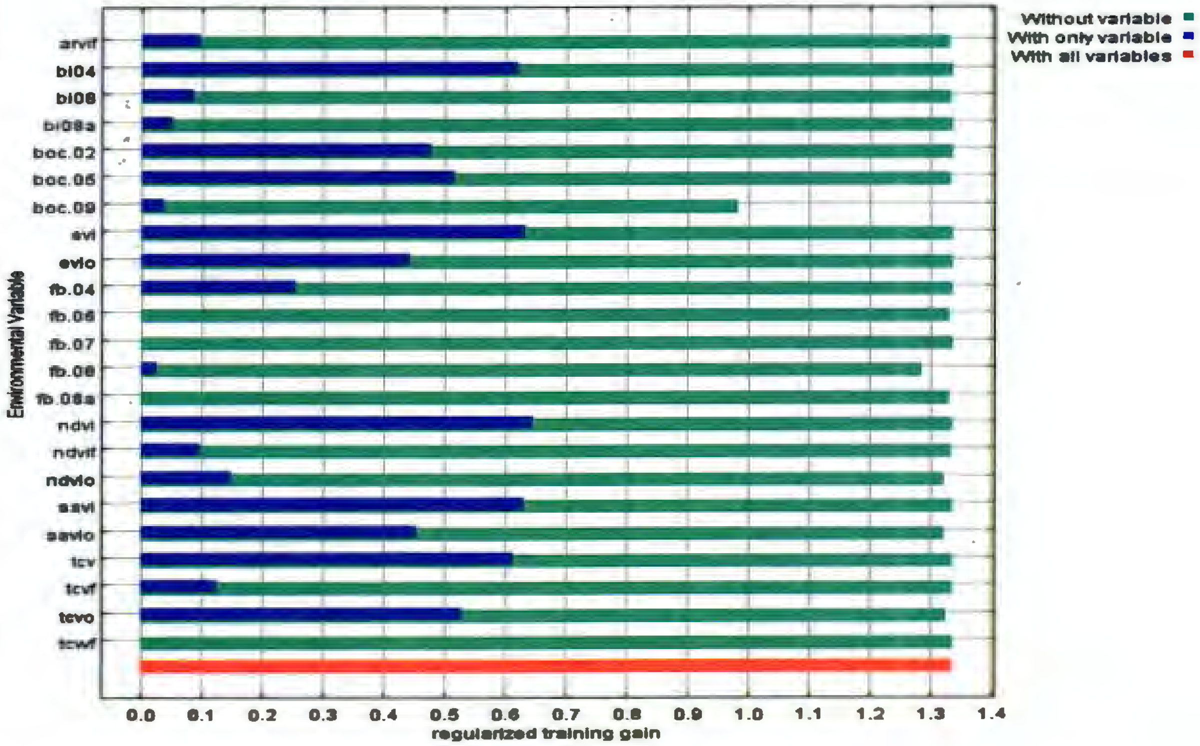
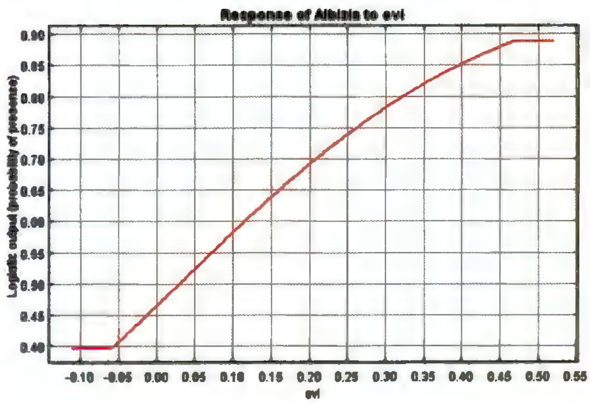
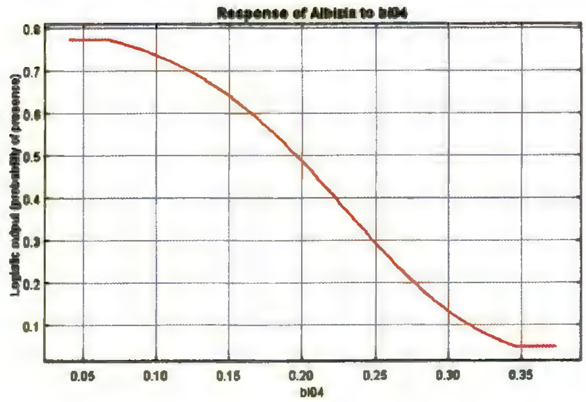


Figure 4. 7: Jackknife of regularized training gain for *Albizia lebbeck*

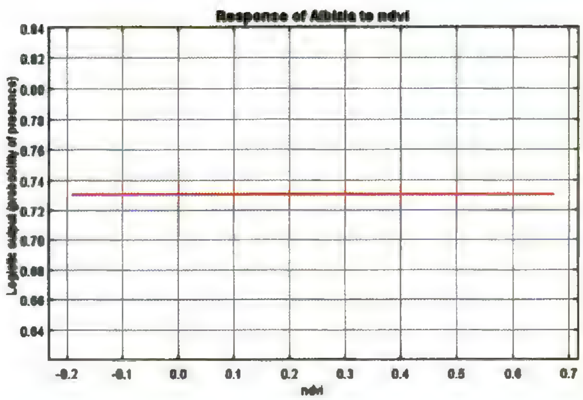
Response curves of important variables for *Albizia lebbeck*



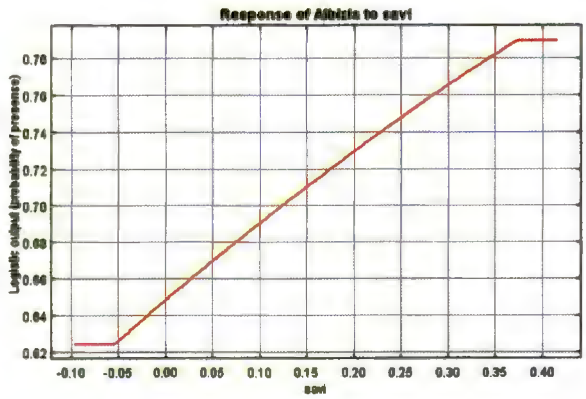
(a)



(b)



(c)



(d)

The above response curves show that how some variable response to *Albizia lebbeck* (a) the variable with highest gain is evi (Enhanced vegetation index _May), which show a positive correlation. It shows maximum prediction of presence at 0.47 threshold. (b) The variable bi.04 (band 4 of May) contributes 4.5 percent but shows high gain in Jackknife test, It has negative correlation. (c) The variable ndvi (Normalized difference vegetation index_May) contributes highest (29.7 percent) but shows no correlation. (d) The variable savi (Soil-adjusted vegetation index_May) shows positive correlation with 4.4 percent contribution and have highest probability of presence at 0.37 threshold.

4.3.3 *Alstonia scholaris* (Shaitan)

It commonly called blackboard tree, devil tree, saitan, shatin and white cheesewood. It is an ever green tropical tree, native to the Subcontinent and Australasia. In Islamabad *Alstonia scholaris* is found commonly in the urban residential areas (Figure 4. 8). Its tendency can be seen in the residential areas, where people have introduced it. Also, it is found along the main roadsides because It is used as an ornamental plant. Specificity and sensitivity results of ROC show 98 percent (AUC= 0.98) accuracy.

Predicted distribution of *Alstonia scholaris* with suitability classes (sector-wise)

The highly suitable cover of *Alstonia scholaris* is approximately 22.9 hectare (<1 percent of the tree class) and with moderately suitable class it is predicted on 43.16 hectare (1.8 percent of the tree class). With highly suitable class sector I-9 is the most significant area with 3.08 hectare other important sectors with significant cover are I-10 (1.93 hectare) and F-6 (1.68 hectare). Further, details of overall study area with different suitability classes are given in the table 4. 4.

Jackknife of regularized training gain for *Alstonia scholaris*

Figure 4. 9, shows the results of Jackknife test, the variable laif (Leaf area index_February), arvif (Atmospherically resistant vegetation index_February), fb.05 (band 5 of February image) and arvi (Atmospherically resistant vegetation index_May) are significant variables and contribute highly. The variable arvif (Atmospherically resistant vegetation index_February) contributes 36.5 percent. According to result of Jackknife regularized training gain (Figure 4. 9) boc.02 (band 2 of October image), boc.04 (band 4 of October image), boc.05 (band 5 of October image) and boc.12 (band 12 of October image) are not noteworthy variables.

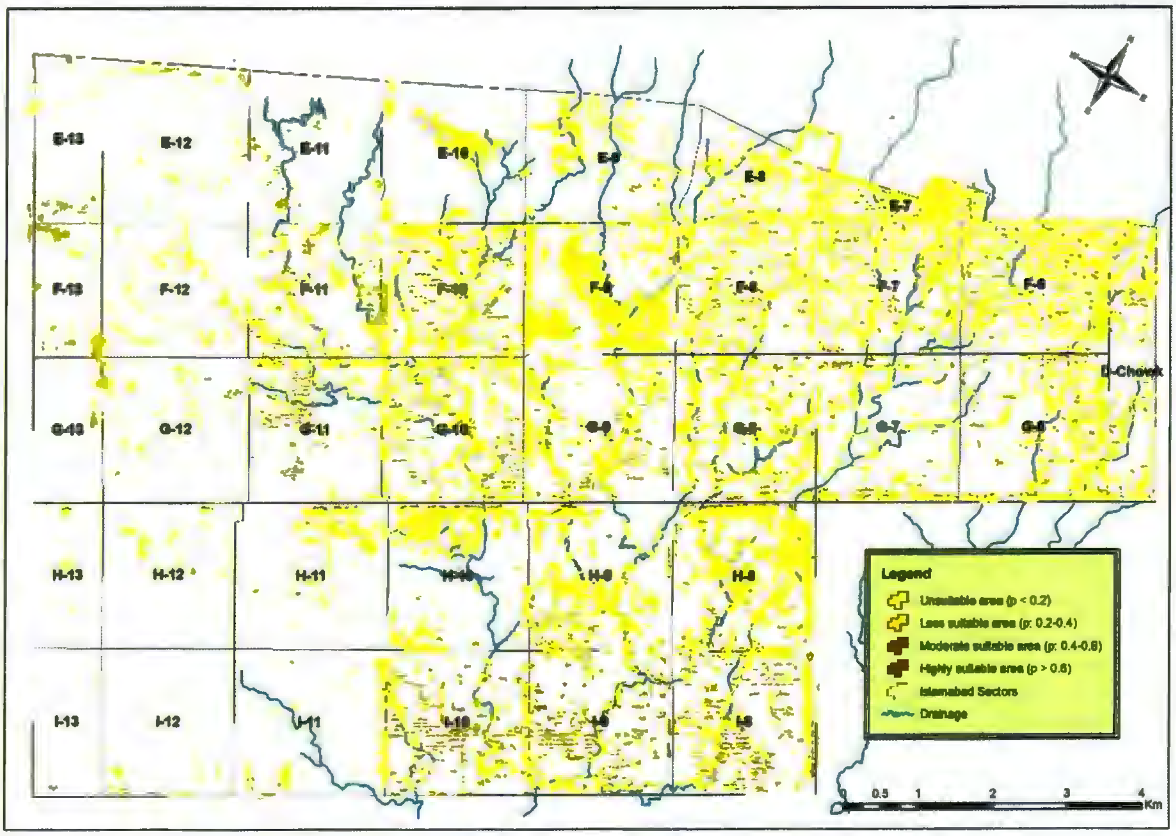


Figure 4. 8: Predicted probability of presence from MAXENT model for *Alstonia scholaris*

Table 4. 4: Suitability of *Alstonia scholaris* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7			
Unsuitable	5.61	13.46	6.55	41.35	53.37	59.48	70.58			
Less suitable	1.61	1.51	1.81	1.11	4.48	3.89	2.83			
Moderately suitable	0.04	0.1	0.16	0.06	0.32	0.41	0.29			
Highly suitable	0	0	0.07	0	0.19	0.26	0.3			
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**	
Unsuitable	13.83	26.11	50.32	109.5	151.7	90.42	103.75	151	51.58	
Less suitable	0.48	2.05	9.45	13.84	4.87	14.71	14.96	17.7	8.82	
Moderately suitable	0.07	0.1	1	1.57	0.25	1.72	2.17	2.47	1.33	
Highly suitable	0.01	0.01	0.57	0.96	0.04	1.25	0.98	1.68	0.67	
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**		
Unsuitable	3.15	14.83	29.18	96.16	85.52	98.02	56.21	88.66		
Less suitable	0.24	1.49	13.73	19.99	18.54	18.09	16.51	20.17		
Moderately suitable	0	0.17	1.67	2.08	1.63	1.82	2.11	2.7		
Highly suitable	0	0.08	0.72	0.81	0.5	1	1.02	1.35		
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***			
Unsuitable	2.9	8.86	33.25	69.18	86.95	136.4				
Less suitable	0.62	1.23	3.37	8.18	17.47	19.4	**Min:**	0		
Moderately suitable	0.06	0.21	0.29	0.69	1.15	2.01	**Max:**	161.7		
Highly suitable	0.04	0.15	0.49	0.44	0.67	0.99				
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**	***Total***	**Total**	**Min**	**Max**
Unsuitable	0.26	4.51	15.53	48.02	41.88	59.69	*Unsuitable*	1988	0.26	161.69
Less suitable	0.19	1.67	2.27	25.41	29.13	27.38	*Less suitable*	349.2	0.19	29.13
Moderately suitable	0.06	0.26	0.17	4.82	4.95	4.25	*Moderately suitable*	43.16	0	4.95
Highly suitable	0	0.11	0.08	1.93	3.08	2.45	*Highly suitable*	22.9	0	3.08

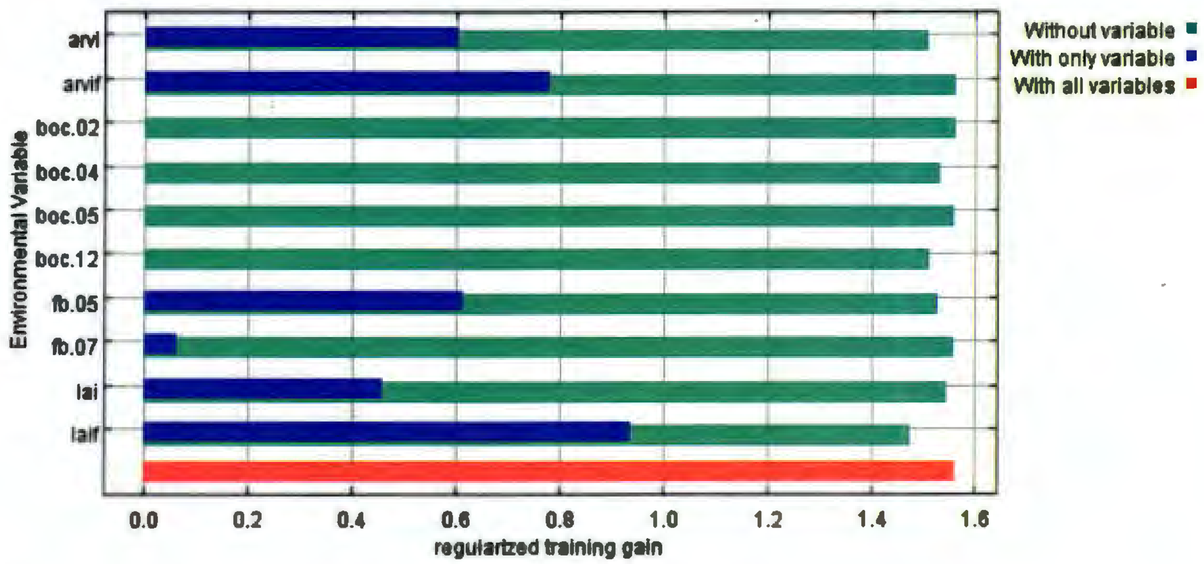
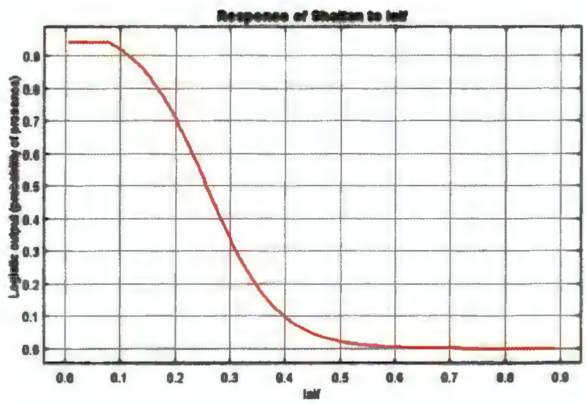
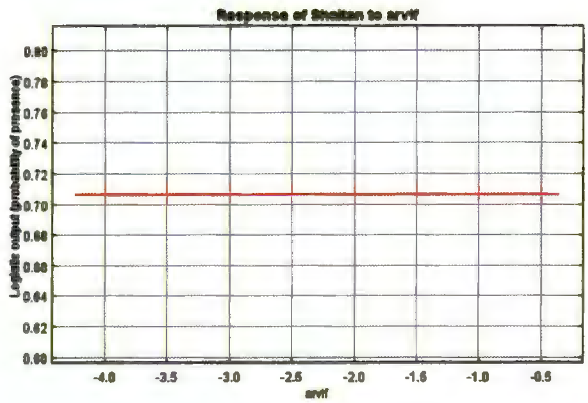


Figure 4. 9: Jackknife of regularized training gain for *Alstonia scholaris*

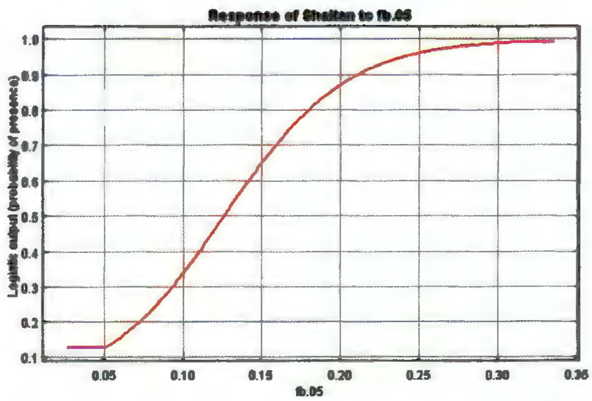
Response curves of important variables for *Alstonia scholaris*



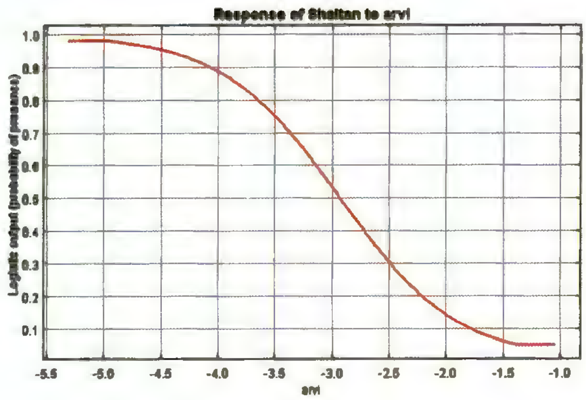
(a)



(b)



(c)



(d)

The different variables response curves for *Alstonia scholaris* show that (a) the variable laif (leaf area index _February) is showing the highest gain with negative correlation. (b) The variable arvif

(Atmospherically resistant vegetation index_February) shows no correlation. (c) In variable Fb.05 (band 5 of February image) curve shows positive correlation and shows highest probability of presence at 0.25 threshold. (d) The variable arvi (Atmospherically resistant vegetation index_May) shows negative correlation.

4.3.4 *Bischofia javanica* (Bishopwood Tree)

It is deciduous tree (20 to 25 meter height) with cylindrical trunk and light-brown to grayish, shallowly and narrowly fissured bark. The genus *Bischofia* was named after the name of G.W. Bischoff, a botanist and entomologist in Royal Academy Amsterdam (AJAIB & ZAHEER-UD-DIN, 2012). In the present study; Receiver operating characteristic (ROC) shows 95 percent accuracy for *Bischofia javanica* (Figure 4. 10).

Prediction distribution of *Bischofia javanica* with suitability classes (sector-wise)

Total area of *Bischofia javanica* with highest suitability is 41.33 hectare (1.7 percent of trees class). Maximum area with same suitability class is predicted to be found in sectors F-6 (5.98 hectare) and E-8 (5.8 hectare). Sectors I-12, I-11, G-12, G-13, E-11, E-12 and E-13 do not show significant cover of *Bischofia javanica*. 53.4 hectare (2.2 percent of the tree class) is predicted with moderately suitable class. While, 366.5 hectare (15.2 percent of the tree class) is predicted with less suitable class (Table 4. 5).

Jackknife of regularized training gain for *Bischofia javanica*

The Jackknife result show that the variable fb.08 (band 8 for February image) as the most important variable with highest gain (0.77) and second most important variable is tcwo (Tasseled cap wetness_October) with 0.5 threshold. Other significance variables include tcvf (Tasseled cap vegetation _February) and fb.04 (band 4 of February image) (Figure 4. 11).

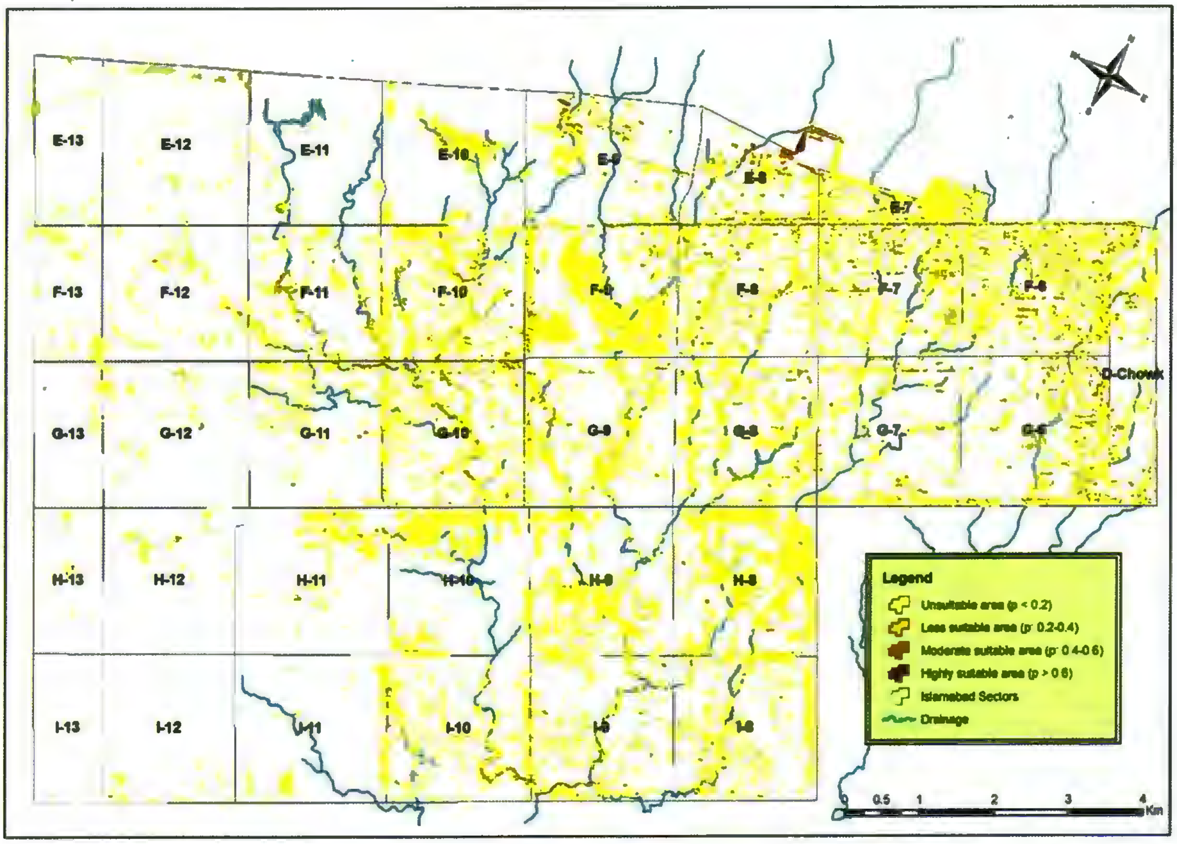


Figure 4. 10: Predicted probability of presence from MAXENT model for *Bischofia javanica*

Table 4. 5: Suitability of *Bischofia javanica* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7			
Unsuitable	7.04	13.8	7.26	34.86	43.97	37.58	58.56			
Less suitable	0.2	1.17	1.05	7.14	10.64	16.38	12.35			
Moderately suitable	0.02	0.08	0.15	0.44	2.09	4.28	1.81			
Highly suitable	0	0.02	0.13	0.08	1.66	5.8	1.28			
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**	
Unsuitable	13.49	25.3	49.34	102.5	147	81.22	91.02	124.7	48.35	
Less suitable	0.78	2.58	9.17	19.23	16.81	20.82	23.04	34.7	10.9	
Moderately suitable	0.1	0.23	1.57	2.66	1.82	3.41	4.3	7.48	1.66	
Highly suitable	0.02	0.16	1.26	1.4	1.22	2.65	3.5	5.98	1.49	
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**		
Unsuitable	3.18	15.2	36.75	93.46	87.11	100.7	57.38	79.97		
Less suitable	0.17	1.04	6.62	21.08	16.58	15.83	14.3	24		
Moderately suitable	0.02	0.17	0.85	2.8	1.6	1.55	2.43	4.78		
Highly suitable	0.02	0.16	1.08	1.7	0.9	0.89	1.74	4.13		
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***			
Unsuitable	3.03	9.13	30.84	71.2	94.71	141.5				
Less suitable	0.52	1.06	5.98	7.02	10.74	15.64	**Min:**	0		
Moderately suitable	0.02	0.17	0.3	0.18	0.63	1.28	**Max:**	147		
Highly suitable	0.05	0.09	0.28	0.09	0.16	0.34				
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**	*Total*	Total	Min	Max
Unsuitable	0.42	5.74	15.56	67.76	64.76	77.3	*Unsuitable*	1942	0.42	147
Less suitable	0.07	0.69	2.28	10.13	11.54	14.26	*Less suitable*	366.5	0.07	34.7
Moderately suitable	0.02	0.1	0.13	1.37	1.49	1.43	*Moderately suitable*	53.42	0.02	7.48
Highly suitable	0	0.02	0.08	0.92	1.25	0.78	*Highly suitable*	41.33	0	5.98

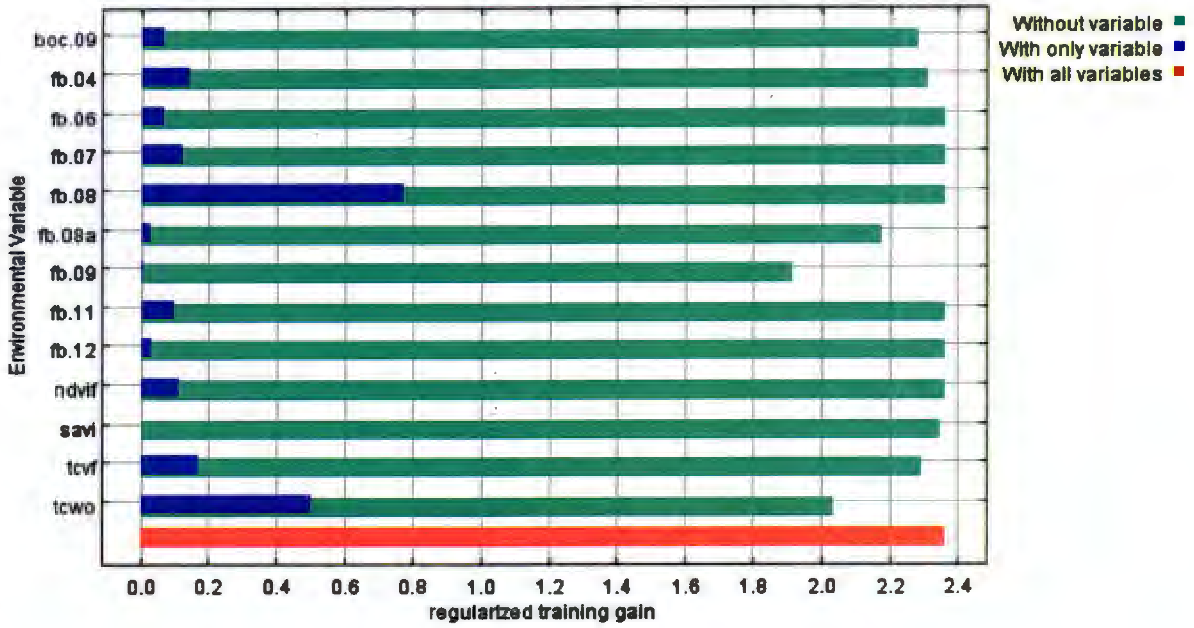
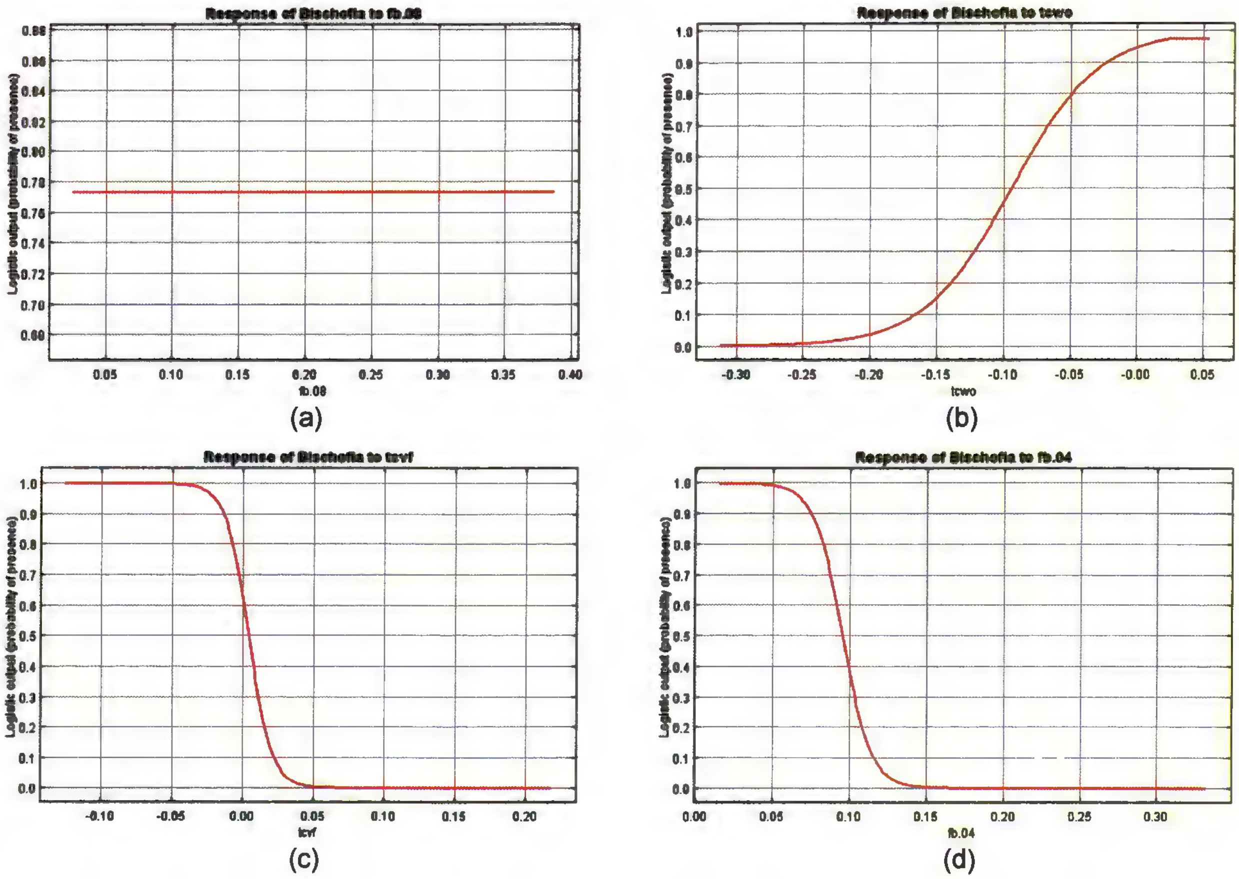


Figure 4. 11: Jackknife of regularized training gain for *Bischofia javanica*

Response curves of important variables for *Bischofia javanica*



The curves show that how some variable response to *Bischofia javanica* (a) The variable with highest gain contribution is fb.08 (band 8 of February) it contributes 45.2 percent but show no correlation. (b) The variable tcwo (Tasseled cap wetness_October)) shows positive correlation with maximum probability if presence on 0.05 threshold. (c) The variable tcvf (Tasseled cap vegetation_February) contribute 1.2 percent but shows significant gain with inverse relationship. (d) Variable fb.04 (band 4 of February imagery) also shows negative correlation.

4.3.5 *Broussonetia papyrifera* (Paper mulberry)

Broussonetia papyrifera usually known with different names like Paper mulberry is native to East Asia. It was presented (seed dispersal intensive arial mode) to Pakistan in 1960's for greening Islamabad and controlling soil erosion. As per estimation 60-70 percent of the trees in Islamabad are of Paper mulberry (Rashid, M., 2014). It is one of the most common occurring tree type in the study area (Figure 4.12).

Prediction distribution of *Broussonetia papyrifera* with suitability classes (sector-wise)

With highest suitability prediction *Broussonetia papyrifera* is spread on 195.5 hectare (8.1 percent of the trees class). It is found in different sectors with highest area 28.4 hectare in H-8. According to moderate suitable class it is predicted on 259.8 hectares (10.8 percent of the tree class) with maximum 30.9 hectare in H-8, with less suitable class 868 hectare (36 percent of the tree class) area is predicted in the study area (Table 4. 6).

Jackknife of Regularized training gain for *Broussonetia papyrifera*

The variables tcwo (Tasseled cap wetness_October) and.boc.5 (band 5 of October image) are most important variables in jackknife test. The other variables with significance gain includes, laio (Leaf area index_October), boc12 (band 12 of October image), tcw (Tasseled cap wetness_May), bi12 (band 12 of May image), fb.02 (band 2 of February image) and fb.07 (band 7 of February image). Further details are given in figure 4. 13.

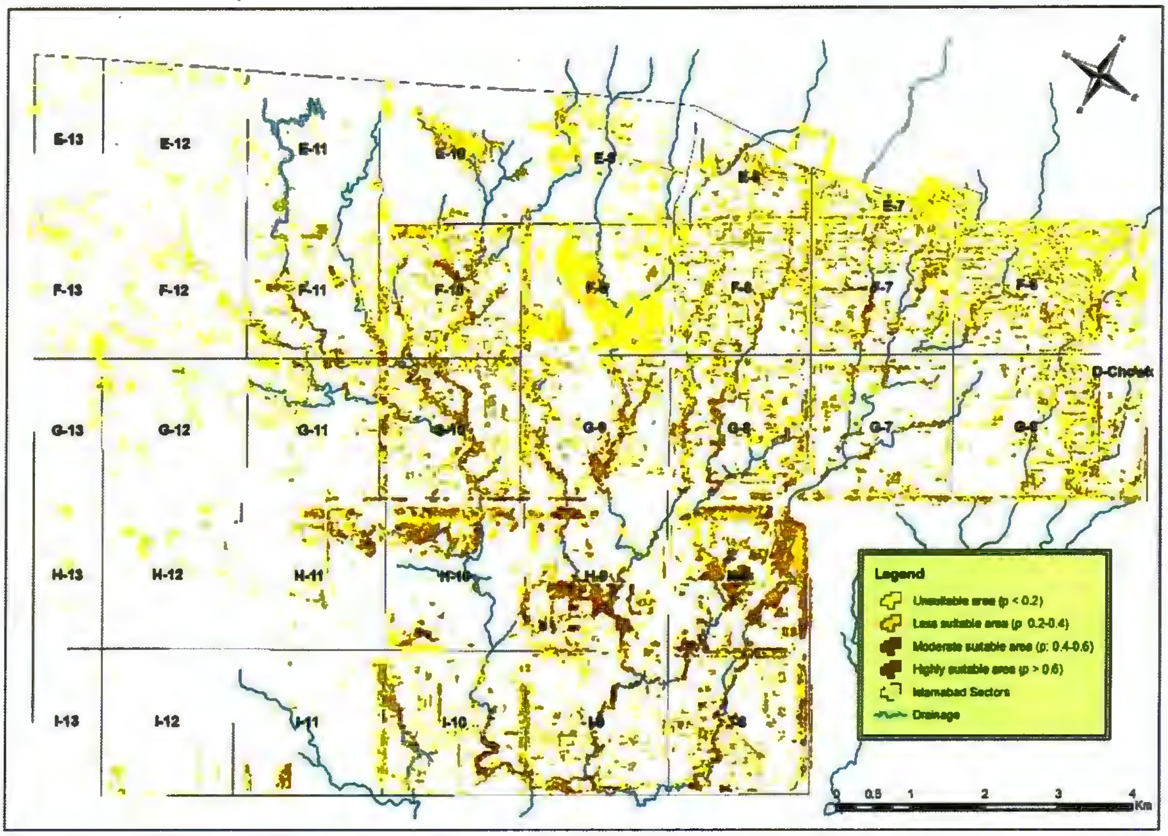


Figure 4. 12: Predicted probability of presence from MAXENT for *Broussonetia papyrifera*

Table 4. 6: Suitability of *Broussonetia papyrifera* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7			
Unsuitable	6.63	13.32	5.95	20.12	39.73	35.36	50.95			
Less suitable	0.63	1.63	2.28	18.78	15.73	21.19	17.86			
Moderately suitable	0	0.11	0.27	2.98	2.21	5.02	3.43			
Highly suitable	0	0.01	0.09	0.64	0.69	2.47	1.76			
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**	
Unsuitable	13.03	23.7	26.95	51.35	120.8	45.36	52.33	94.86	35.91	
Less suitable	1.34	4.25	22.94	53.17	39.27	45.67	45.34	55.46	18.26	
Moderately suitable	0.02	0.29	6.36	13.12	5.35	11.55	13.79	13.89	4.78	
Highly suitable	0	0.03	5.09	8.19	1.46	5.52	10.4	8.66	3.45	
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**		
Unsuitable	2.86	13.45	23.03	37.39	36.22	39.93	28.68	50.76		
Less suitable	0.49	2.68	15.32	49.38	45.21	50.43	30.59	43.12		
Moderately suitable	0.04	0.39	4.31	17.93	14.42	16.7	8.84	11.31		
Highly suitable	0	0.05	2.64	14.34	10.34	11.87	7.74	7.69		
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***			
Unsuitable	3.08	8.22	9.54	19.15	23.53	29.47				
Less suitable	0.53	1.97	17.95	36.82	41.12	69.91	**Min:**	0		
Moderately suitable	0.01	0.22	6.21	14.86	19.86	30.94	**Max:**	120.8		
Highly suitable	0	0.04	3.7	7.66	21.73	28.43				
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**	***Total***	**Total**	**Min**	**Max**
Unsuitable	0.51	4.18	8.55	37.76	32.24	34.11	*Unsuitable*	1079	0.51	120.77
Less suitable	0	2.14	6.55	27.45	29.22	33.91	*Less suitable*	868.6	0	69.91
Moderately suitable	0	0.2	2.02	8.06	8.89	11.46	*Moderately suitable*	259.8	0	30.94
Highly suitable	0	0.03	0.93	6.91	8.69	14.29	*Highly suitable*	195.5	0	28.43

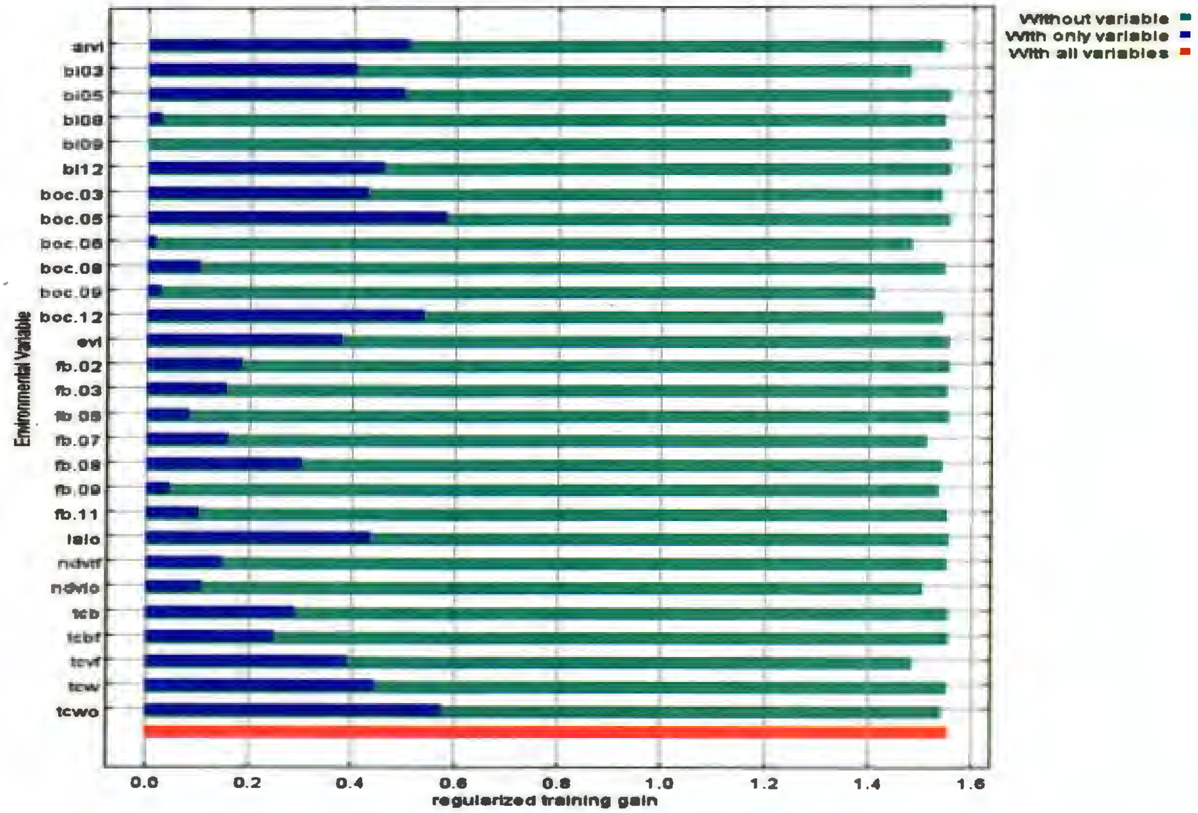
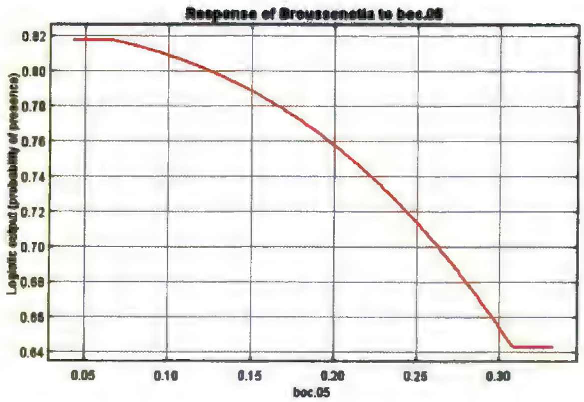
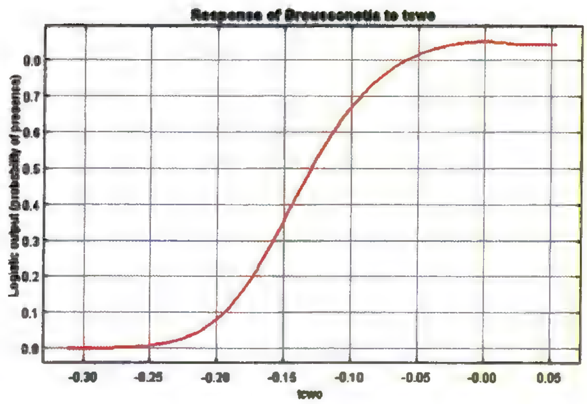


Figure 4. 13: Jackknife of regularized training gain for *Broussonetia papyrifera*

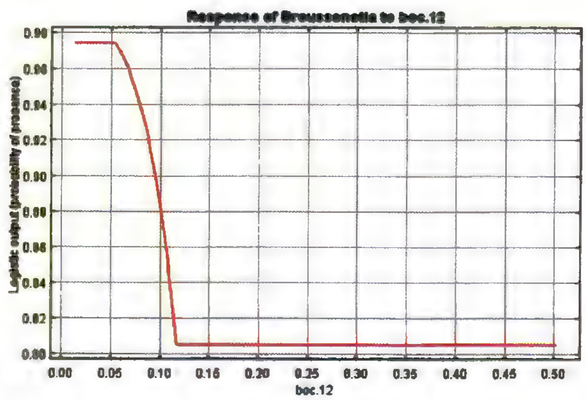
Response curves of important variables for *Broussonetia papyrifera*



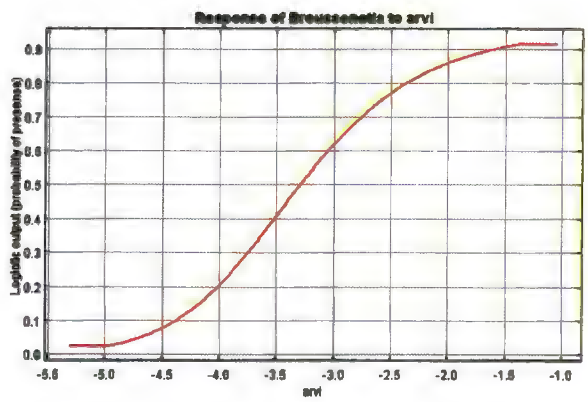
(a)



(b)



(c)



(d)

The variables response curves to *Broussonetia papyrifera* (a) shows that variable with highest gain boc.05 (band 5 of october) shows negative correlation. (b) The variable boc.09 (band 9 of October) shows high gain in Jackknife test, and have positive correlation with maximum probability of presence at 0.00 threshold. (c) The variable boc.12 shows negative correlation. (d) The variable arvi (Atmospherically resistant vegetation index_May) graph shows positive correlation, and have highest probability of presence at -1.5 threshold.

4.3.6 *Callistemon citrinus* (Bottle Brush)

Callistemon citrinus is commonly known as bottlebrush, It is a small but spectacular evergreen tree or shrub. It is easy to grow and cherishes warmth, moisture and sun. *Callistemon citrinus* is native to Australia (Prakash, 1969) and also, rapidly growing in Islamabad, especially in urban residential areas. Maximum land cover (area) of bottle with highest suitability class is 55.5 hectare (Figure 4. 14).

Prediction distribution of *Callistemon citrinus* with suitability classes (sector-wise)

The largest area of *Callistemon citrinus* with highest suitability class is located in sector I-9 (9.71 hectare), also with moderate suitability class the same sector has significant cover (18.26 hectare). 94 hectare *Callistemon citrinus* cover lies in sector F-6. Further, detail of each sector is given with different classes of suitability in table 4. 7.

Jackknife of Regularized training gain for *Callistemon citrinus*

The Jackknife result of *Callistemon citrinus* (Figure 4. 15) shows, variable fi.07 (band 7 of May image) with highest gain (0.65) and bi.08 (band 8 of May image) as second most important variable (0.62 threshold). The other variables with significance gain are bi.09 (band 9 of May image), fb.02 (band 2 of February image), fb.07 (band 7 of February mage) and tcwo (Tasseled cap wetness_October).

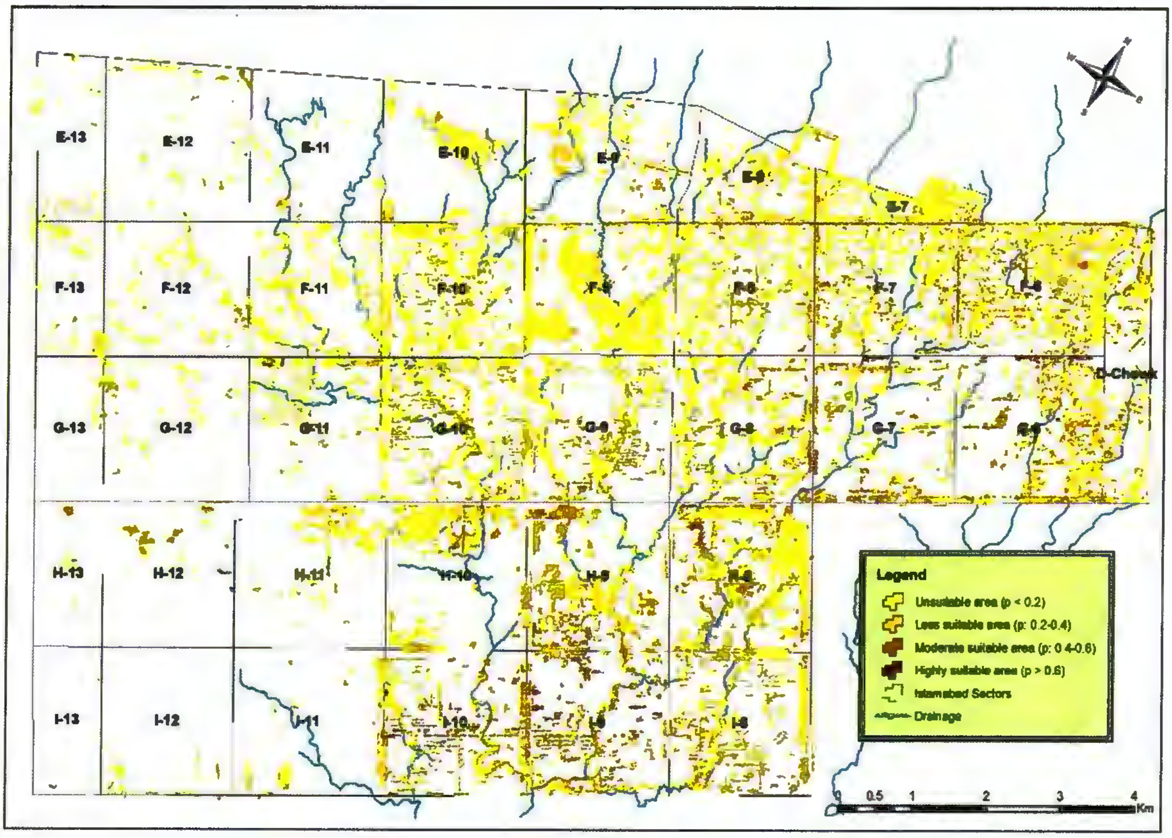


Figure 4. 14: Predicted probability of presence from MAXENT model for *Callistemon citrinus*

Table 4. 7: Suitability of *Callistemon citrinus* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7
Unsuitable	3.47	7.01	4.78	28.77	27.02	33.18	48.19
Less suitable	3.62	7.55	3.49	13.29	29.04	28.81	24.41
Moderately suitable	0.17	0.35	0.29	0.44	2.06	1.71	1.17
Highly suitable	0	0.16	0.03	0.02	0.24	0.34	0.23

Suitability ↓ Sector →	F-13	F-12	F-11	F-10	F-9	F-8	F-7	F-6	D-Chowk
Unsuitable	9.57	19.81	46.09	88.62	131.6	58.14	49.26	61.28	18.56
Less suitable	4.72	8.14	14.95	36.31	32.55	43.63	60.95	94.04	35.83
Moderately suitable	0.06	0.3	0.29	0.81	2.51	5.08	8.94	14	5.97
Highly suitable	0.04	0.02	0.01	0.09	0.21	1.25	2.71	3.55	2.04

Suitability ↓ Sector →	G-13	G-12	G-11	G-10	G-9	G-8	G-7	G-6
Unsuitable	2.57	10.57	19.96	59.94	51.41	54.35	20.03	25.19
Less suitable	0.82	5.65	22.89	52.9	46.81	53.56	39.23	64.77
Moderately suitable	0	0.15	1.75	5.07	6.67	8.74	10.92	15.5
Highly suitable	0	0.2	0.7	1.13	1.3	2.28	5.67	7.42

Suitability ↓ Sector →	H-13	H-12	H-11	H-10	H-9	H-8
Unsuitable	1.34	2.65	21.18	36	23.65	83.22
Less suitable	1.39	4.69	15.39	37.39	65.93	62.33
Moderately suitable	0.7	2.09	0.77	4.27	13.26	9.74
Highly suitable	0.19	1.02	0.06	0.83	3.4	3.46

Suitability statistic	
Min:	0
Max:	131.6

Suitability ↓ Sector →	I-13	I-12	I-11	I-10	I-9	I-8
Unsuitable	0.06	2.26	8.86	15.72	7.14	31.29
Less suitable	0.26	4.08	8.19	45.09	43.93	54.32
Moderately suitable	0.14	0.17	0.84	13.39	18.26	7.16
Highly suitable	0.05	0.04	0.16	5.98	9.71	1

Total	Total	Min	Max
Unsuitable	1113	0.06	131.58
Less suitable	1071	0.26	94.04
Moderately suitable	163.7	0	18.26
Highly suitable	55.54	0	9.71

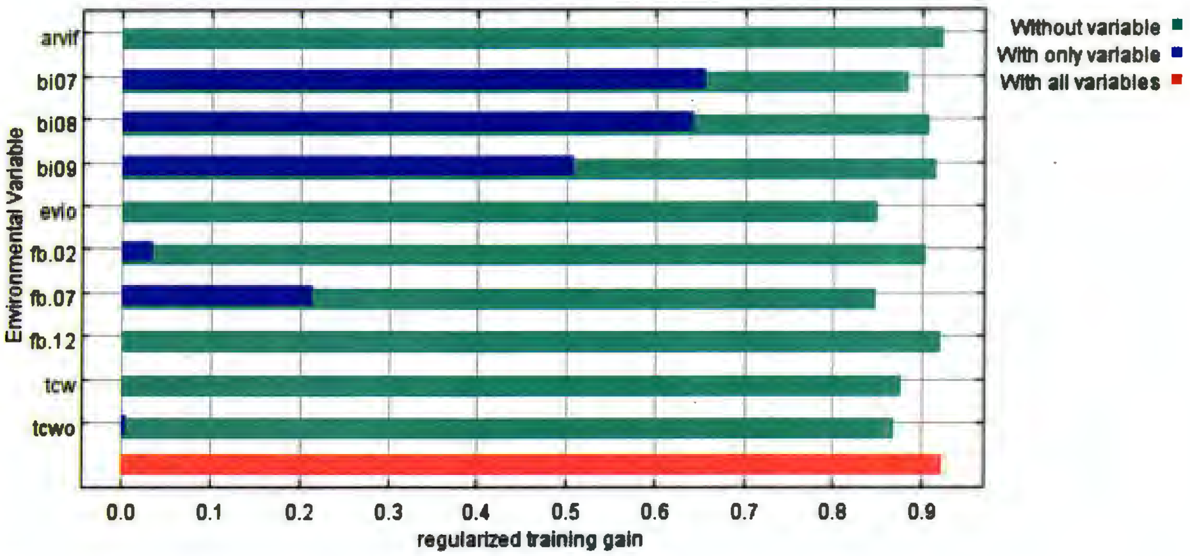
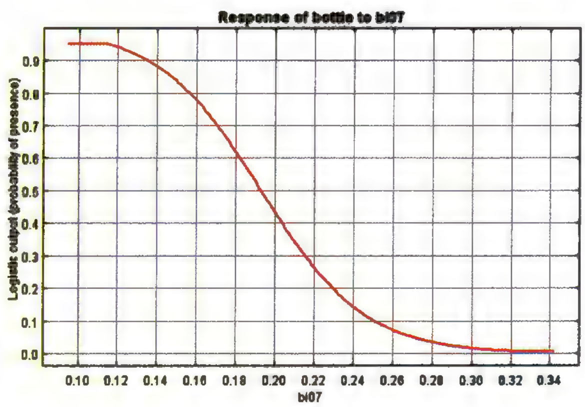
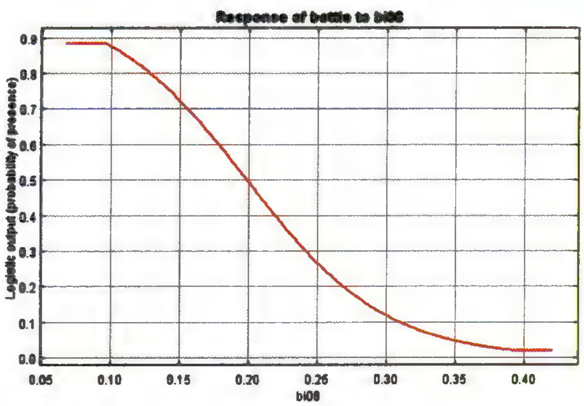


Figure 4. 15: Jackknife of regularized training gain for *Callistemon citrinus*

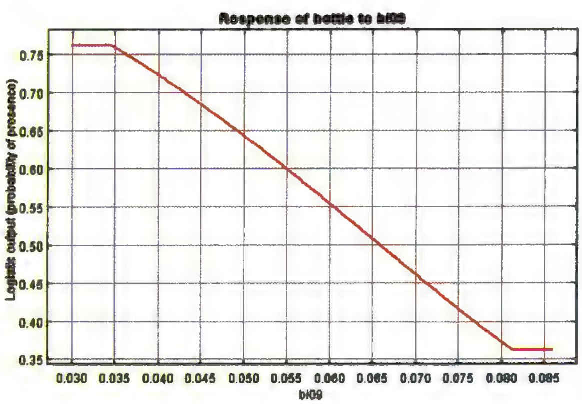
Response curves of important variables for *Callistemon citrinus*



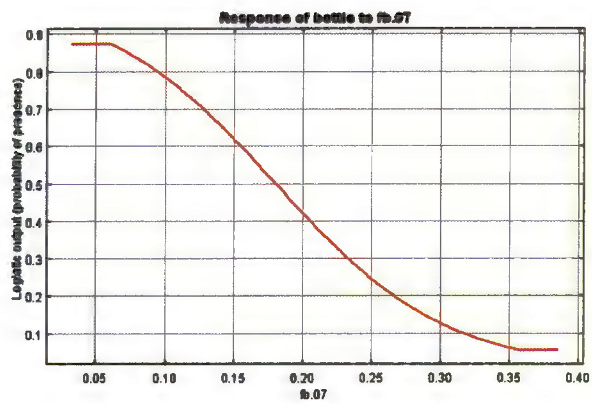
(a)



(b)



(c)



(d)

Response curves of all significant variables including (a) variable bi07 (band 7 of May Imagery) shows highest gain but negative correlation, (b) Variables bi08 (band 8 of May), (c) bi09(band 9 of May and (d) fb.07(band 7 of February Imagery) show inverse relationship.

4.3.7 *Cedrela serrata*

It is a medium size deciduous tree found in the different areas of Islamabad. Figure 4.16 is the representation of the MAXENT model for *Cedrela serrata,* high suitable areas with better prediction have dark colours in the map. Receiver operating characteristic (ROC) shows good result with 99 percent (AUC= 0.996) accuracy.

Prediction distribution of *Cedrela serrata* with suitability classes (sector-wise)

Cedrela serrata is predicted to be found on 19.15 hectare (0.8 percent of tree class). Sector I-9 with high suitable range is predicted to have 4.15 hectare. The other important sector includes G-6 (3.87 hectare), H-10 (3.47 hectare) and I-10 (1.67 hecare). With moderate suitable class Sector G-6 (4.21 hectare) and I-9 (3.64 hectare) are prominent areas of urban Islamabad. Table. 4. 8 shows *Cedrela serrata* cover with different suitability classes.

Jackknife of Regularized training gain for *Cedrela serrata*

The Jackknife result shows that the variable boc.09 (band 9 of October image) and bi09 (band 9 of May image) have maximum gain. Other significant variables with less gain include fb.08a (band 8a of February image), fb.07 (band 7 of February) and tcvf (Tasseled cap vegetation_February). The gain of these varibale is shown in the figure 4. 17.

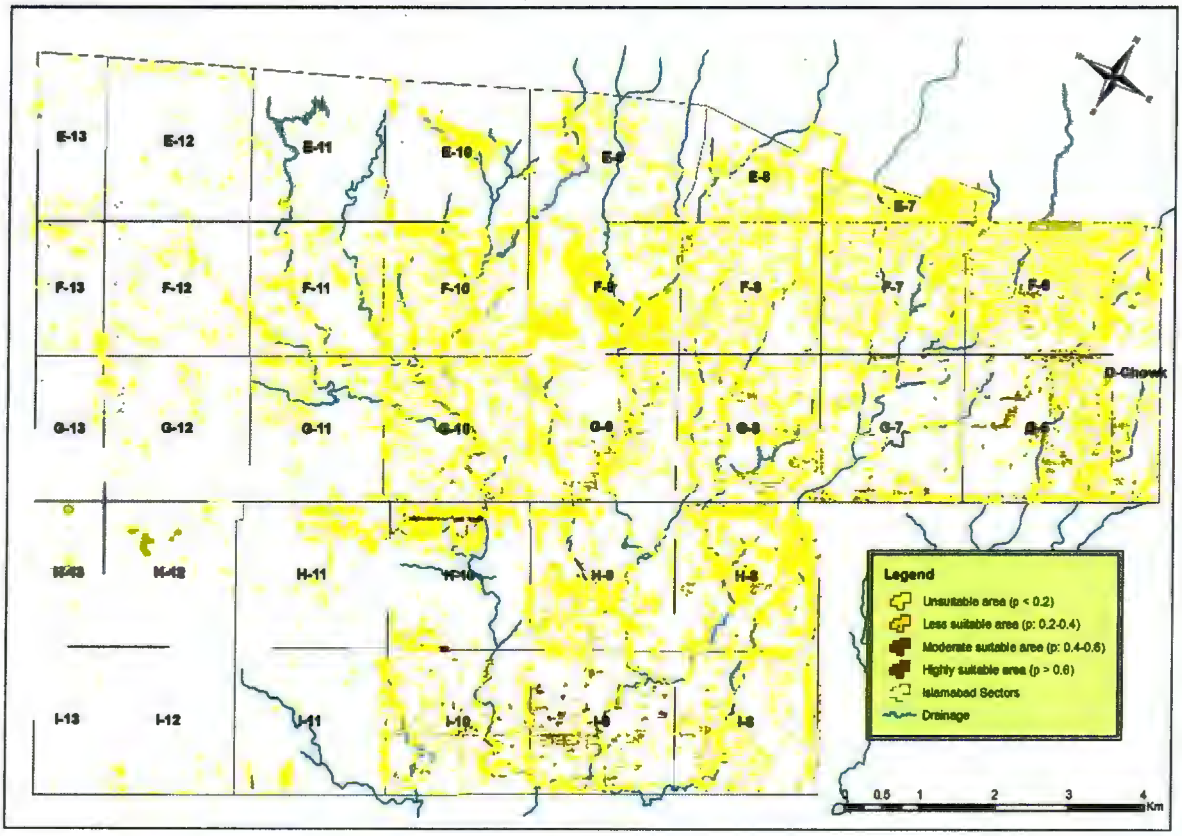


Figure 4. 16: Predicted probability of presence from MAXENT model for *Cedrela serrata*

Table 4. 8: Suitability of *Cedrela serrata* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7			
Unsuitable	7.26	15.07	8.55	42.52	57.91	63.33	73.61			
Less suitable	0	0	0.04	0	0.41	0.63	0.38			
Moderately suitable	0	0	0	0	0.04	0.06	0.01			
Highly suitable	0	0	0	0	0	0.02	0			
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**	
Unsuitable	14.39	28.18	61.05	125.4	166.7	103.6	114.56	160.1	57.37	
Less suitable	0	0.09	0.27	0.37	0.13	4.16	6.57	10.74	4.16	
Moderately suitable	0	0	0.02	0.06	0.02	0.23	0.6	1.41	0.53	
Highly suitable	0	0	0	0	0	0.13	0.13	0.67	0.34	
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**		
Unsuitable	3.39	16.56	44.76	111.9	96.41	108.6	61.23	85.08		
Less suitable	0	0.01	0.51	5.9	8.1	8.47	10.87	19.72		
Moderately suitable	0	0	0.03	0.59	1.05	1.36	1.93	4.21		
Highly suitable	0	0	0	0.68	0.63	0.54	1.82	3.87		
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***			
Unsuitable	3.62	9.97	35.95	67.46	100.8	150.4				
Less suitable	0	0.41	1.29	6.14	4.89	6.92	**Min:**	0		
Moderately suitable	0	0.01	0.14	1.42	0.37	0.91	**Max:**	166.7		
Highly suitable	0	0.06	0.02	3.47	0.18	0.5				
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**	***Total***	**Total**	**Min**	**Max**
Unsuitable	0.47	6.32	17.47	63.2	53.43	84.99	*Unsuitable*	2221	0.47	166.7
Less suitable	0.04	0.21	0.46	13.1	17.82	7.92	*Less suitable*	140.7	0	19.72
Moderately suitable	0	0.02	0.04	2.21	3.64	0.67	*Moderately suitable*	21.58	0	4.21
Highly suitable	0	0	0.08	1.67	4.15	0.19	*Highly suitable*	19.15	0	4.15

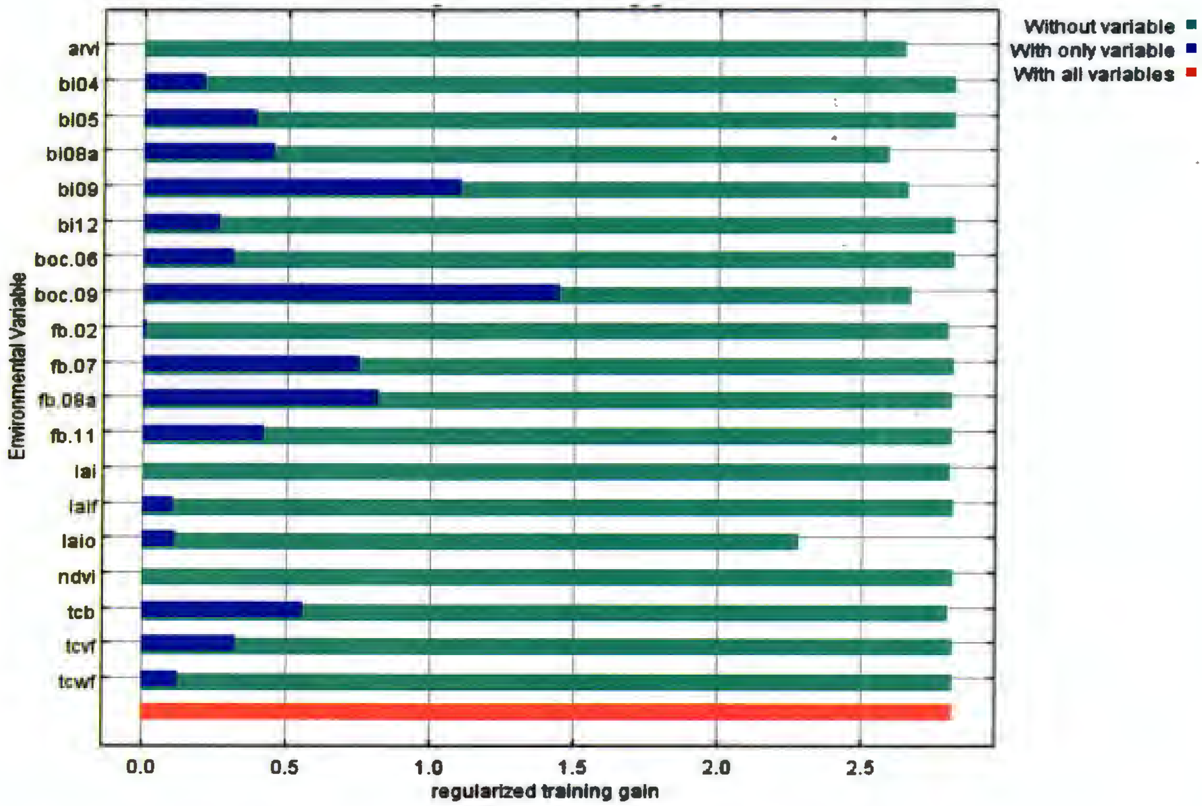
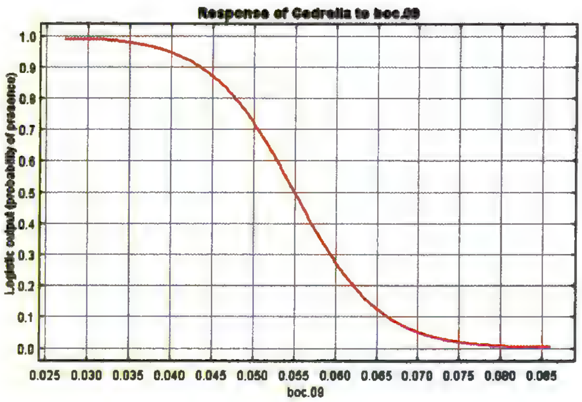
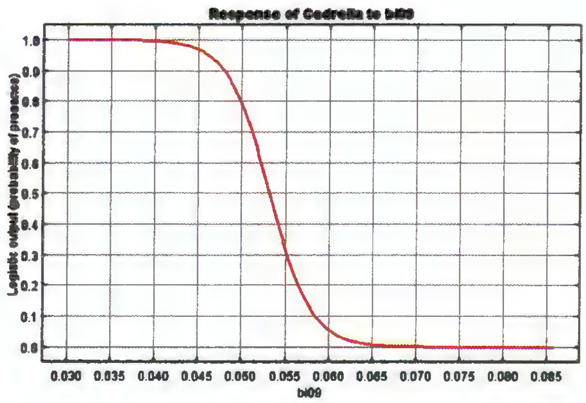


Figure 4. 17: Jackknife of regularized training gain for *Cedrela serrata*

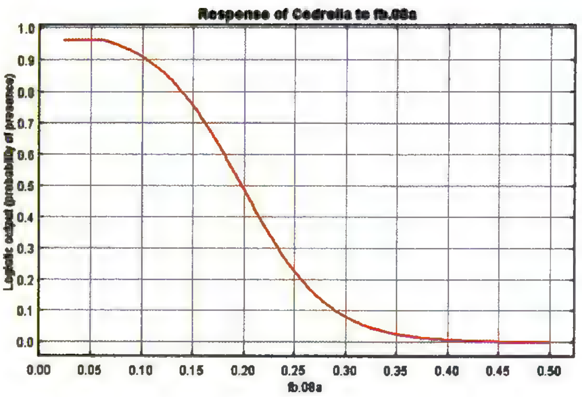
Response curves of important variables for *Cedrela serrata*



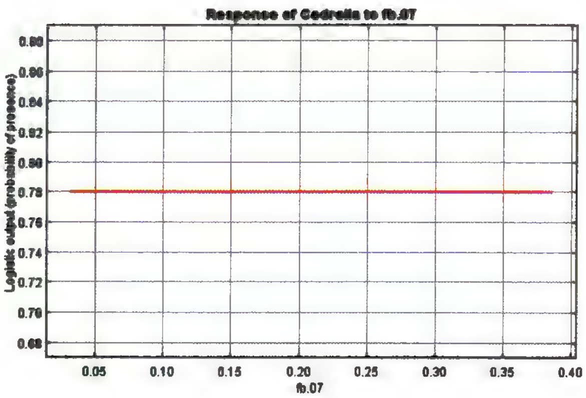
(a)



(b)



(c)



(d)

(a) The variable with highest gain is boc.09 (band 9 of October image), its response curve shows negative correlation. (b) The variable bi09(Band 9 of May image) show inverse relationship. (c) Variable fb.08a (band 8a of February image) also show negative correlation. (d) The variable fb.07 (band 7 of February image) shows no correlation.

4.3.8 *Celtis australis* (Honeyberry)

It is commonly known as the European nettle tree, Mediterranean hackberry, lote-tree, or honeyberry. It is a deciduous tree native to Southern Europe and North Africa (Demır *et al.*, 2002). Figure 4.18 shows that the *Celtis australis* is mostly grown in streets and along the roads sides of Islamabad city.

Prediction distribution of *Celtis australis* with suitability classes (sector-wise)

In the study area, 110.1 hectare (4.6 percent area of total tree class) is predicted with highly suitable class covered with *Celtis australis*. It makes *Celtis australis* as one of the important tree species in Islamabad. Sector-wise F-6 (11.75 hectare) and G-6 (11.5 hectare) have significant area with highly suitable class. With moderately suitable class, It is predicted to be found on 398.2 hectare (16.6 percent of the tree class) and 1401 hectare (58.3 percent of the tree class) with less suitable class. More details are given in table 4. 9.

Jackknife of Regularized training gain for *Celtis australis*

According to jackknife test of variable importance boc.07 (band 7 of October image) highest gain. Other important variable with significant training gain are boc.06 (band 6 of October image) and boc.09 (band 9 of October image). The variable with less gain includes boc.11 (band 11 of October image), fb.05 (band 5 of February image), tcwf (Tasseled cap wetness_February) and fb.06 (band 6 of February image). Further details are given in figure 4. 19.

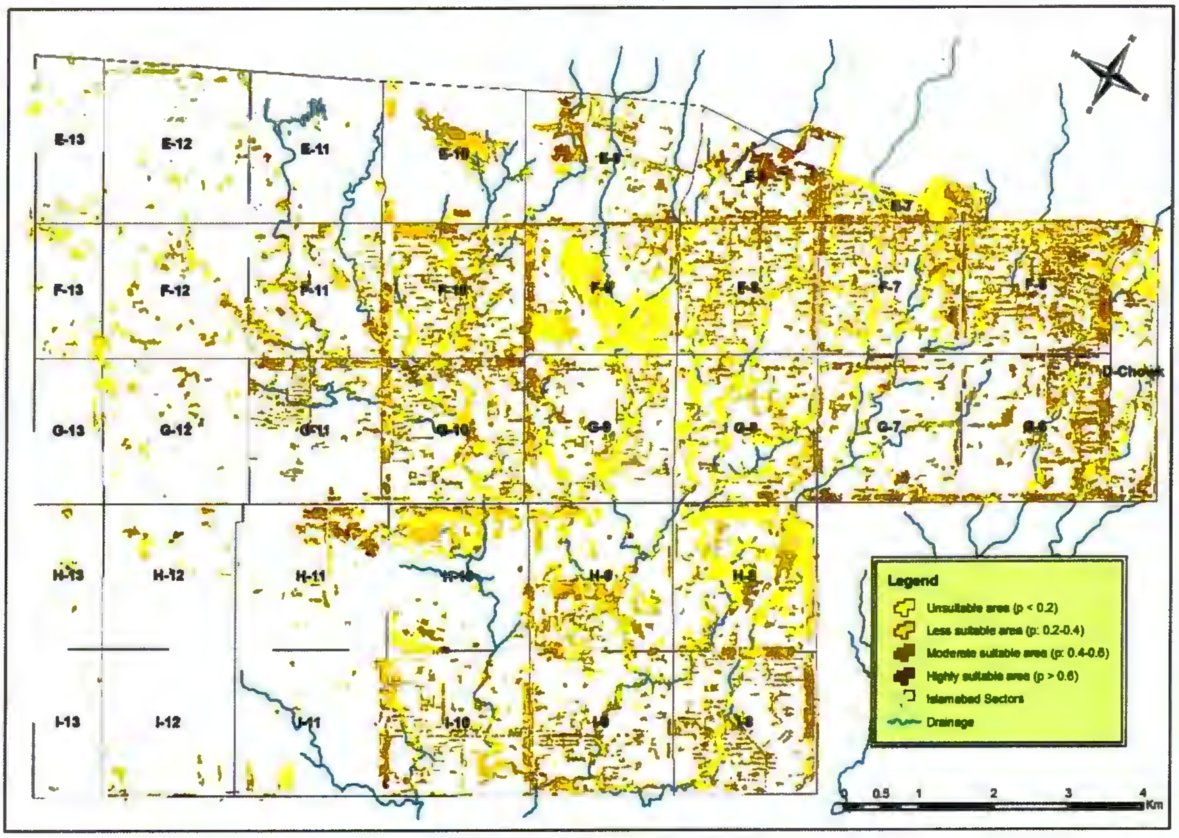


Figure 4. 18: Predicted probability of presence from MAXENT model for *Celtis australis*

Table 4. 9: Suitability of *Celtis australis* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7		
Unsuitable	1.77	2.58	0.64	2.99	3.16	3.67	23.41		
Less suitable	5.28	11.82	6.2	35.65	36.53	27.94	37.92		
Moderately suitable	0.21	0.55	1.32	3.5	15.42	23.72	9.51		
Highly suitable	0	0.12	0.43	0.38	3.25	8.71	3.16		
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**
Unsuitable	4.07	3.81	5.07	19.31	93.42	18.8	19.08	13.36	15.42
Less suitable	9.87	21.28	44.71	82.98	59.65	67.86	80.24	110.7	32.37
Moderately suitable	0.42	2.72	8.49	18.26	11.28	16.95	17.4	37.02	10.5
Highly suitable	0.03	0.46	3.07	5.28	2.5	4.49	5.14	11.75	4.11
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**	
Unsuitable	1.24	3.05	1.44	18.32	27.91	41.84	8.05	7.31	
Less suitable	2.06	11.23	28.11	71.25	60.28	61.82	39.96	59.1	
Moderately suitable	0.09	1.77	12.53	23.78	14.42	11.92	21.35	34.97	
Highly suitable	0	0.52	3.22	5.69	3.58	3.35	6.49	11.5	
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***		
Unsuitable	0.14	1.89	1.74	22.97	19.2	77.51			
Less suitable	2.62	6.43	23.42	48.51	75.46	67.63	**Min:**	0	
Moderately suitable	0.7	1.01	9.83	5.84	9.88	10.95	**Max:**	110.7	
Highly suitable	0.16	1.12	2.41	1.17	1.7	2.66			
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**	***Total***	**Total**	**Min**
Unsuitable	0	0.22	4.41	7.29	7.55	10.81	*Unsuitable*	493.5	0
Less suitable	0.29	4.42	9.8	56.79	48.86	52.17	*Less suitable*	1401	0.29
Moderately suitable	0.17	1.02	3.07	13.8	17.85	25.98	*Moderately suitable*	398.2	0.09
Highly suitable	0.05	0.89	0.77	2.3	4.78	4.81	*Highly suitable*	110.1	0

Total	Total	Min	Max
Unsuitable	493.5	0	93.42
Less suitable	1401	0.29	110.74
Moderately suitable	398.2	0.09	37.02
Highly suitable	110.1	0	11.75

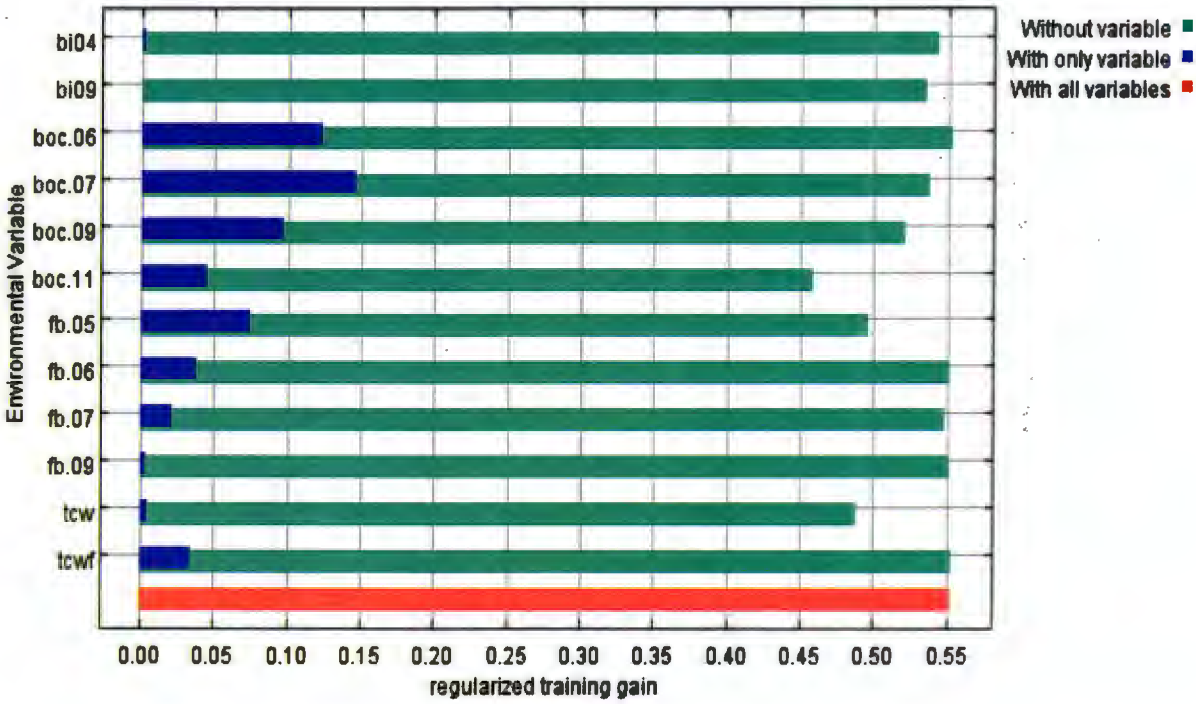
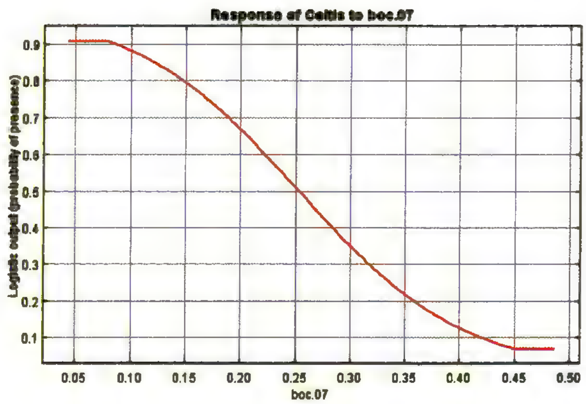
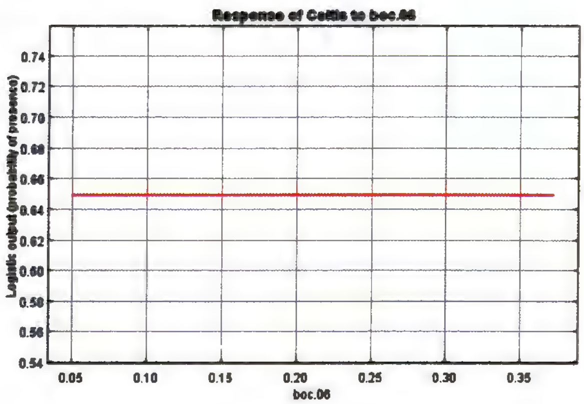


Figure 4. 19: Jackknife of regularized training for *Celtis australis*

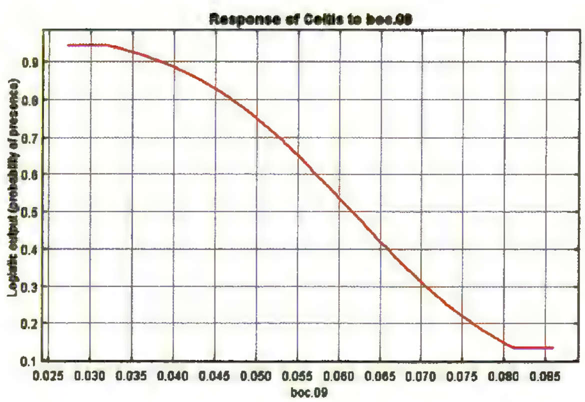
Response curves of important variables for *Celtis australis*



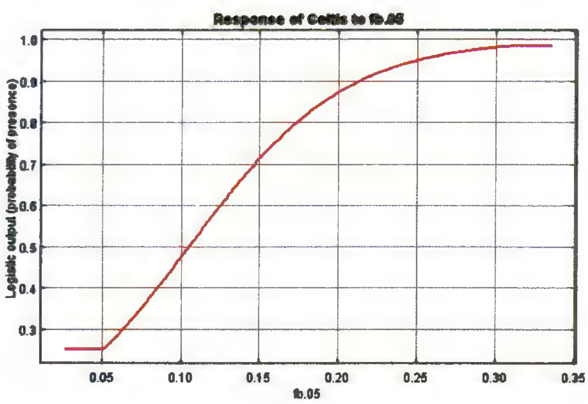
(a)



(b)



(c)



(d)

The response curves of important variables for *Celtis australis* show that (a) Variable boc.07 (band 7 of October mage) shows negative correlation. (b) Variable boc.06 (band 6 of October imagery) does not show any relation. (c) Variable boc.09 (band 9 of October image) also shows negative correlation. (d) Variable fb.05 (band 5 of February image) shows positive correlation and highest probability of presence at 0.15 threshold.

4.3.9 *Citharexylum spinosum* (Fiddlewood)

An attractive little tree that offers fascinating foliage throughout the entire year (Starr *et al.*, 2003). Its large oval and shiny leaves are green during winter, changing to shades of yellow, orange and gold for the months from spring to autumn. It is common but found in very small patches in greenbelts and roads sides. The Receiver operating characteristic (ROC) shows 99 percent accuracy (AUC=0.99). The spatial prediction of occurrence is shown in figure 4. 20.

Prediction distribution of *Citharexylum spinosum* with suitability classes (sector-wise)

It is predicted to be presented with highly suitable class on 22.5 hectare (<1 percent of the tree class) major sectors with significant cover are, I-9 (3.46 hectare), G-6 (3.04 hectare), G-7 (2.72 hectare), F-7 (2.71 hectare) and F-6 (1.67 hectare). With moderately suitable class 27.6 hectare (1.1percent of whole tree class) and 178 hectare (7.4 percent of tree class) area with less suitable class is predicted for *Citharexylum spinosum*. Detail of each sector is tabulated in table 4. 10.

Jackknife of Regularized training gain for *Citharexylum spinosum*

Figure 4.21, shows that the variable bi09 (band 9 of May image) shows highest gain in jackknife test. Moreover, the variables boc.09 (band 9 of October image) and boc.11 (band 11 of October image) show significance gain. The other important variables with less gain include, savio (Soil-adjusted vegetation index_October), boc.04 (band 4 of October image), and bi07 (band 7 of May image).

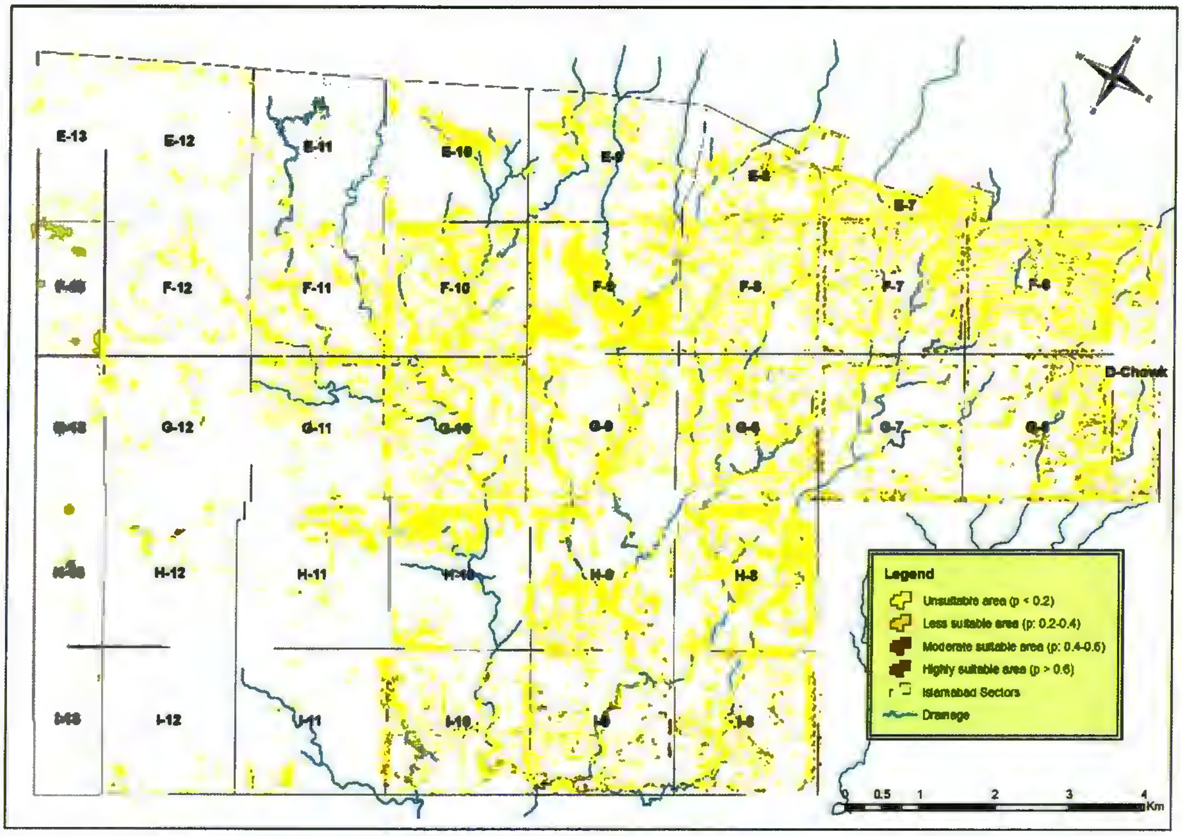


Figure 4. 20: Predicted probability of presence from MAXENT model for *Citharexylum spinosum*

Table 4. 10: Suitability of *Citharexylum spinosum* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7
Unsuitable	7.25	14.93	8.34	42.27	55.63	53.06	69.25
Less suitable	0.01	0.14	0.24	0.24	2.5	8.99	3.65
Moderately suitable	0	0	0.01	0.01	0.13	1.36	0.63
Highly suitable	0	0	0	0	0.1	0.63	0.47

Suitability ↓ Sector →	F-13	F-12	F-11	F-10	F-9	F-8	F-7	F-6	D-Chowk
Unsuitable	14.34	27.97	60.73	124.2	162.9	100.1	104.02	151.4	53.34
Less suitable	0.05	0.21	0.54	1.48	3.15	6.55	12.58	17.21	6.83
Moderately suitable	0	0.05	0.05	0.08	0.5	0.69	2.65	2.63	1.3
Highly suitable	0	0.04	0.02	0.05	0.29	0.76	2.61	1.67	0.93

Suitability ↓ Sector →	G-13	G-12	G-11	G-10	G-9	G-8	G-7	G-6
Unsuitable	3.39	16.34	41.52	115.9	101.8	110.1	57.51	81.56
Less suitable	0	0.13	3.36	2.76	3.88	6.76	13.19	24.25
Moderately suitable	0	0.06	0.28	0.2	0.28	0.89	2.43	4.03
Highly suitable	0	0.04	0.14	0.18	0.19	1.17	2.72	3.04

Suitability ↓ Sector →	H-13	H-12	H-11	H-10	H-9	H-8	*Suitability statistic*	
Unsuitable	3.23	8.75	35.77	77.99	101.1	153.8		
Less suitable	0.33	0.82	1.27	0.5	4.21	4.28	**Min:**	0
Moderately suitable	0.03	0.24	0.2	0	0.65	0.41	**Max:**	162.9
Highly suitable	0.03	0.64	0.16	0	0.28	0.28		

Suitability ↓ Sector →	I-13	I-12	I-11	I-10	I-9	I-8	*Total*	Total	Min	Max
Unsuitable	0.47	5.53	14.14	63.26	57.35	75.54	*Unsuitable*	2175	0.47	162.91
Less suitable	0.03	0.82	3.32	13.81	15.36	14.53	*Less suitable*	178	0	24.25
Moderately suitable	0.01	0.19	0.33	2.07	2.87	2.37	*Moderately suitable*	27.63	0	4.03
Highly suitable	0	0.01	0.26	1.04	3.46	1.33	*Highly suitable*	22.54	0	3.46

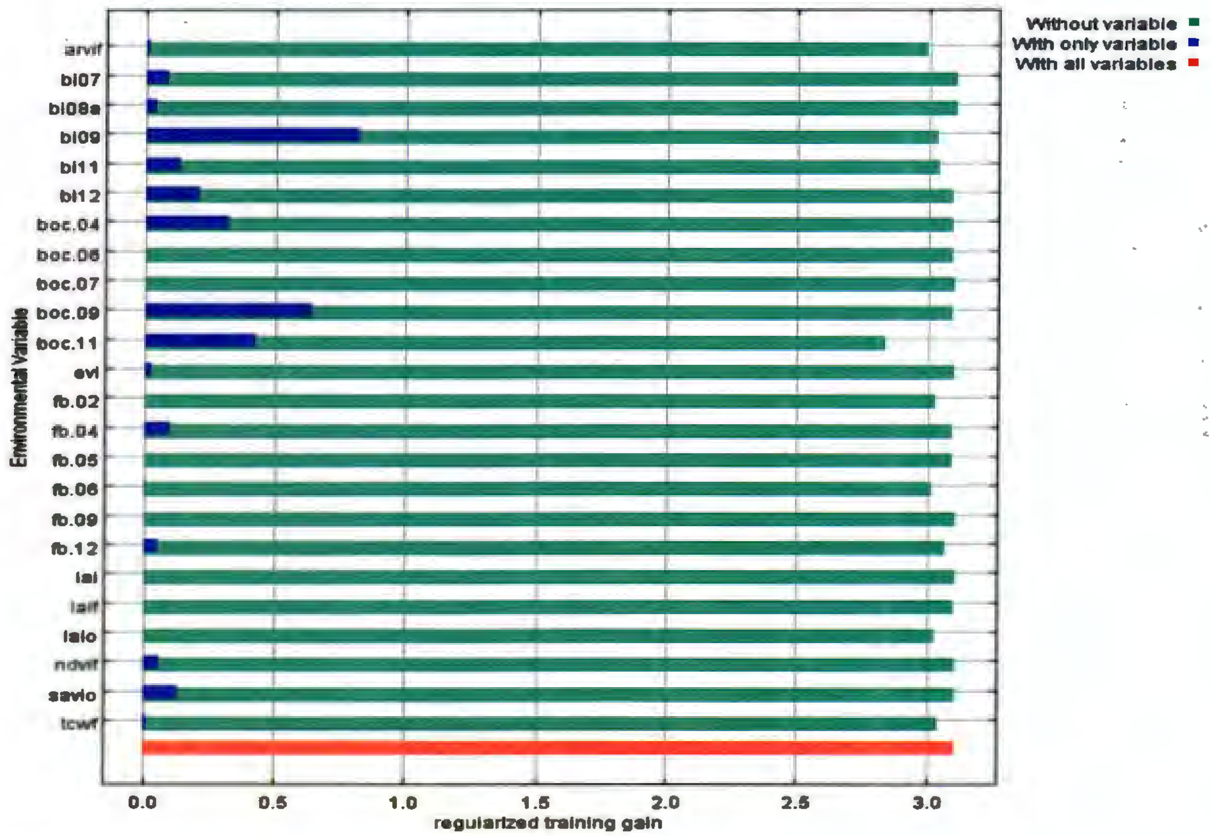
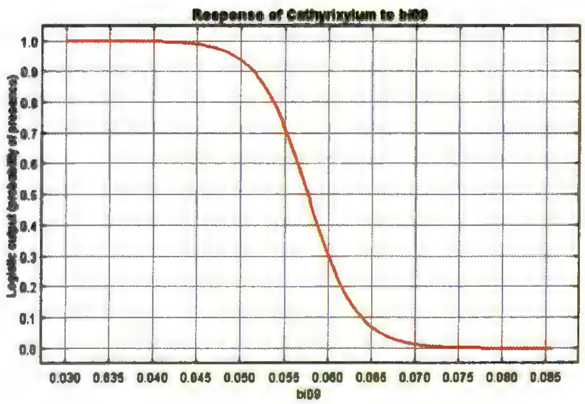
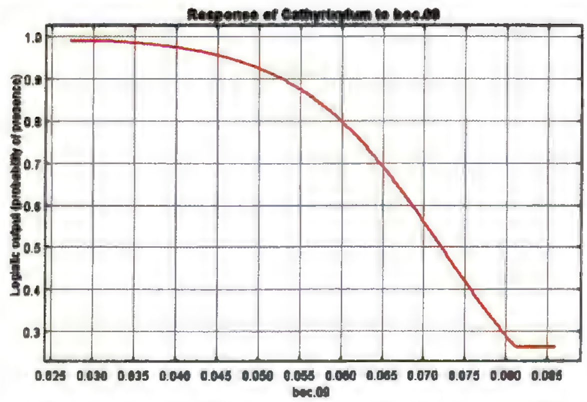


Figure 4. 21: Jackknife of regularized training gain for *Citharexylum spinosum*

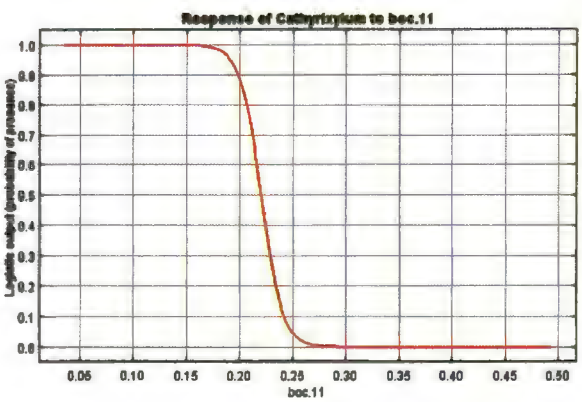
Response curves of important variables for *Citharexylum spinosum*



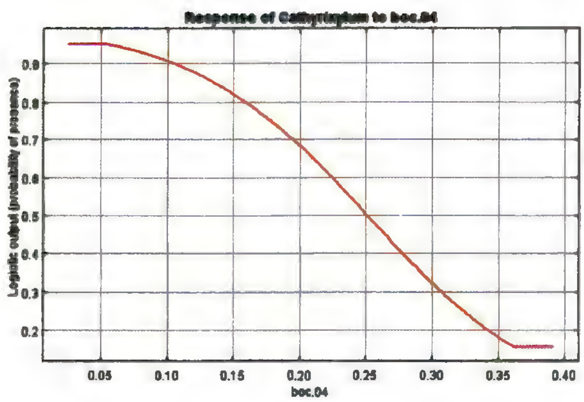
(a)



(b)



(c)



(d)

Graph (a) shows that variable bi.09 (band 9 of May image) shows negetive correlation and it have maximum prediction of presence at 0.04 threshold. (b) Variables boc.09 (band 9 of October image) shows negative correlation. (c) Variable boc.11 (band 11 of October image) also shows negative correlation. (d) Similarly variable boc04 (band 4 of October image) shows negative correlation.

4.3.10 *Dalbergia sissoo* (Sheesham)

Dalbergia sissoo commonly known as Sheesham or Shisham is one of the most common occurring species in the study area. In figure 4. 22, MAXENT model prediction for *Dalbergia sissoo* shows Its prediction of occurrence, It is abundantly found in green belts and along the drainage pattern of the city (Ali & Malik, 2010). The Receiver operating characteristic (ROC) shows 93 percent accuracy (AUC=0.931).

Predicted distribution of *Dalbergia sissoo* with suitability classes (sector-wise)

Table 4. 11 shows distribution of *Dalbergia sissoo* in Islamabad with different suitability classes. It is predicted with highly suitable class to be found on 106.2 hectare (4.4 percent of tree class) and 208.3 hectare (8.6 percent of tree class) with moderately suitable class. Sectors having significant cover with highly suitable class includes G-10 (11.67 hectare), F-10 (9.97 hectare), I-8 (7.14 hectare) and H-9 (6.76 hectare).

Jackknife of Regularized training gain for *Dalbergia sissoo*

The results of Jackknife regularized training gain for *Dalbergia sissoo* shows that variable fb.08a (band 8a of February image) has highest gain (Figure 4. 23). The other important variables with significant gain include, tcwf (Tasseled cap wetness_February), fb.08 (band 8 of October image), savio (Soil-adjusted vegetation index_October) and evio (Enhanced vegetation index _October).

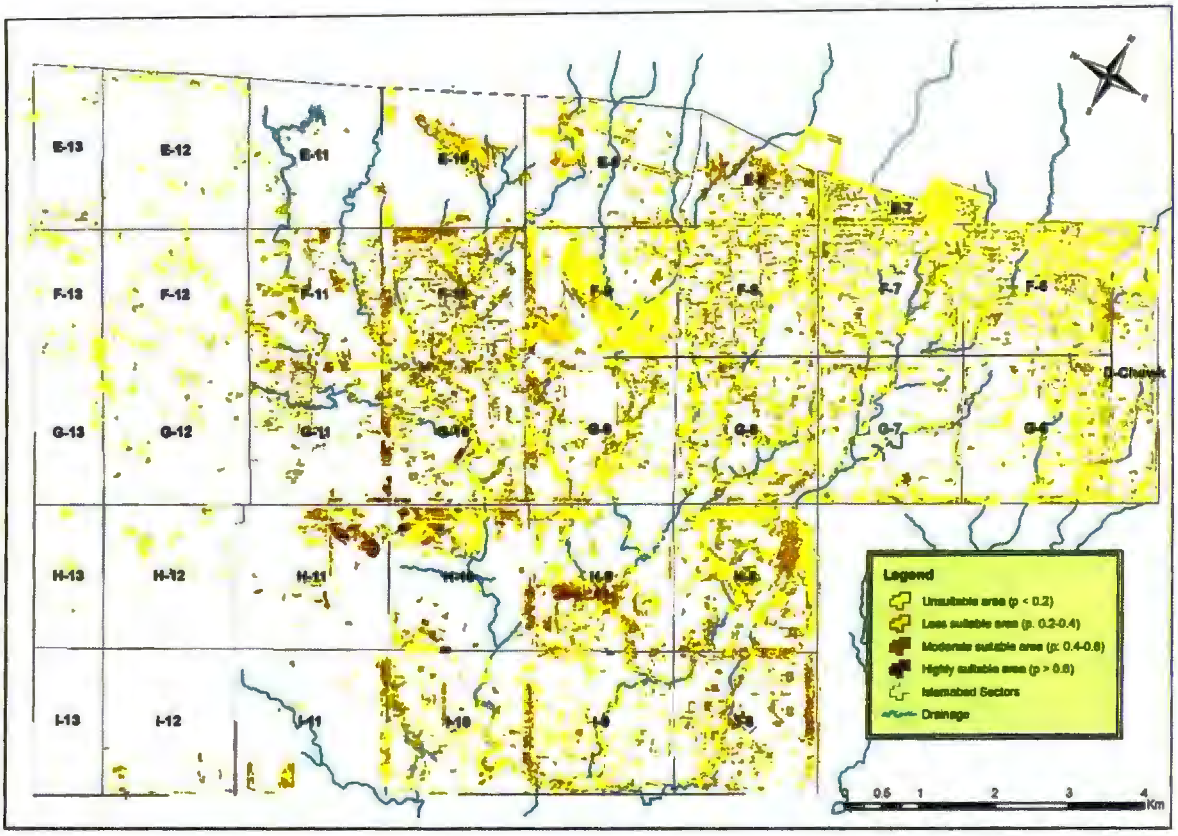


Figure 4. 22: Predicted probability of presence from MAXENT model for *Dalbergia sissoo*

Table 4. 11: Suitability of *Dalbergia sissoo* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7
Unsuitable	4.5	9.86	4.27	12.67	26.71	27.61	55.9
Less suitable	2.13	4.5	3.21	24.94	25.49	24.77	14.03
Moderately suitable	0.35	0.54	0.73	4.17	4.82	7.53	2.93
Highly suitable	0.28	0.17	0.38	0.74	1.34	4.13	1.14

Suitability ↓ Sector →	F-13	F-12	F-11	F-10	F-9	F-8	F-7	F-6	D-Chowk
Unsuitable	12.21	21.73	19.74	38.7	113.2	47.94	74.71	121.8	43.54
Less suitable	1.98	5.42	28.82	57.82	43.94	45.95	38.44	41.85	14.11
Moderately suitable	0.12	0.84	8.92	19.34	6.61	9.94	6.26	6.42	3.24
Highly suitable	0.08	0.28	3.86	9.97	3.1	4.27	2.45	2.85	1.51

Suitability ↓ Sector →	G-13	G-12	G-11	G-10	G-9	G-8	G-7	G-6
Unsuitable	2.84	11.83	15.76	44.03	51.99	61.87	40.8	81.08
Less suitable	0.52	3.57	17.43	46.76	39.64	43.26	26.04	25.76
Moderately suitable	0.02	0.85	7.23	16.58	9.9	9.27	5.88	3.86
Highly suitable	0.01	0.32	4.88	11.67	4.66	4.53	3.13	2.18

Suitability ↓ Sector →	H-13	H-12	H-11	H-10	H-9	H-8
Unsuitable	2.84	6.46	7.49	31.78	41.79	82.44
Less suitable	0.67	3.51	15.2	31.57	44.37	56.5
Moderately suitable	0.1	0.41	8.11	9.55	13.32	13.7
Highly suitable	0.01	0.07	6.6	5.59	6.76	6.11

Suitability statistic	
Min:	0
Max:	121.8

Suitability ↓ Sector →	I-13	I-12	I-11	I-10	I-9	I-8
Unsuitable	0.49	2.43	7.12	45.08	44.59	33.06
Less suitable	0.02	2.79	7.55	26.33	27.34	41.45
Moderately suitable	0	0.94	2.38	5.91	5.36	12.12
Highly suitable	0	0.39	1	2.86	1.75	7.14

Total	Total	Min	Max
Unsuitable	1251	0.49	121.75
Less suitable	837.7	0.02	57.82
Moderately suitable	208.3	0	19.34
Highly suitable	106.2	0	11.67

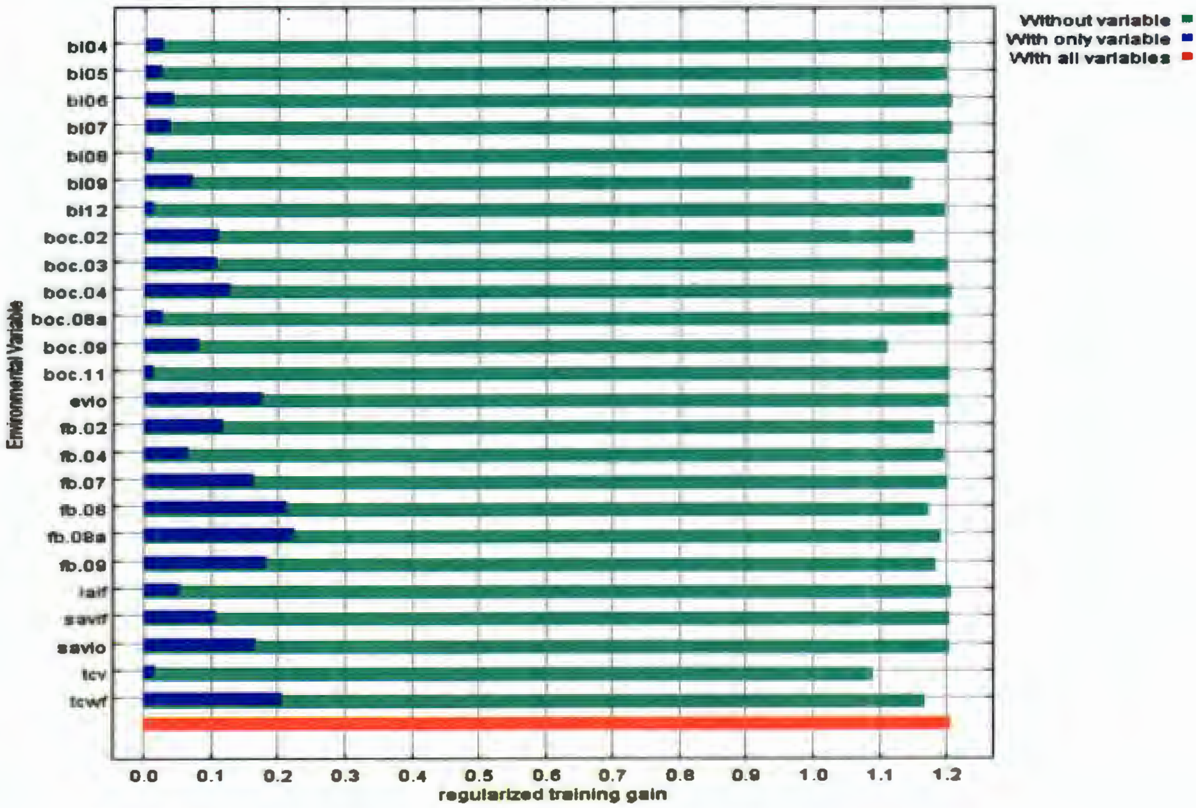
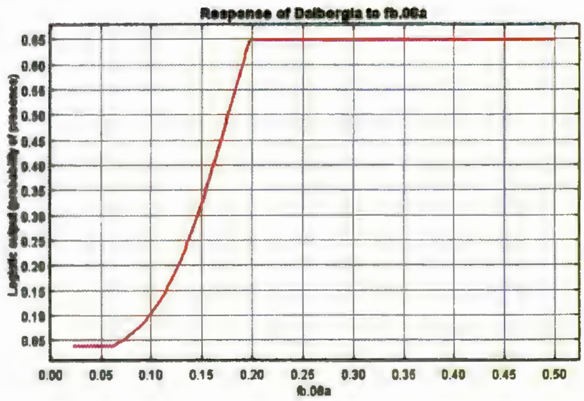
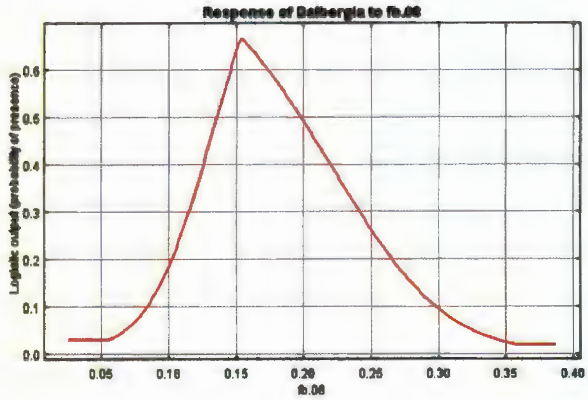


Figure 4. 23: Jackknife of regularized training gain for *Dalbergia sissoo*

Response curves of important variables for *Dalbergia sissoo*



(a)



(b)

(c)

(d)

(a) The variable fb.08a (band 8a of February image) shows highest gain when used in isolation and the response curve showing a positive correlation. (b) The variable fb.08 (band 8 of February image) decreases the most gain when It is omitted, response curve shows the maximum prediction at 0.15 threshold. (c) Variable tcwf (Tasseled cap wetness_February) shows negative correlation. (d) Response curve of fb.09 (band 9 of February image) shows positive correlation.

4.3.11 *Eucalyptus camaldulensis* (Eucalyptus / Sufeda)

Figure 4. 24 is a representation of the MAXENT model for *Eucalyptus camaldulensis*, dark colors show areas with better predicted conditions. It is mostly planted along the road side and somehow along the drainage area. Its significance cover is found in sectors F-6 and I-9 (Industrial Sector). Receiver operating characteristic (ROC) shows the 96 percent accuracy (AUC=0.963) for *Eucalyptus camaldulensis*.

Predicted distribution of *Eucalyptus camaldulensis* with suitability classes (sector-wise)

Eucalyptus camaldulensis is one commonly occurring tree of Islamabad along the road sides and highways. Approximately, 94.16 hectare (3.9 percent of tree class) is predicted with highest suitability to have the *Eucalyptus camaldulensis*. The important sectors include sector F-6 (13.18 hectare), I-9 (8.72 hectare), F-8 (7.02 hectare) and G-7 (6.35 hectare). With moderately suitable class 159.1 hectare (6.6 percent of the tree class) and 600 hectare (25 percent of the tree class) with less suitable class is predicted in the study area (Table 4. 12).

Jackknife of regularized training gain for *Eucalyptus camaldulensis*

Jackknife training gain result show that among various used variables, bio05 (band 5 of October image), bi06 (band 6 of May image), bi08 (band 8 of May image), bi12 (band 12 of May image), tcvf (Tasseled cap vegetation_February), tcw (Tasseled cap wetness_May) and tcwo (Tasseled cap wetness_October) show significant gain. While, tcv (Tasseled cap wetness_May), boc.12 (band 12 of October image) show less gain (Figure 4. 25).

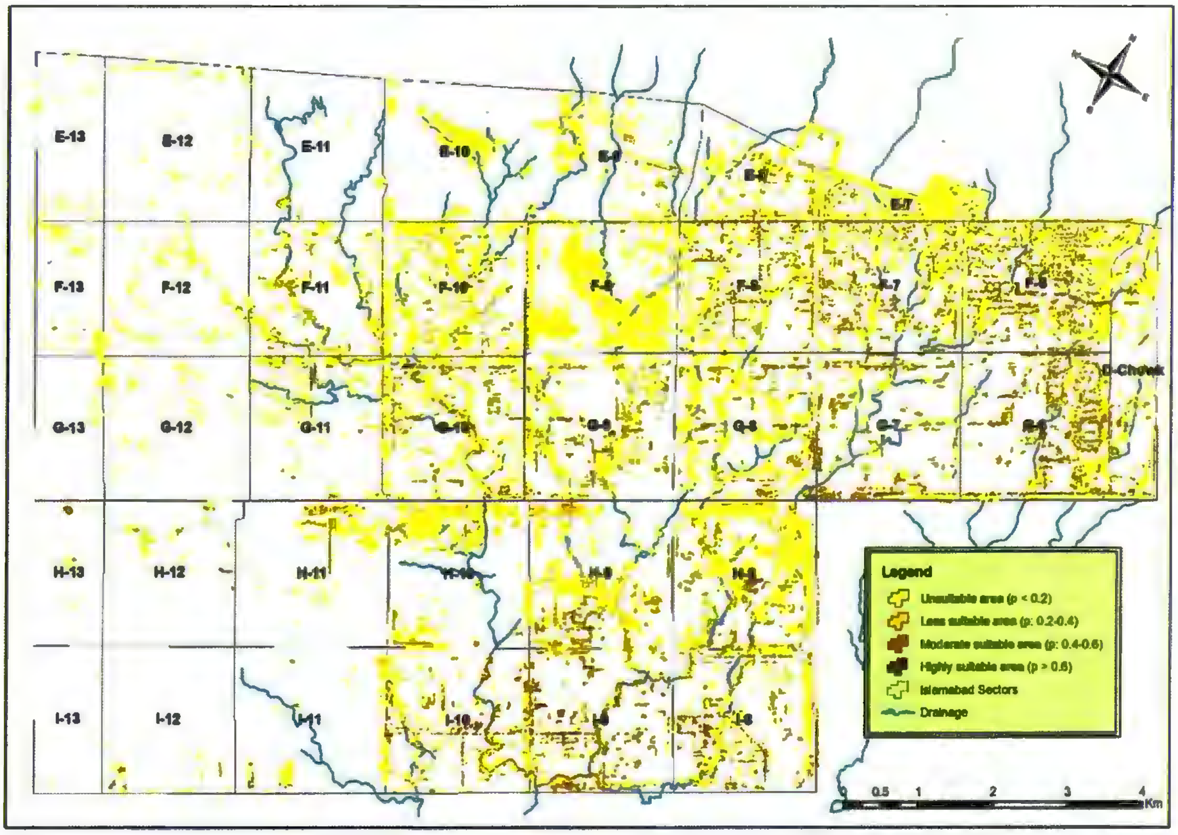


Figure 4. 24: Predicted probability of presence from MAXENT model for *Eucalyptus camaldulensis*

Table 4. 12: Suitability of *Eucalyptus camaldulensis* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7		
Unsuitable	7.19	13.72	6.22	36.78	48.22	45.52	61.55		
Less suitable	0.07	1.31	1.9	5.55	8.35	13.87	9.49		
Moderately suitable	0	0.04	0.35	0.15	1.37	3.12	2.15		
Highly suitable	0	0	0.12	0.04	0.42	1.53	0.81		
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**
Unsuitable	13.72	27.13	41.84	93.94	154.7	59.41	64.72	94.53	38.89
Less suitable	0.58	1	15.98	26.17	9.14	31.32	36.14	47.11	16.59
Moderately suitable	0.08	0.13	2.61	4.37	1.75	10.35	12.6	18.05	3.91
Highly suitable	0.01	0.01	0.91	1.35	1.24	7.02	8.4	13.18	3.01
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**	
Unsuitable	3.09	15.42	29.5	72	67.59	78.77	33.96	47.27	
Less suitable	0.29	1.12	12.1	35.78	28.45	28.62	25.18	37.08	
Moderately suitable	0.01	0.01	2.38	7.84	6.88	7.65	10.36	15.79	
Highly suitable	0	0.02	1.32	3.42	3.27	3.89	6.35	12.74	
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***		
Unsuitable	2.29	6.38	25.05	54.24	59.45	113.2			
Less suitable	0.46	2.94	10.29	22.22	37.99	37.43	**Min:**	0	
Moderately suitable	0.57	0.91	1.6	1.69	6.78	5.63	**Max:**	154.7	
Highly suitable	0.3	0.22	0.46	0.34	2.02	2.48			
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**	***Total***	**Total**	**Min** / **Max**
Unsuitable	0.45	4.05	13.44	39.08	26.24	48.86	*Unsuitable*	1548	0.45 / 154.72
Less suitable	0.05	1.81	3.58	27.6	31.62	31.52	*Less suitable*	600.7	0.05 / 47.11
Moderately suitable	0.01	0.44	0.77	8.42	12.46	8.42	*Moderately suitable*	159.7	0 / 18.05
Highly suitable	0	0.25	0.26	5.08	8.72	4.97	*Highly suitable*	94.16	0 / 13.18

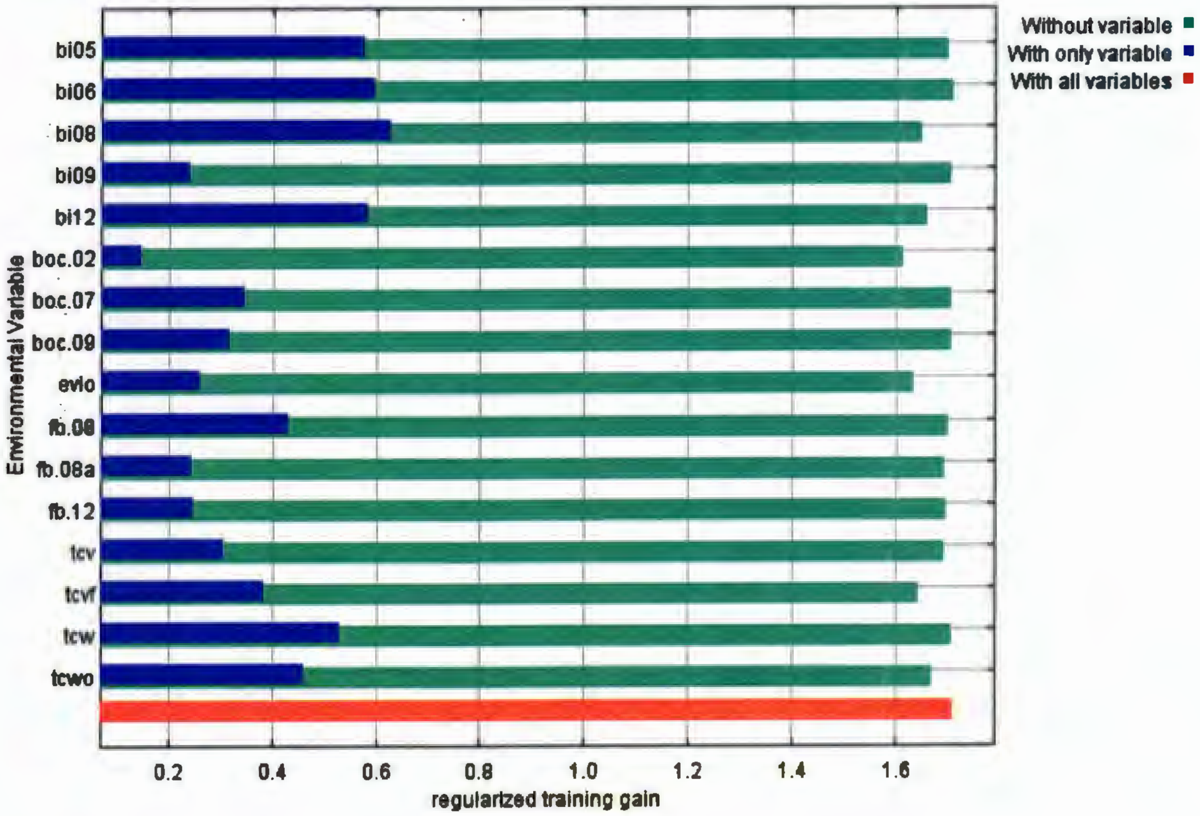
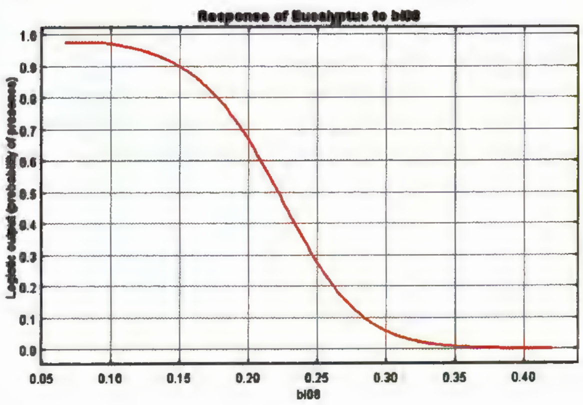
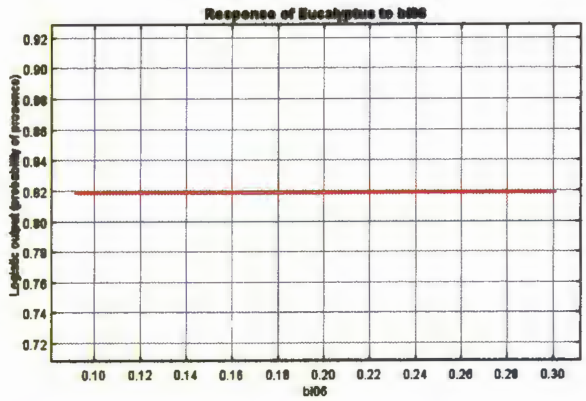


Figure 4. 25: Jackknife of regularized training gain for *Eucalyptus camaldulensis.*

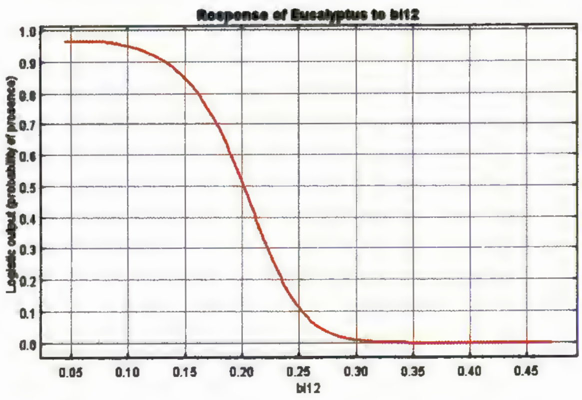
Response curves of important variables for *Eucalyptus camaldulensis*



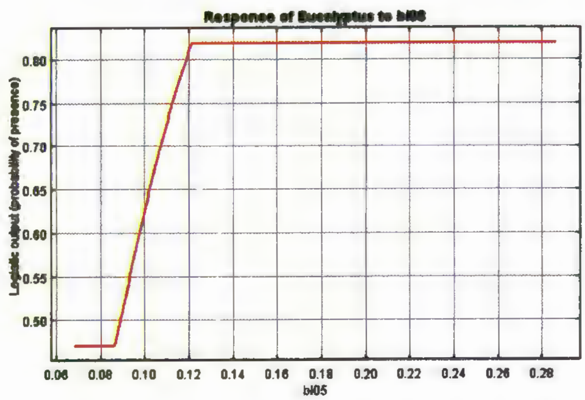
(a)



(b)



(c)



(d)

The response curves of important variables include (a) bi08 (band 8 of May image) which shows highest gain with negative correlation. (b) Variable bi06 (band 6 of May image) receives significance gain but does not show any trend/correlation. (c) Response curve of bi12 (band 12 of May image) shows the negative trend. (d) bi05 shows positive correlation.

4.3.12 *Ficus elastica* (Rubber Tree)

It is commonly known as Rubber tree rubber bush, rubber plant, or Indian rubber bush. it is an evergreen tree commonly planted in the urban areas. Its height is approximately 20 ft (Stone *et al.*, 1967). The results of receiver operating characteristic (ROC) curve shows the threshold value 0.870 which show 87 percent accuracy of predicted areas. Figure 4. 26 shows the result of MAXENT model prediction for *Ficus elastic* in the study area.

Predicted distribution of *Ficus elastica* with suitability classes (sector-wise)

It is predicted with the highly suitable class on 80.72 hectare area (3.3 percent of tree class) sector I-9 with 9.22 hectare is having largest cover, other significant sectors with highly suitable class are F-6 (6,79 hectare), I-10 (6.73 hectare) and G-10 (5.88 hectare). While, with moderate suitable class it covers 1346 hectare (56 percent of the total tree class) area and only sector H-8 consists of 125.7 hectare cover (Table 4. 13).

Jackknife of regularized training gain for *Ficus elastic*

According to figure 4. 27, variable fb.05 (band 5 of February image) shows the highest regularized training gain as the band 5 of Sentinel-2 is 20 m spectral resolution band. It is important for identification of vegetation cover. Another variable with significant gain is fb.12 (band 12 of February image) among less significance variables tcwo (Tasseled cap wetness_October), bi12 (band 12 of May image) and fb.11 (band 11 of February image).

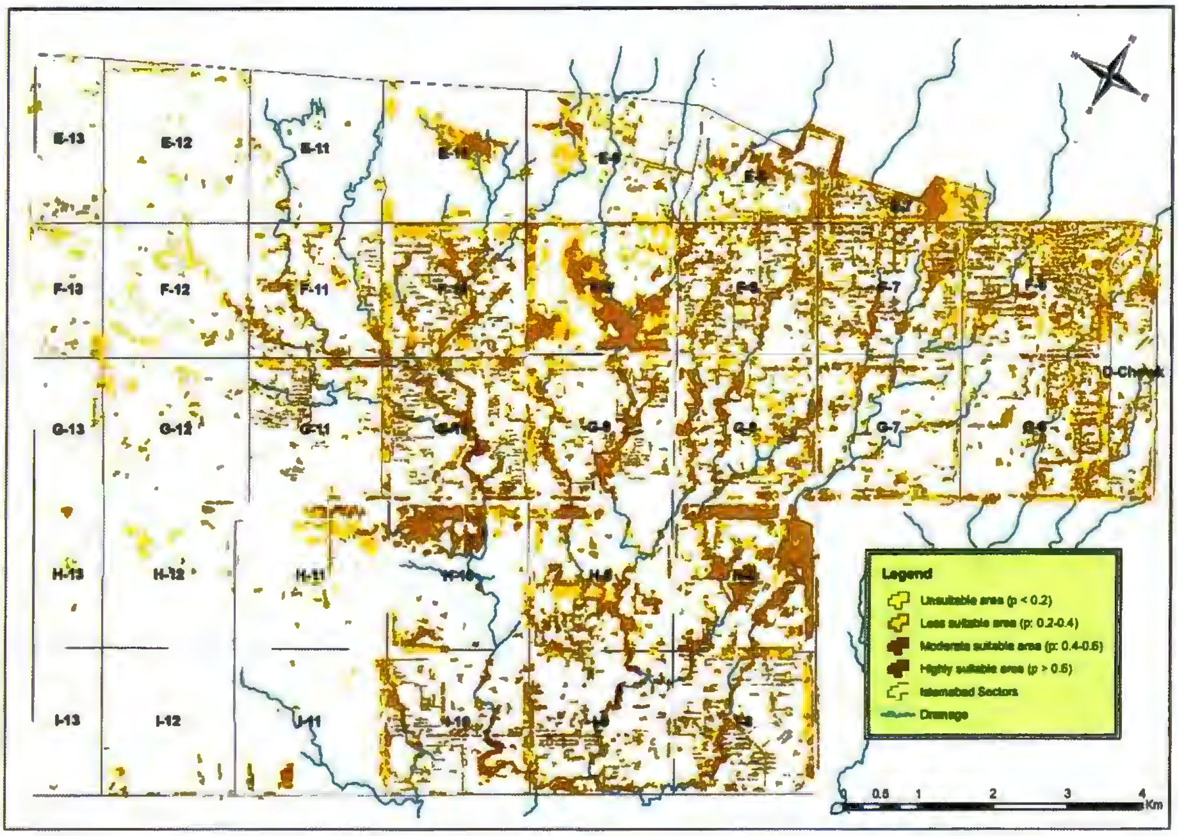


Figure 4. 26: Predicted probability of presence from MAXENT model for *Ficus elastic*

Table 4. 13: Suitability of *Ficus elastic* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7		
Unsuitable	0	0	0	0	0	0	0		
Less suitable	4.98	13.58	5.23	33	40.06	26.87	40.88		
Moderately suitable	2.28	1.49	3.14	9.52	18.05	36.14	31.67		
Highly suitable	0	0	0.22	0	0.25	1.03	1.45		
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**
Unsuitable	0.06	0.39	0	0	0	0	0	0	0
Less suitable	13.55	24.45	24.6	62.25	92.88	32.33	44.67	78.11	27.77
Moderately suitable	0.77	3.36	34.41	60.27	73.76	70.49	71.09	87.97	33.1
Highly suitable	0.01	0.07	2.33	3.31	0.21	5.28	6.1	6.79	1.53
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**	
Unsuitable	0	0.02	0	0	0	0	0	0	
Less suitable	2.4	13.52	15.95	33.3	32.93	42.38	28.81	42.31	
Moderately suitable	0.96	2.86	26.42	79.86	70.34	74.79	45.45	66.14	
Highly suitable	0.03	0.17	2.93	5.88	2.92	1.76	1.59	4.43	
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***		
Unsuitable	0.02	0	0.01	0	0	0			
Less suitable	2.46	8.95	23.51	20.23	38.72	29.36	Min:	0	
Moderately suitable	1.12	1.1	13.05	55.1	65.29	125.8	Max:	125.8	
Highly suitable	0.02	0.4	0.83	3.16	2.23	3.64			

Suitability ↓ Sector →	I-13	I-12	I-11	I-10	I-9	I-8	*Total*	Total	Min	Max
Unsuitable	0	0	0.03	0	0	0	*Unsuitable*	0.53	0	0.39
Less suitable	0.23	2.99	9.5	20	12.83	28.91	*Less suitable*	974.5	0.23	92.88
Moderately suitable	0.28	3.46	8.36	53.45	56.99	58.92	*Moderately suitable*	1347	0.28	125.75
Highly suitable	0	0.1	0.16	6.73	9.22	5.94	*Highly suitable*	80.72	0	9.22

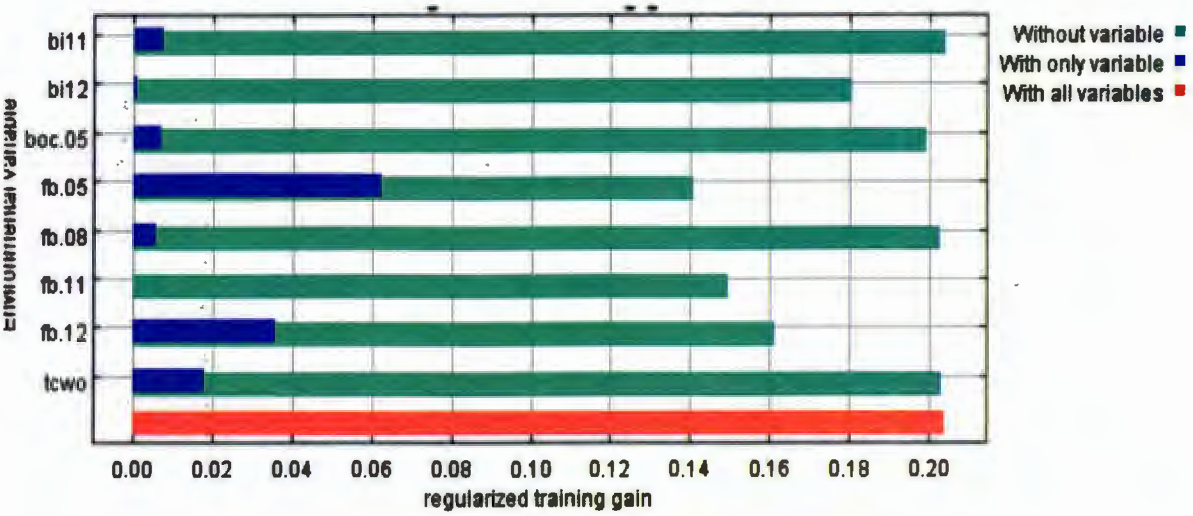
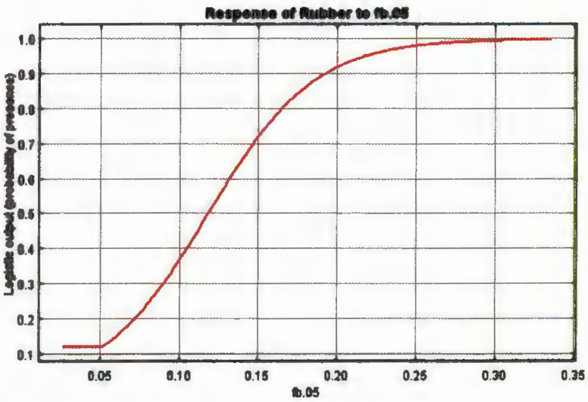
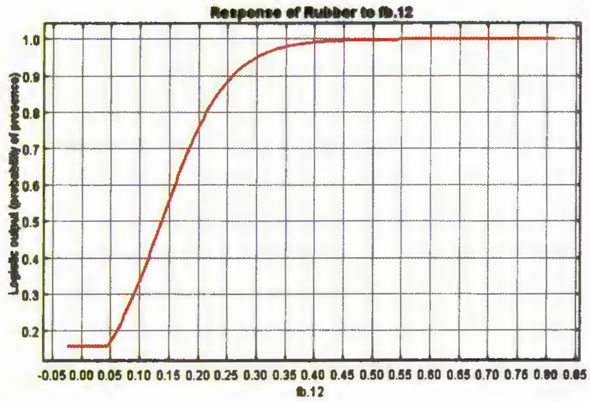


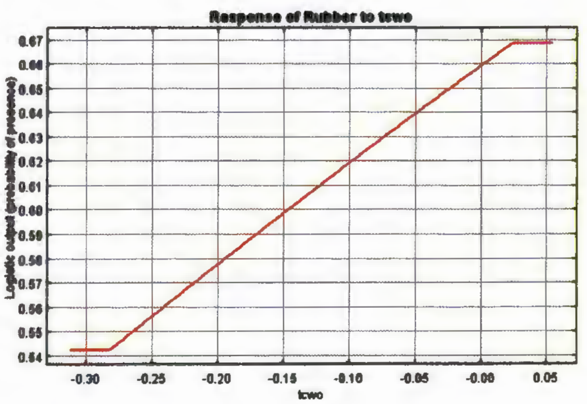
Figure 4. 27: Jackknife of regularized training gain for *Ficus elastic*

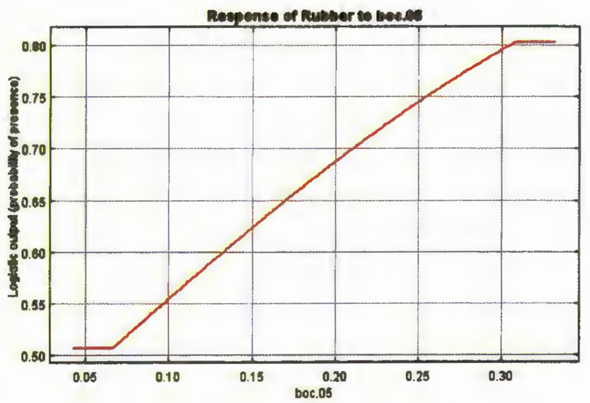
Response curves of important variables for *Ficus elastic*





(a) (b)





(c) (d)

(a) The variable fb05 (band 5 of February image) shows positive correlation and have maximum probability of presence at 0.30 threshold. (b) Variable fb.12 (band 12 of February image), (c) tcwo (Tasseled Cap Wetness_ October) and (d) boc.05 (band 5 of October image) shows positive correlation.

4.3.13 *Jackaranda mimosifolia* (Gul-e-Neelam)

Basically *Jackaranda* is a sub-tropical tree and it has been widely planted in Islamabad due to its attractive and long-lasting blue flowers. It has been planted along the road side and in residential area because of its attraction. MAXENT model respresntation of *Jackaranda mimosifolia* shows that it is occurred with high suitabality along the drainage areas and green belts (Figure 4. 28).

Predicted distribution of *Jackaranda mimosifolia* with suitability classes (sector-wise)

174.7 hactare (7.3 percent of total tree class) has been predicted by MAXENT model under the *Jackaranda* with highly suitable class. 36.31 hectare cover of *Jackaranda* makes sector G-6 the most significant with highly suitable class. Also, sector F-7 (32.6 hectare) and I-8 (12.19 hectare) have significant cover. With Moderately suitable class it is predicted to be present on 284.6 hectare (11.8 percent of the tree class) area (Table 4. 14).

Jackknife of regularized training gain for *Jackaranda mimosifolia*

Jackknife resut shows the bi.11 (band 11 of May month) as a varaible with maximum gain,0.37 regularized training gain, the variable bi.12 (band 12 of May image), bi.04 (band 4 of May) and tcbo (Tasseled cap brightness_October) also shows gnificance gian. While other band with less significane includes arvi (Atmospherically resistant vegetation index_May) and ndvif (Normalized difference vegetation index_February) (Figure 4. 29).

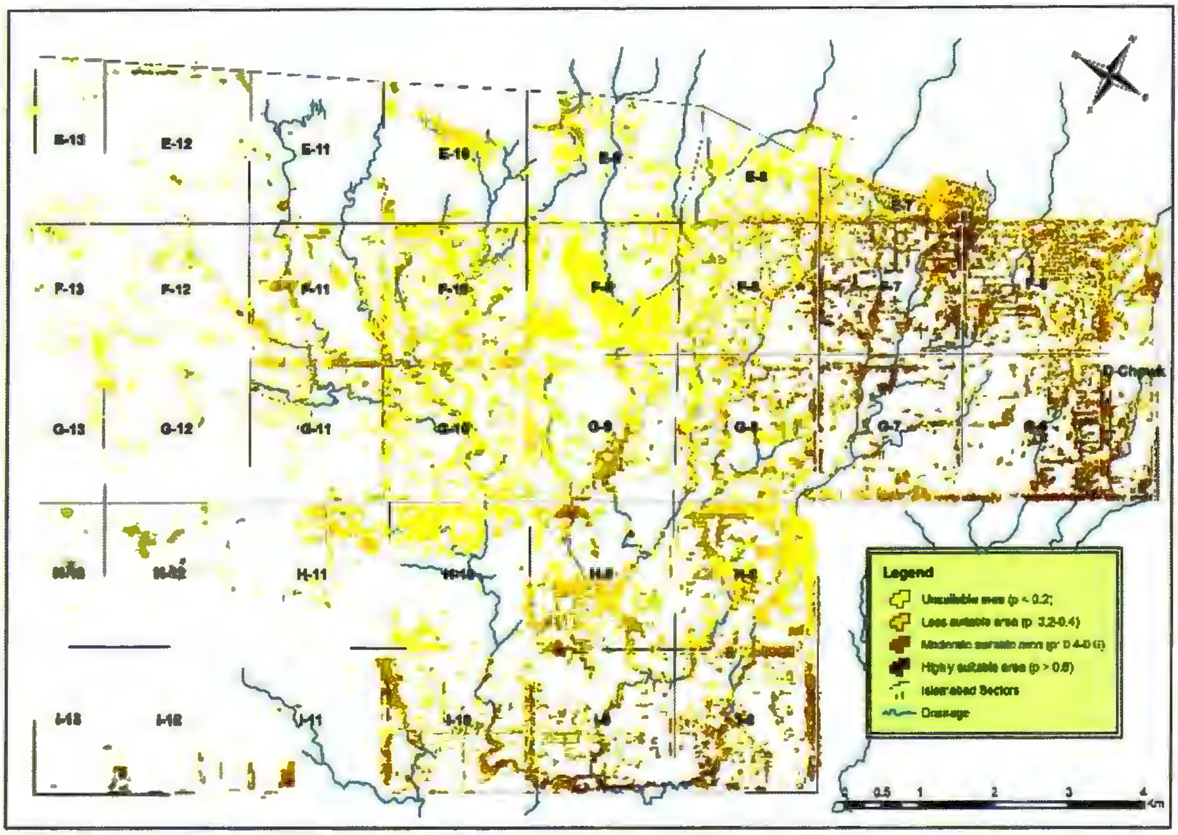


Figure 4. 28: Predicted probability of presence from MAXENT for *Jackaranda mimosifolia*

Table 4. 14: Suitability of *Jackaranda mimosifolia* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7
Unsuitable	6.3	7.97	3.25	21.91	36.27	38.29	10.45
Less suitable	0.95	4.7	4.16	20.17	21.22	23.08	45.74
Moderately suitable	0.01	1.59	0.95	0.39	0.84	2.26	12.97
Highly suitable	0	0.81	0.23	0.05	0.03	0.41	4.84

Suitability ↓ Sector →	F-13	F-12	F-11	F-10	F-9	F-8	F-7	F-6	D-Chowk
Unsuitable	10.51	21.59	23	66.9	131.6	36.13	7.82	17.07	7.85
Less suitable	3.78	5.9	34.8	57.12	34.52	56.99	46.23	82.84	28.53
Moderately suitable	0.07	0.74	3.34	1.61	0.63	10.85	35.21	44.95	14.13
Highly suitable	0.03	0.04	0.2	0.2	0.06	4.13	32.6	28.01	11.89

Suitability ↓ Sector →	G-13	G-12	G-11	G-10	G-9	G-8	G-7	G-6
Unsuitable	2.7	12.97	18.37	67.26	49.28	29.01	4.12	5.76
Less suitable	0.69	3.41	22.51	49.81	51.51	71.64	34.94	37.29
Moderately suitable	0	0.1	3.83	1.71	4.43	14.41	20.33	33.52
Highly suitable	0	0.09	0.59	0.26	0.97	3.87	16.46	36.31

Suitability ↓ Sector →	H-13	H-12	H-11	H-10	H-9	H-8
Unsuitable	2.23	4.51	15.32	62.17	27.85	54.1
Less suitable	1.34	5.75	21.4	16.25	68.93	94.53
Moderately suitable	0.03	0.19	0.6	0.06	8.01	8.67
Highly suitable	0.02	0	0.08	0.01	1.45	1.45

Suitability ↓ Sector →	I-13	I-12	I-11	I-10	I-9	I-8
Unsuitable	0.24	1.06	3.36	20.73	13.24	11.83
Less suitable	0.27	2	9.37	43.1	40.32	44.76
Moderately suitable	0	1.67	4.03	12.48	15.02	24.99
Highly suitable	0	1.82	1.29	3.87	10.46	12.19

Suitability statistic	
Min:	0
Max:	131.6

Total	Total	Min	Max
Unsuitable	853.1	0.24	131.64
Less suitable	1091	0.27	94.53
Moderately suitable	284.6	0	44.95
Highly suitable	174.7	0	36.31

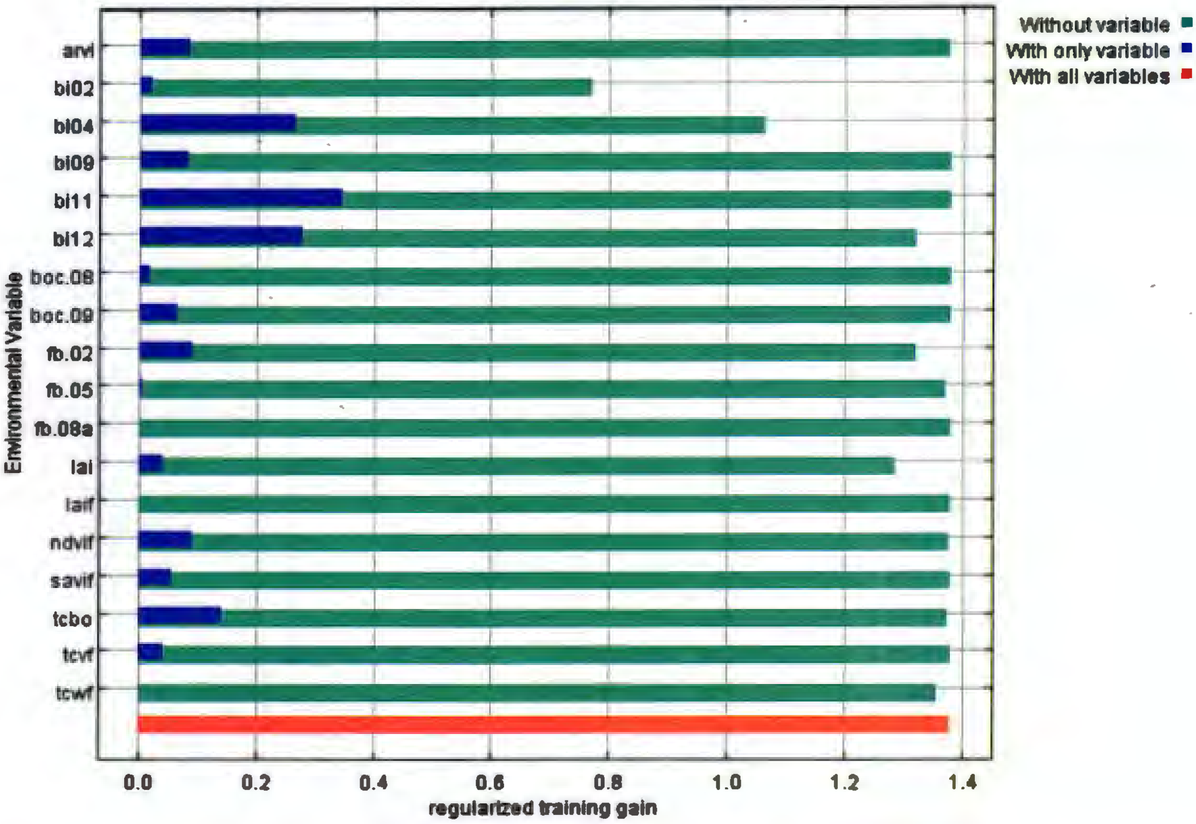
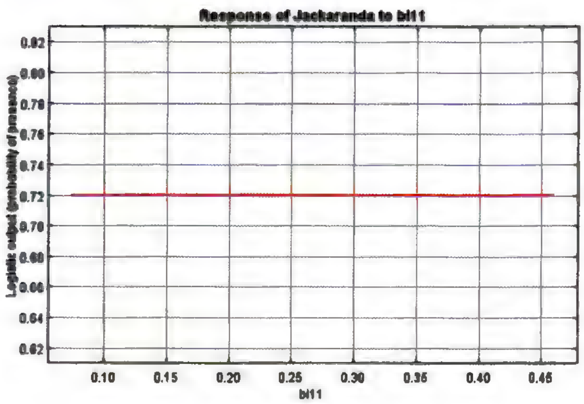
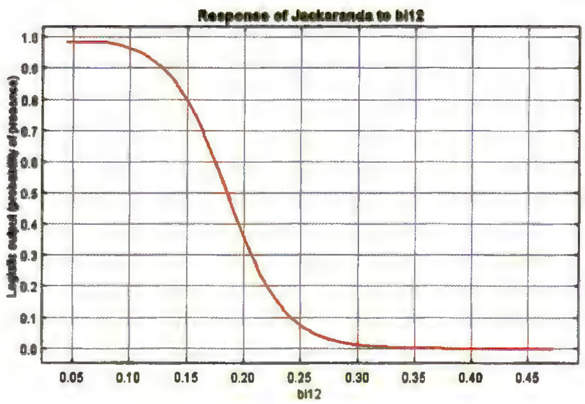


Figure 4. 29: Jackknife of regularized training gain for *Jackaranda mimosifolia*

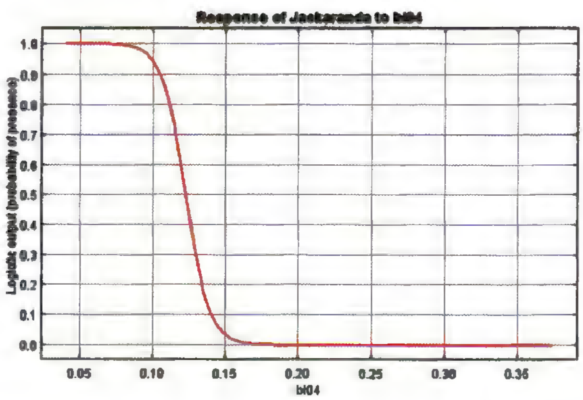
Response curves of important variables for *Jackaranda mimosifolia*



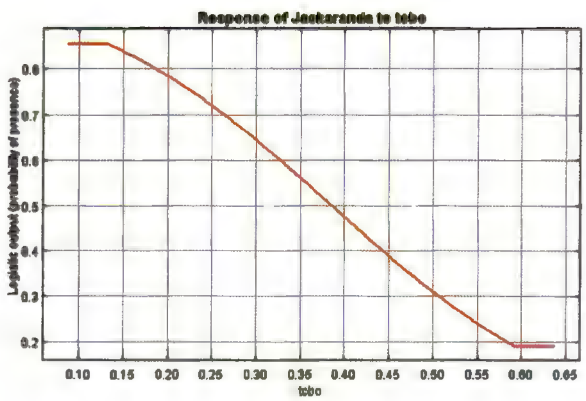
(a)



(b)



(c)



(d)

(a) Variable bi.11 (band 11 of May image) shows maximum gain and does not show any trend. (b) Variable bi.12 (band 12 of May image) shows negative correlation. (c) Variable bi.04 (band 4 of May image) is a red edge visible spectral band which shows negative correlation. (d) Variable tcbo (Tasseled cap brightness_October) also shows negetive correlation.

4.3.14 *Pinus roxburghii* (Chir / Pine)

It is extensively found tree in the urban areas of Islamabad because it is native to Himalayas. Locally it is known as "Chir". It is also used as wood, dye, ink, illumination, resin and charcoal and also planted in the residential areas as an ornamental tree (Siddiqui *et al.*, 2009). Receiver operating characteristic (ROC) value show 95 percent accuracy (AUC=0.95), predicted probability of distribution in the study area is shown in figure 4. 30.

Predicted distribution of *Pinus roxburghii* with suitability classes (sector-wise)

The *Pinus roxburghii* is predicted with high suitability class on 33 hectare area (1.3 percent of the tree class), sector-wise maximum cover lies in sectors F-6 (6.1 hectare) and F-8 (2.81 hectare). It is predicted to be found on 80.4 hectare (3.3 percent of the tree class) with moderately suitable class and 537.4 hectare (22.3 percent of the tree class) with less suitable class. Further sector wise distribution detail with different suitability classes is given in table 4. 15.

Jackknife of regularized training gain for *Pinus roxburghii*

Jackknife of regularized training gain of variables importance for *Pinus roxburghii* shows that variable bi.08 (band 8 of May image) shows highest gain. Also, tcb (Tasseled cap brightness_May), lai (Leaf area index _May), bi.07 (band 7 of May image) and boc.09 (band 9 of October image) are important variables. Also, variables ndvio (Normalized difference vegetation index_October) and savio (Soil-adjusted vegetation index_October) show significant contribution (Figure 4. 31).

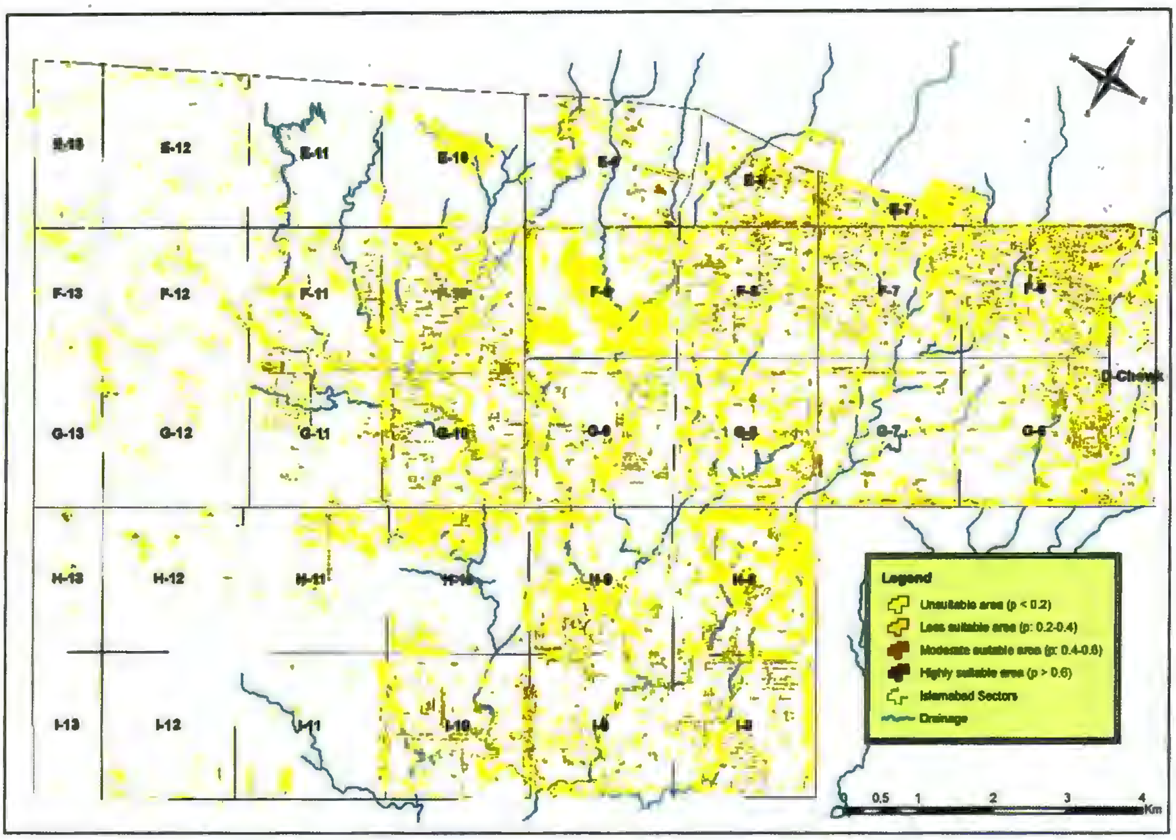


Figure 4. 30: Predicted probability of presence from MAXENT model for *Pinus roxburghii*

Table 4. 15: Suitability of *Pinus roxburghii* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7			
Unsuitable	6.68	14.1	7.15	39.2	38.03	37.6	58.31			
Less suitable	0.56	0.88	1.29	3.23	16.77	20.89	12.62			
Moderately suitable	0.02	0.06	0.12	0.08	2.66	4.05	2.07			
Highly suitable	0	0.03	0.03	0.01	0.9	1.5	1			
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**	
Unsuitable	12.63	25.08	47.35	97.33	154.3	69.06	79.61	91.66	43.25	
Less suitable	1.63	3.03	12.18	24.15	10.29	30.94	33.47	63.01	15.56	
Moderately suitable	0.11	0.13	1.39	3.46	1.65	5.29	6.15	12.1	2.53	
Highly suitable	0.02	0.03	0.42	0.89	0.65	2.81	2.63	6.1	1.06	
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**		
Unsuitable	3.27	15.05	29.25	83.71	78.46	94.58	48.26	68.05		
Less suitable	0.12	1.4	12.49	28.91	22.55	21.39	22.71	37.96		
Moderately suitable	0	0.07	2.47	4.34	3.72	2.29	3.69	4.98		
Highly suitable	0	0.05	1.09	2.08	1.46	0.67	1.19	1.89		
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***			
Unsuitable	2.07	7.18	29.94	64.06	77.91	135.6				
Less suitable	1.1	3.03	6.96	13.39	24.31	19.82	**Min:**	0		
Moderately suitable	0.18	0.24	0.28	0.8	2.69	2.45	**Max:**	154.3		
Highly suitable	0.27	0	0.22	0.24	1.33	0.92				
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**	***Total***	**Total**	**Min**	**Max**
Unsuitable	0.43	5.09	14.71	54.46	52.68	66.04	*Unsuitable*	1752	0.43	154.26
Less suitable	0.08	1.31	2.79	21.48	21.94	23.17	*Less suitable*	537.4	0.08	63.01
Moderately suitable	0	0.1	0.36	3.15	3.13	3.66	*Moderately suitable*	80.47	0	12.1
Highly suitable	0	0.05	0.19	1.09	1.29	0.9	*Highly suitable*	33.01	0	6.1

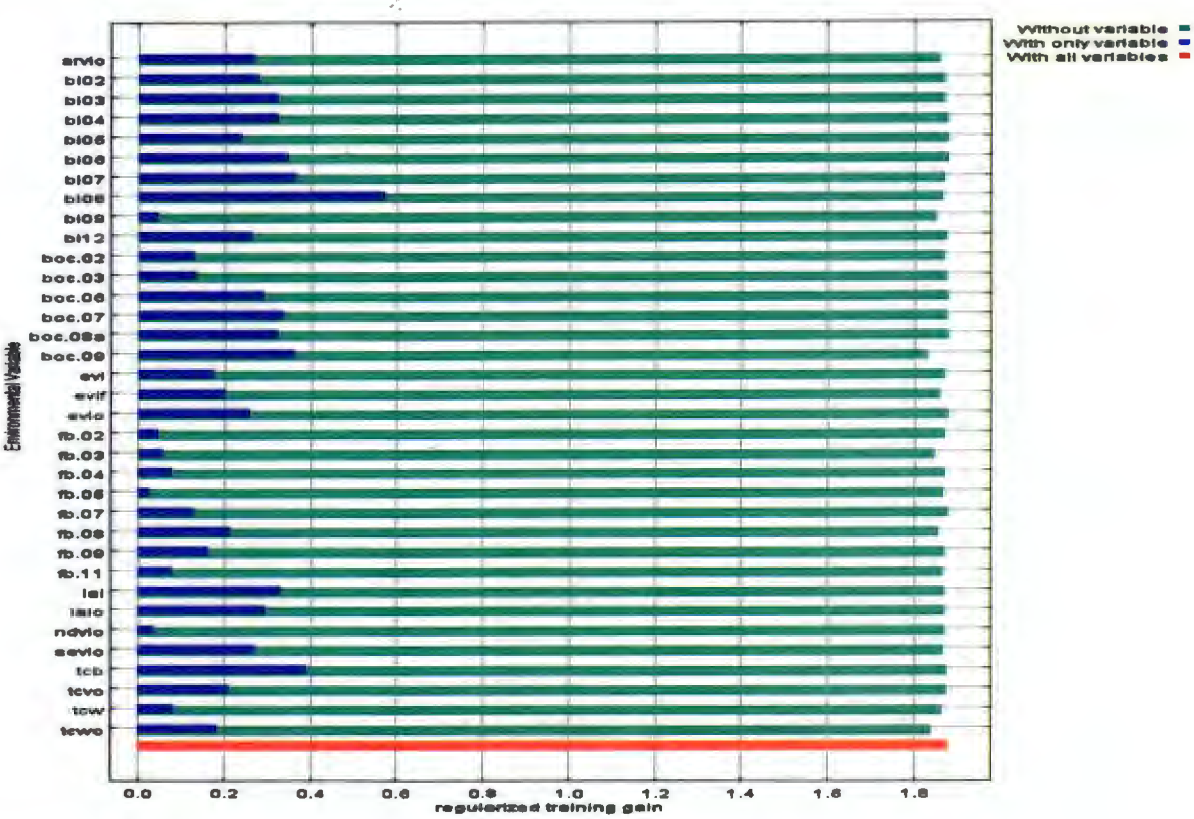
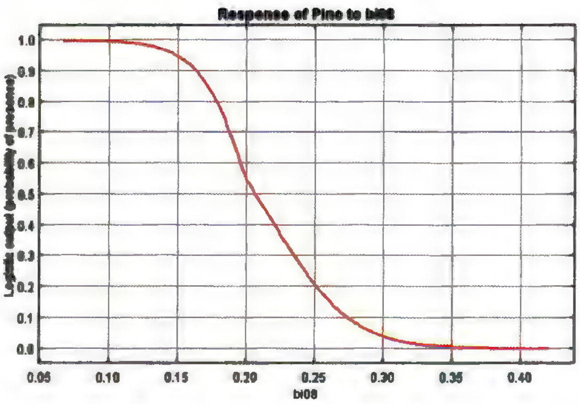
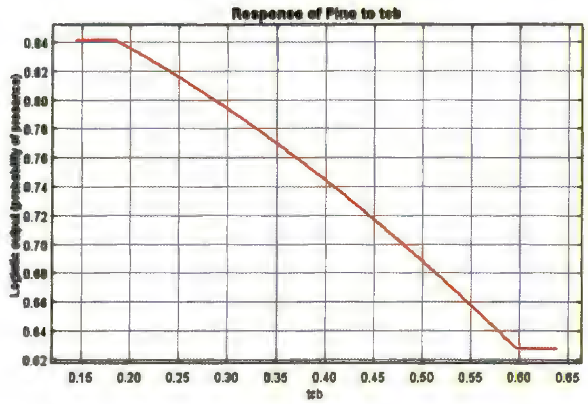


Figure 4. 31: Jackknife of regularized training gain for *Pinus roxburghii.*

Response curves of important variables for *Pinus roxburghii*



(a)



(b)

(c)

(d)

These curves show how each variable affects the MAXENT prediction e. g., (a) the variable bi.08 (band 9 of May Image) (b) tcb (Tasseled cap brightness_May) and (c) bi.07 show the same negative correlation. (d) Variable bi.09 (band 9 of May image) shows positive correlation with maximum probability of presence at 0.05 threshold.

4.3.15 *Pongamia pinnata*

It is a tree of 12–15 m height, with spread branches. The pongame oil is non-edible oil extracted from seeds of *Pongamia pinnata,* it is native in tropical and temperate Asia including parts of Indian subcontinent. It is commonly found in urban Islamabad. It is predicted to be present on 17.22 hectare (<1 percent of the tree class) area. Receiver operating characteristic (ROC) curve show the 97.8 percent accuracy. Figure 4. 32 shows the distribution of *Pongamia pinnata*, it can be seen that it is not found in large patches but it is sparsely scattered in the urban areas.

Predicted distribution of *Pongamia pinnata* with suitability classes (sector-wise)

Sector wise distribution result are given in the table 4. 16. It shows that highly suitable predicted cover of *Pongamia pinnata* is 17.22 hectare (<1 percent of the tree class). Sector G-11 (2.46 hectare) and I-8 (2.44 hectare) have significant cover with same class. With moderately suitable class 1.8 hectare (1.3 percent of the tree class) area is predicted to have the same species. 171 hectare area (almost 7 percent of tree class) has probability of presence with less suitable class. While, 2182 hectare (91 percent of tree class) area is unsuitable for *Pongamia pinnata* with less than 0.2 threshold.

Jackknife of regularized training gain for *Pongamia pinnata*

Figure 4. 33 shows the Jackknife test for *Pongamia pinnata*, it is observed that the most significant variables with significant gain are boc.04 (band 04 of October imagery), boc.02 (band 02 of October image), evio (Enhanced vegetation index_October)), boc.03 (band 03 of October imagery) and fb.07 (band 07 of February imagery). Other significant variables are fb.08a (band 08a of February image), fb.07 ((band 07 of February image) and tcv (Tasseled cap vegetation _May).

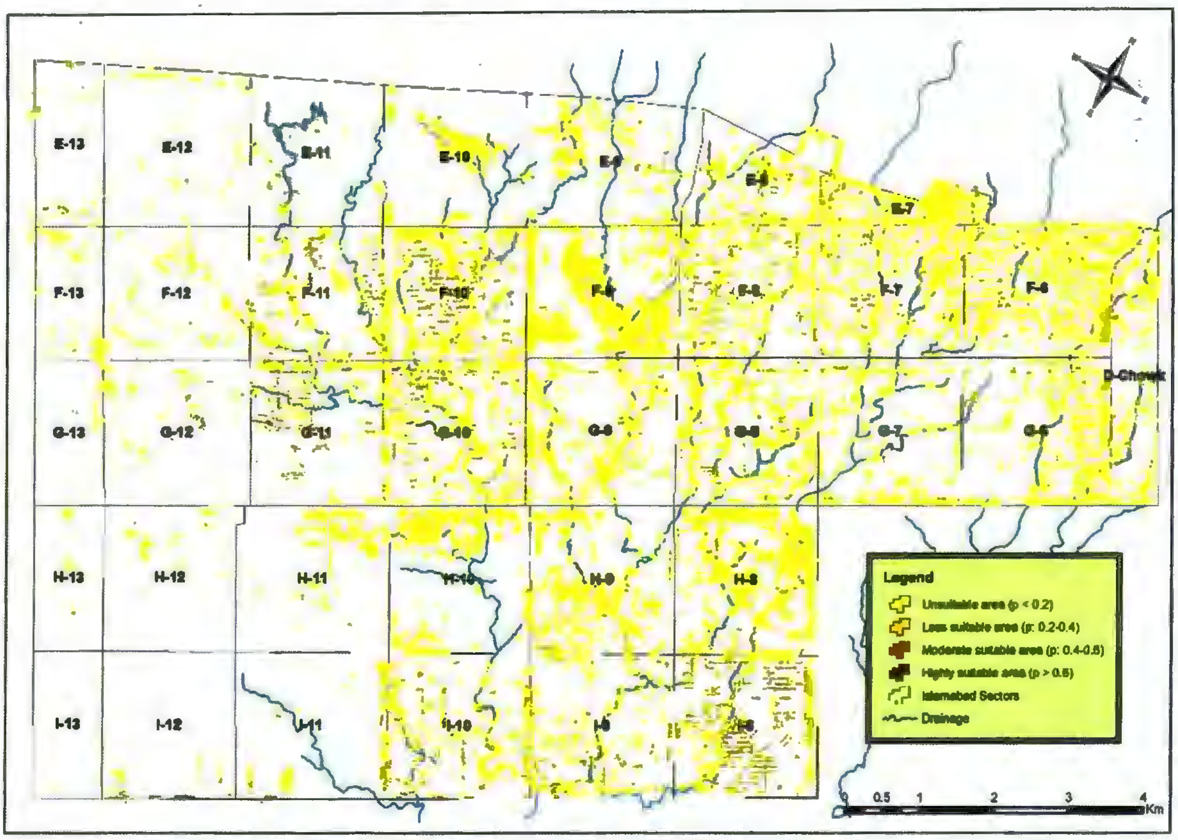


Figure 4. 32: Predicted probability of presence from MAXENT model for *Pongamia pinnata*

Table 4. 16: Suitability of *Pongamia pinnata* in the study area (hectare)

Suitability ↓ Sector →	**E-13**	**E-12**	**E-11**	**E-10**	**E-9**	**E-8**	**E-7**			
Unsuitable	6.2	14.01	6.92	42.42	54.97	56.6	71.17			
Less suitable	0.89	0.99	1.33	0.1	2.57	5.62	2.4			
Moderately suitable	0.09	0.05	0.23	0	0.57	1.31	0.28			
Highly suitable	0.08	0.02	0.11	0	0.25	0.51	0.15			
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**	
Unsuitable	13.97	25.95	49.95	110.3	164.7	92.69	111.75	161.8	59.25	
Less suitable	0.38	2.12	8.53	12.14	1.58	11.96	8.34	8.79	2.55	
Moderately suitable	0.03	0.15	1.77	2.23	0.32	2.29	1.24	1.44	0.43	
Highly suitable	0.01	0.05	1.09	1.15	0.28	1.16	0.53	0.88	0.17	
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**		
Unsuitable	3.28	13.99	31.68	106.2	98.32	110.9	70.12	106.5		
Less suitable	0.11	1.95	8.76	10.57	6.64	6.28	4.64	5.19		
Moderately suitable	0	0.41	2.4	1.65	0.87	1.15	0.8	0.78		
Highly suitable	0	0.22	2.46	0.58	0.36	0.58	0.29	0.45		
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***			
Unsuitable	3.22	10.17	35.78	77.27	100.5	152.9				
Less suitable	0.35	0.23	1.4	1.13	4.86	4.91	**Min:**	0		
Moderately suitable	0.04	0.04	0.15	0.09	0.58	0.75	**Max:**	164.7		
Highly suitable	0.01	0.01	0.07	0	0.28	0.15				
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**	***Total***	**Total**	**Min**	**Max**
Unsuitable	0.44	3.48	14.3	63.7	66.35	70.36	*Unsuitable*	2182	0.44	164.67
Less suitable	0.07	1.56	2.73	13.69	9.94	16.5	*Less suitable*	171.8	0.07	16.5
Moderately suitable	0	0.78	0.57	2.03	1.81	4.47	*Moderately suitable*	31.8	0	4.47
Highly suitable	0	0.73	0.45	0.76	0.94	2.44	*Highly suitable*	17.22	0	2.46

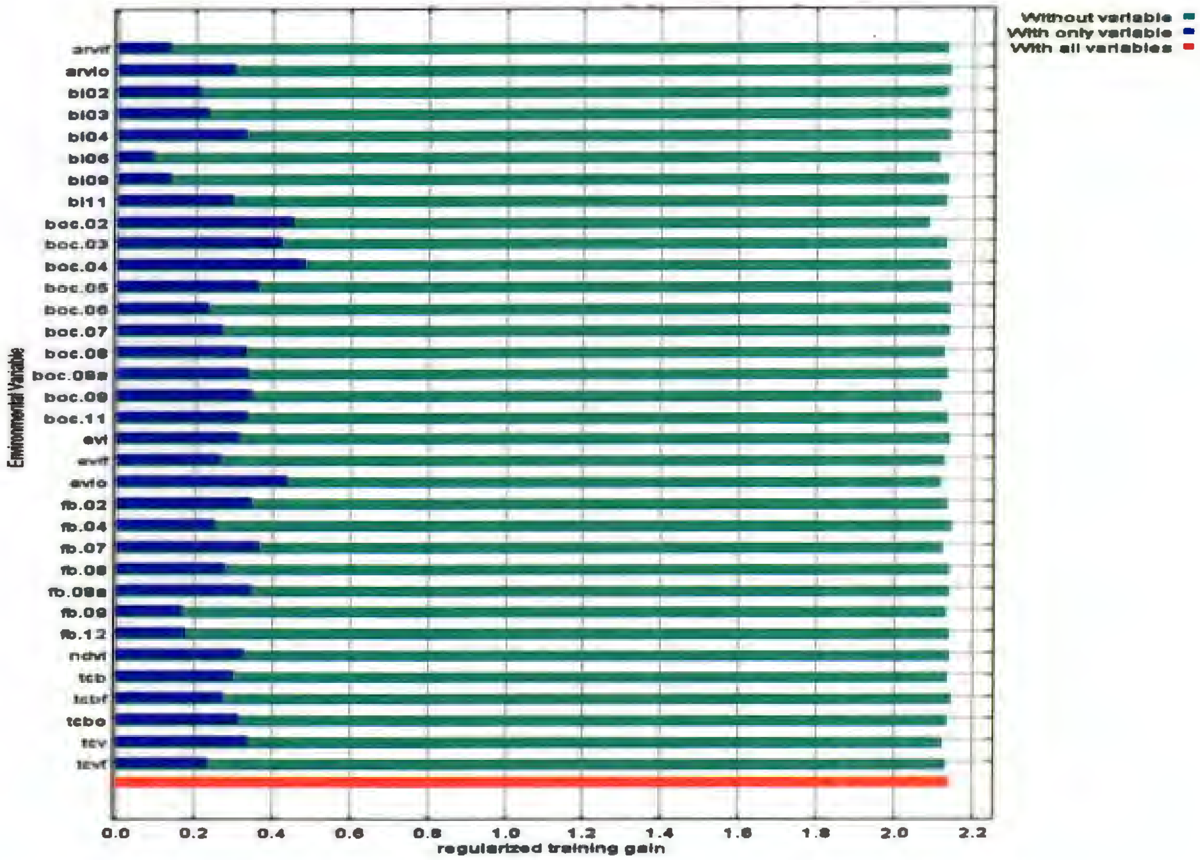
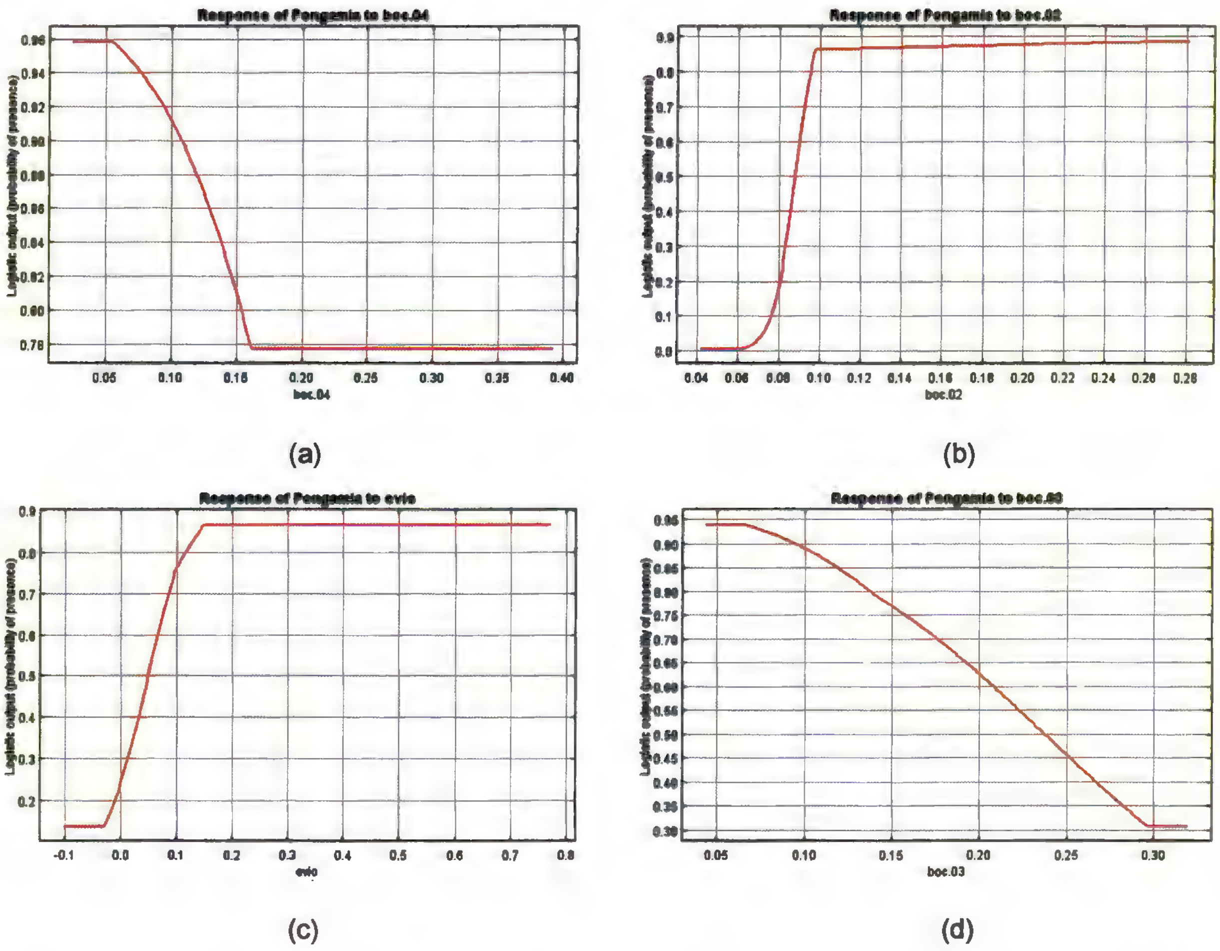


Figure 4. 33: Jackknife of regularized training gain for *Pongamia pinnata*

Response curves of important variables for *Pongamia pinnata*



(a) The variable with highest gain when used in isolation is boc.04 (band 4 of October image) shows negative correlation. (b) Band 2 of sentinel-2 is a blue colour band, boc.02 (band 2 of October image) is showing positive correlation. (c) The variable evio (Enhanced vegetation index_October) curve shows positive correlation with highest probability of presence at 0.15 threshold. (d) Response curve of variable boc.03 (band 3 of October image) shows negative correlation.

4.3.16 *Populus ciliate* (Populus)

It is deciduous flowering commonly occurring tree in urban Islamabad. Receiver operating characteristic (ROC) curve of accuracy assessment exhibit satisfactory results for *Populus ciliate* with 93 % accuracy (AUC= 0.93). The figure 4. 34 shows prediction of occurrence for *Populus ciliate* in the study area with different classes suitability range. Maximum prediction of occurrence can be seen along the water channels of the study area.

Predicted distribution of *Populus ciliata* with suitability classes (sector-wise)

Populus ciliata is predicted to be present on 107.4 hectare (4.4 percent of the tree class) with the highly suitable class. In assessed area and largest highly suitable cover of *Populus ciliata* is found in sector F-9 (11.49 hectare) and sectors F-10 (9.14 hectare), G-10 (8.4 hectare), H-8 (7.65 hectare) and G-8 (6.75 hectare) have significance populous covers with the same class. Table. 4. 17 shows that with moderately suitable class it covers 415 hectare (17 percent of the tree class), 1565 hectare (65 percent of tree class) with less suitable and 315.hectare (13 percent of total tree class) with unsuitable class.

Jackknife of regularized training gain for *Populus ciliate*

The environmental variable with highest gain when used in isolation *Populus ciliata* is ndvif (Normalized difference vegetation index_February), which therefore appears to have the most useful information and variable that decreases the gain the most when it is omitted is boc.08 the response graph of both is also given in figure 4. 35.

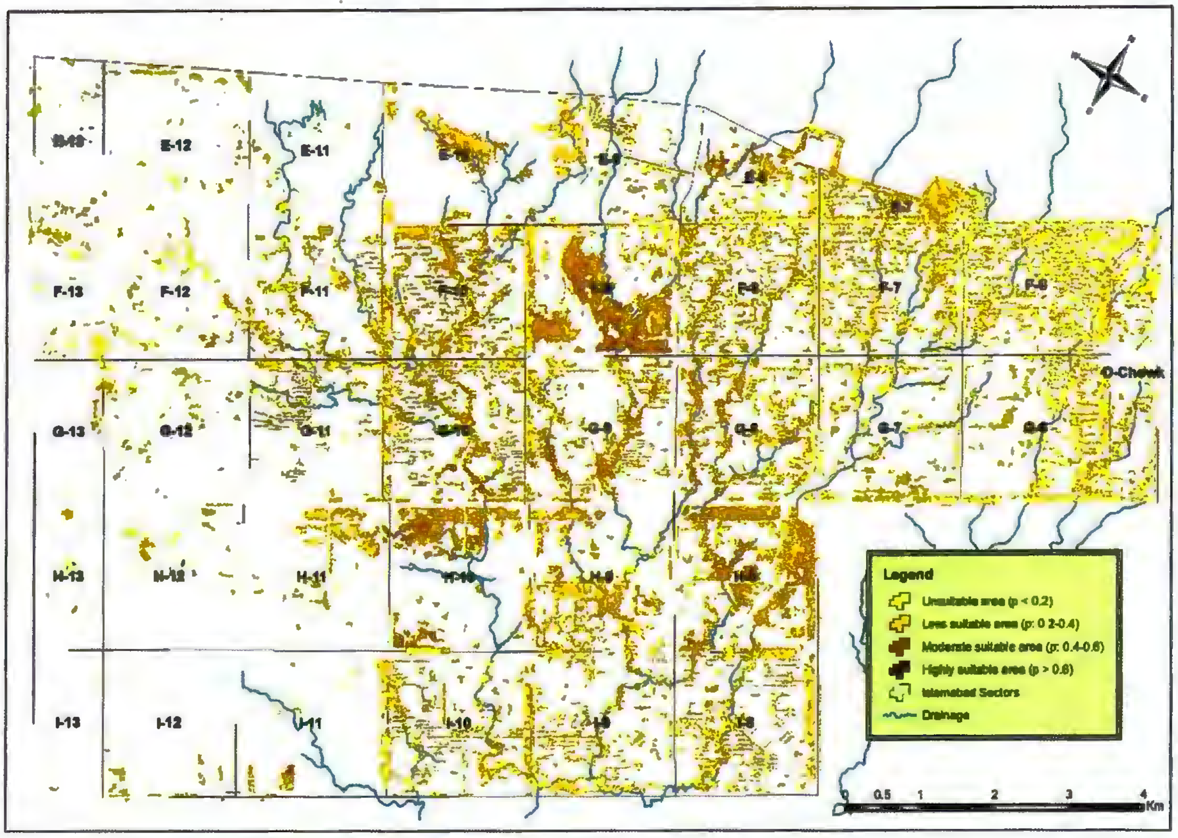


Figure 4. 34: Predicted probability of presence from MAXENT model for *Populus ciliate*

Table 4. 17: Suitability of *Populus ciliata* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7			
Unsuitable	1.41	1.81	0.82	1	5.96	7.86	13.83			
Less suitable	3.78	10.42	5.47	33.9	41.73	40.4	51.12			
Moderately suitable	1.78	2.5	1.81	7.17	8.12	11.41	7.31			
Highly suitable	0.29	0.34	0.49	0.45	2.55	4.37	1.74			
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**	
Unsuitable	3.47	7.48	5.29	8.71	9.32	11.38	24.44	50.24	16.64	
Less suitable	9.43	15.45	39.72	81.65	100.2	70.85	79.35	103.7	37.24	
Moderately suitable	1.27	4.5	12.17	26.33	45.88	19.57	14.59	15.17	6.31	
Highly suitable	0.22	0.84	4.16	9.14	11.49	6.3	3.48	3.73	2.21	
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**		
Unsuitable	0.35	3.57	4.59	8.09	6.89	13.3	16.97	27.96		
Less suitable	1.92	9.18	26.15	75.79	68.55	76.2	49.01	73.2		
Moderately suitable	0.92	3.11	10.23	26.76	24.06	22.68	8.16	9.79		
Highly suitable	0.2	0.71	4.33	8.4	6.69	6.75	1.71	1.93		
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**	***Suitability statistic***			
Unsuitable	0.86	1.78	1.59	1.57	7.58	11.26				
Less suitable	2.3	7.33	28.53	48.49	79.64	104.4	**Min:**	0.02		
Moderately suitable	0.4	1.14	6.34	24.32	16.09	35.47	**Max:**	104.4		
Highly suitable	0.06	0.2	0.94	4.11	2.93	7.65				
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**	***Total***	**Total**	**Min**	**Max**
Unsuitable	0.16	0.51	2.49	10.34	11.93	13.54	*Unsuitable*	315	0.16	50.24
Less suitable	0.2	4.53	12.27	55.12	54.72	62.82	*Less suitable*	1565	0.2	104.37
Moderately suitable	0.13	1.13	2.36	12.11	10.48	14.29	*Moderately suitable*	415.9	0.13	45.88
Highly suitable	0.02	0.38	0.93	2.61	1.91	3.12	*Highly suitable*	107.4	0.02	11.49

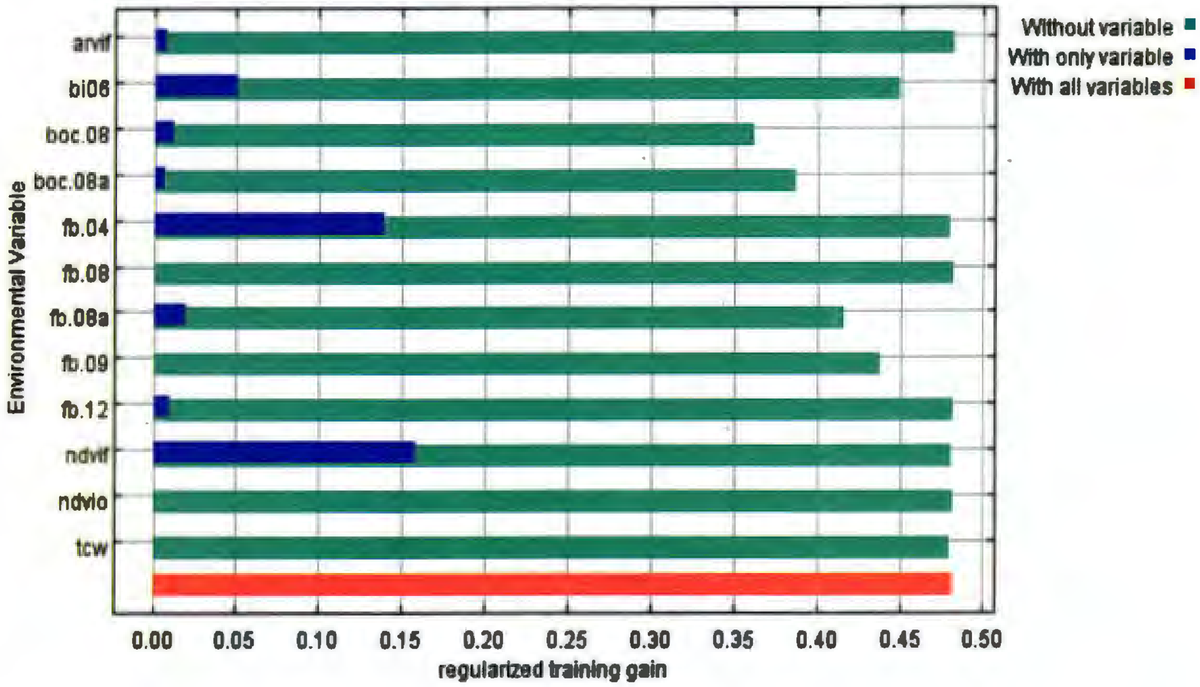
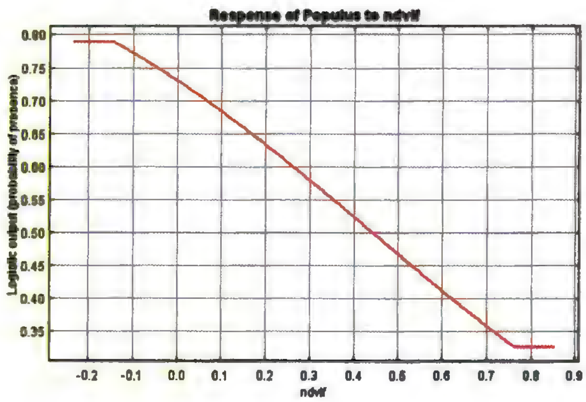
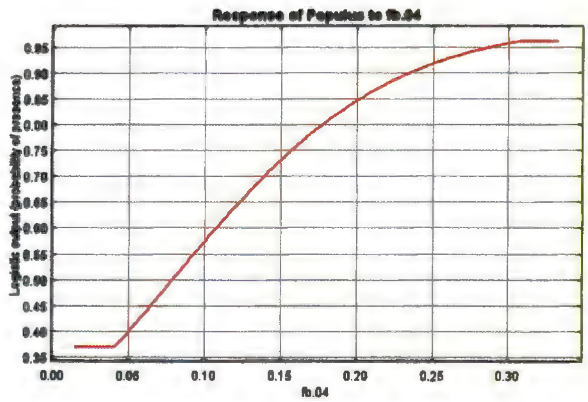


Figure 4. 35: Jackknife of regularized training gain for *Populus ciliata*

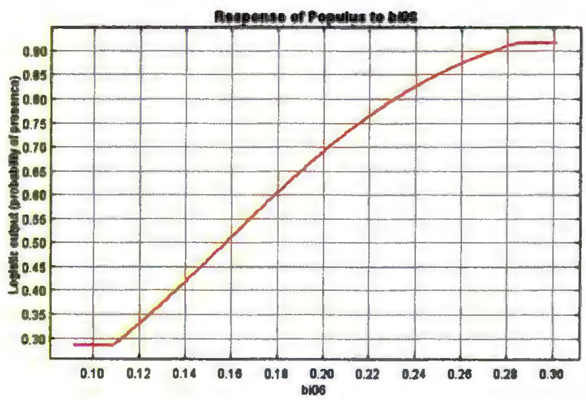
Response curves of important variables for *Populus ciliata*



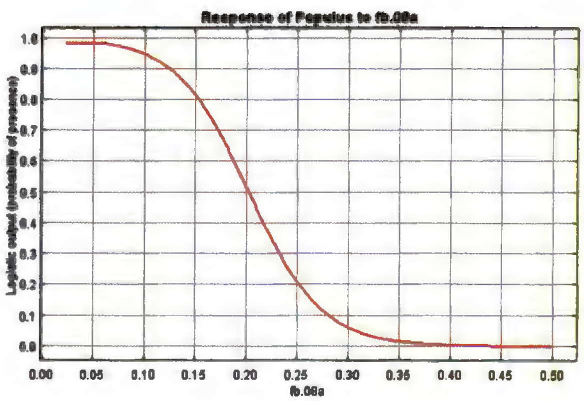
(a)



(b)



(c)



(d)

According to jackknife test the most important variable with maximum gain is ndvi (Normalized difference vegetation index_May). (a) Graph shows that ndvi (Normalized difference vegetation index_May) have negative correlation. (b) The variable fb.04 (band 4 of February month) shows positive correlation with highest probability of presence at 0.30 threshold. (c) the Variable bi06 (band 6 of May month) shows positive correlation. (d) Band fb.08a (band 8a of February month) shows negative response for *Populus ciliate.*

4.3.17 *Sapium sebiferum* (Chinese tallow-tree)

It is commonly called chinese tallow-tree, chinese tallow, florida aspen and candleberry tree (Bruce *et al.*, 1998) although the predicted cover with highly suitable class is very less but ROC curve of *Sapium sebiferum* shows 99 percent accuracy in the prediction of this tree, which makes this species as the most successful species to model. The figure 4. 36 shows the spatial distribution of *Sapium sebiferum*, it is sparsely spread in the study area.

Predicted distribution of *Sapium sebiferum* with suitability classes (sector-wise)

It is slightly distributed in various sectors. Its total area with high suitability is 6.29 hectare (<1 percent of the total tree class). Sector G-11 is predicted to have maximum cover of *Sapium sebiferum* with highly suitable class (0.61 hectare). other significant sectors include F-6 (0.55 hectare), F-8 (0.52 hectare) and F-10 (0.51 hectare). With moderately suitable class it covers about 9.89 hectare (<1 percent of the total tree class), with less suitable class 61.2 hectare (2.5 percent of the whole tree class) and 2326 hectare (96.7 percent) with unsuitable class (Table 4. 18).

Jackknife of regularized training gain for *Sapium sebiferum*

In Figure 4. 37, Jackknife test shows that the fb.05 (band 5 for February month) shows satisfactory results for identification of *Sapium sebiferum* as band 5 of Sentinel-2 is suitable for vegetation monitoring. Other variables with significant training gain include tcv (Tasseled cap vegetation_May), tcvo (Tasseled cap vegetation_October), arvif (Atmospherically resistant vegetation index_February) and laif (Leaf area index_February).

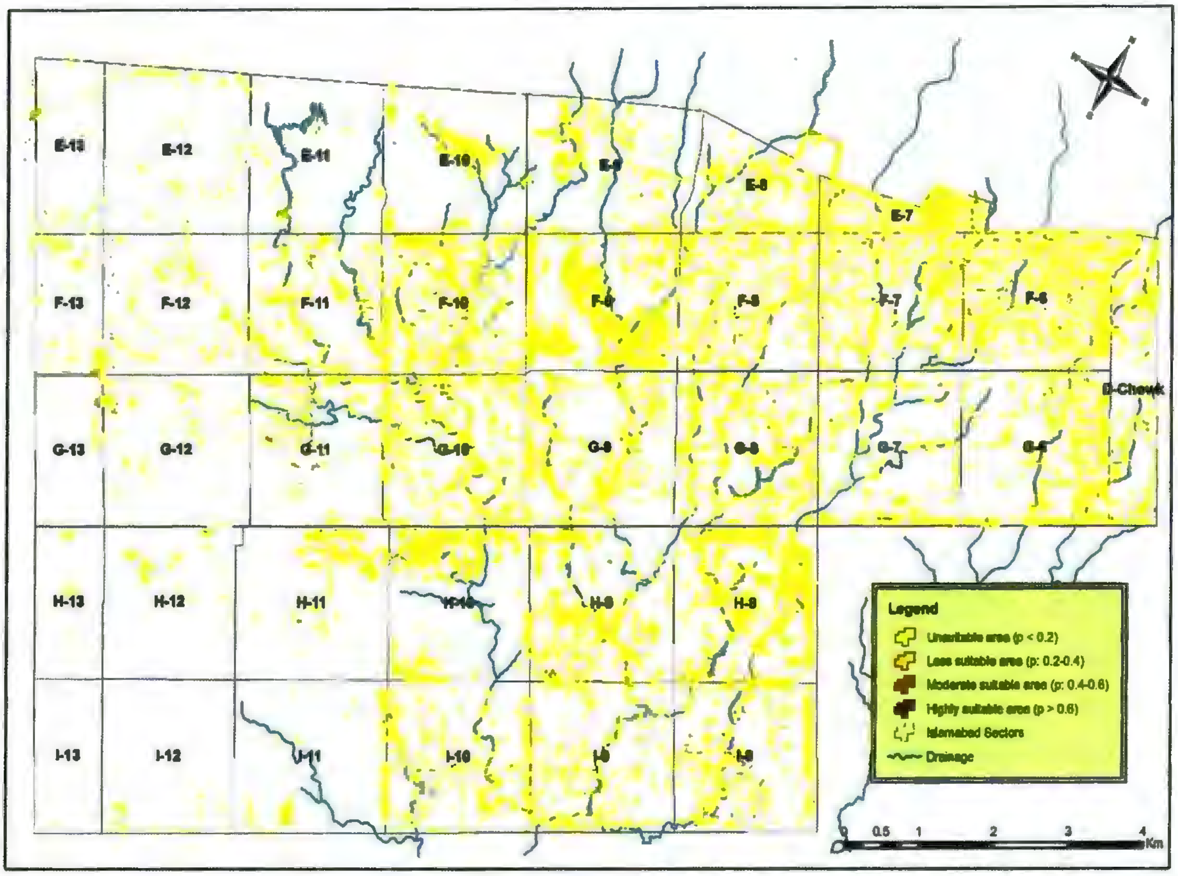


Figure 4. 36: Predicted probability of presence from MAXENT model for *Sapium sebiferum*

Table 4. 18: Suitability of *Sapium sebiferum* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7		
Unsuitable	6.95	14.33	8.03	42.4	57.36	62.56	72.76		
Less suitable	0.27	0.62	0.45	0.11	0.84	1.17	0.97		
Moderately suitable	0.04	0.04	0.07	0	0.12	0.2	0.18		
Highly suitable	0	0.08	0.04	0.01	0.04	0.11	0.09		
Suitability ↓ Sector →	**F-13**	**F-12**	**F-11**	**F-10**	**F-9**	**F-8**	**F-7**	**F-6**	**D-Chowk**
Unsuitable	14.36	28.14	58.06	120.5	164.6	102.3	117.14	167.4	59.52
Less suitable	0.03	0.13	2.55	4.11	1.47	4.48	3.63	4.19	1.95
Moderately suitable	0	0	0.41	0.69	0.45	0.76	0.66	0.76	0.49
Highly suitable	0	0	0.32	0.51	0.37	0.52	0.43	0.56	0.44
Suitability ↓ Sector →	**G-13**	**G-12**	**G-11**	**G-10**	**G-9**	**G-8**	**G-7**	**G-6**	
Unsuitable	3.36	16.27	40.41	115.4	102.6	116.1	71.99	109	
Less suitable	0.03	0.28	3.42	3.05	3.04	2.49	2.96	3.1	
Moderately suitable	0	0.02	0.86	0.45	0.39	0.25	0.48	0.52	
Highly suitable	0	0	0.61	0.1	0.13	0.12	0.42	0.25	
Suitability ↓ Sector →	**H-13**	**H-12**	**H-11**	**H-10**	**H-9**	**H-8**			
Unsuitable	3.45	10.11	36.65	77.85	104.1	156.2			
Less suitable	0.16	0.24	0.53	0.48	1.66	2.17			
Moderately suitable	0.01	0.02	0.12	0.13	0.24	0.28			
Highly suitable	0	0.08	0.1	0.03	0.2	0.09			
Suitability ↓ Sector →	**I-13**	**I-12**	**I-11**	**I-10**	**I-9**	**I-8**			
Unsuitable	0.5	6.22	17.69	77.35	76.19	87.64			
Less suitable	0.01	0.3	0.33	2.5	2.47	5.01			
Moderately suitable	0	0.03	0.02	0.26	0.28	0.66			
Highly suitable	0	0	0.01	0.07	0.1	0.46			

Suitability statistic	
Min:	0
Max:	167.4

Total	Total	Min	Max
Unsuitable	2326	0.5	167.36
Less suitable	61.2	0.01	5.01
Moderately suitable	9.89	0	0.86
Highly suitable	6.29	0	0.61

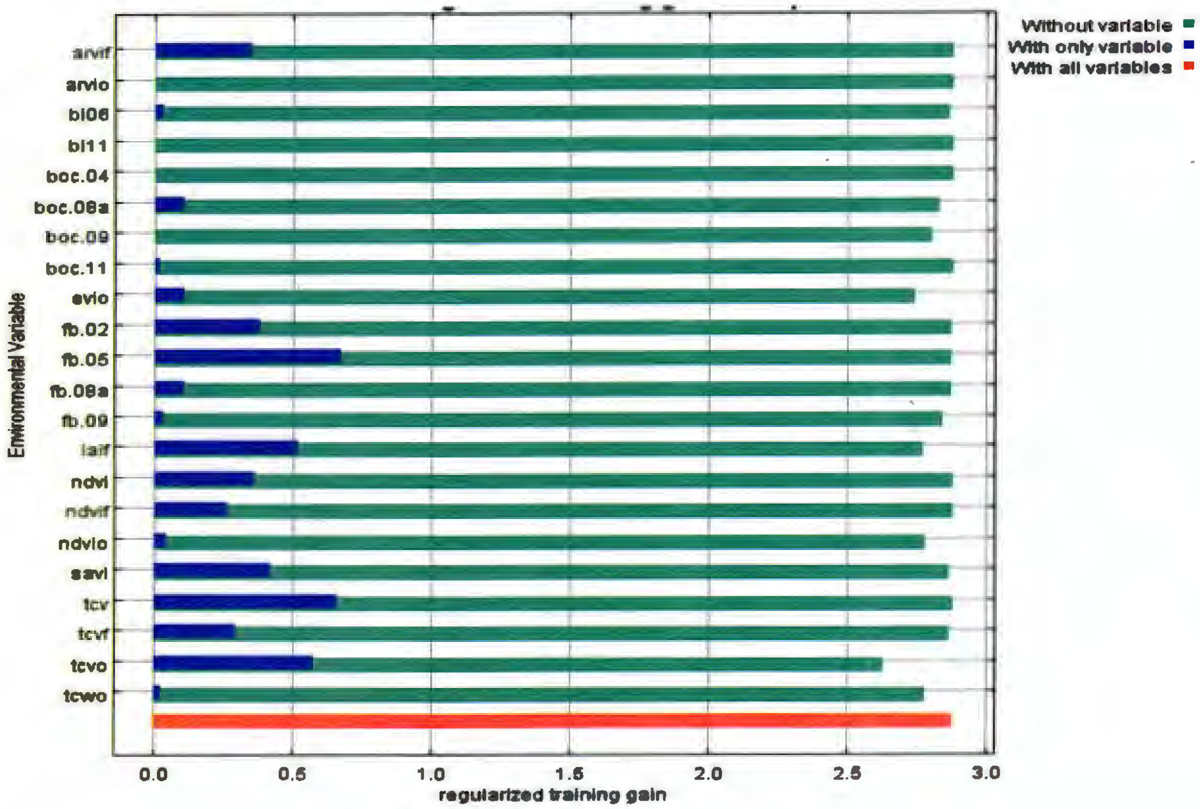
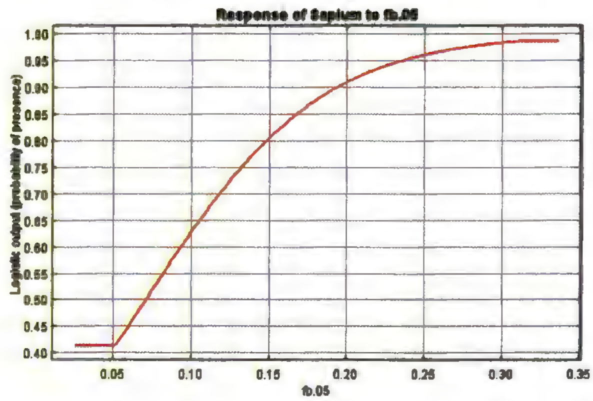
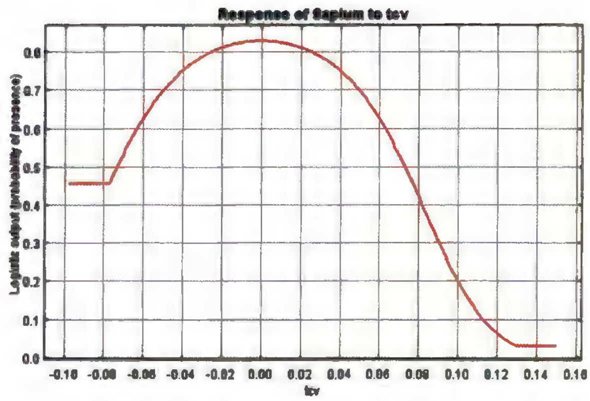


Figure 4. 37: Jackknife of regularized training gain for *Sapium sebiferum*

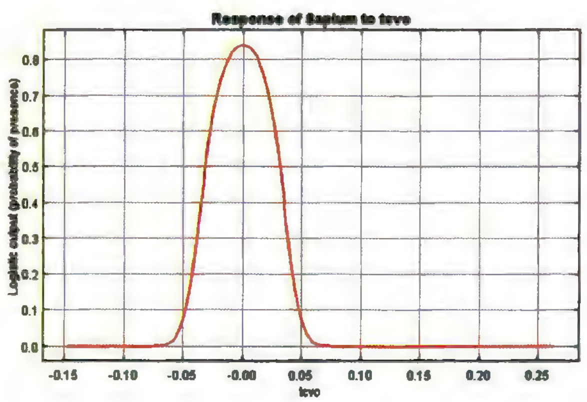
Response curves of important variables for *Sapium sebiferum*



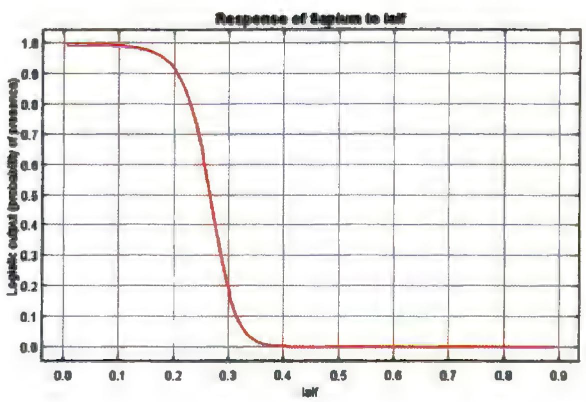
(a)



(b)



(c)



(d)

The above curves show that how variables respond to *Sapium sebiferum.* Response curve (a) shows the response of variable fb.05 (band 5 of February image) have positive correlation and maximum probability at 0.30 threshold. (b) The variable tcv (tasseled cap vegetation of May image) shows the negative correlation. (c) Variable tcvo (Tasseled cap vegetation_October) have maximum prediction at 0.00 threshold. (d) The predictive variable laif (leaf area index of February image) shows negative correlation.

4.3.18 *Terminalia arjuna* (Arjun tree)

Terminalia arjuna is eatable nut bearing tropical tree, are inclined to leaf twist when developed in territories where their actually broad root system is limited or where the soil needs basic nutrients and trace elements. Dark colour show the highest probability of prediction of *Terminalia arjuna* in study area (Figure 4. 38).

Predicted distribution of *Terminalia arjuna* with suitability classes (sector-wise)

Table 4. 19 shows that *Terminalia arjuna* is predicted with highly suitable class on 64.67 hectare (2.69 percent of the total tree class) area. Sector E-8 is having maximum 12.68 hectare with the highly suitable prediction. Also, sector F-9 (6.49 hectare), E-7 (4.69 hectare) and F-6 (3.43 hectare) have significant land cover with highly suitable class. With moderately suitable class it is predicted to be present on 1204 hectare (47.1 percent of the total tree class). While, with less suitable class it is spread over 1134 hectare (50.1 percent of the total tree class).

Jackknife of regularized training gain for *Terminalia arjuna*

Jackknife test for *Terminalia arjuna* shows some important variable which are fb.08 (band 08 of February image) and fb.09 (band 09 of February image) show highest gain when used in isolation. The variables bio8a (band 08a of October image) contribute 12.9 percent but show no gain. Band 02 of sentinel-2 is highly suitable band for vegetation detection but fb.02 (band 02 of February image) does not show any gain in the test (Figure 4. 39).

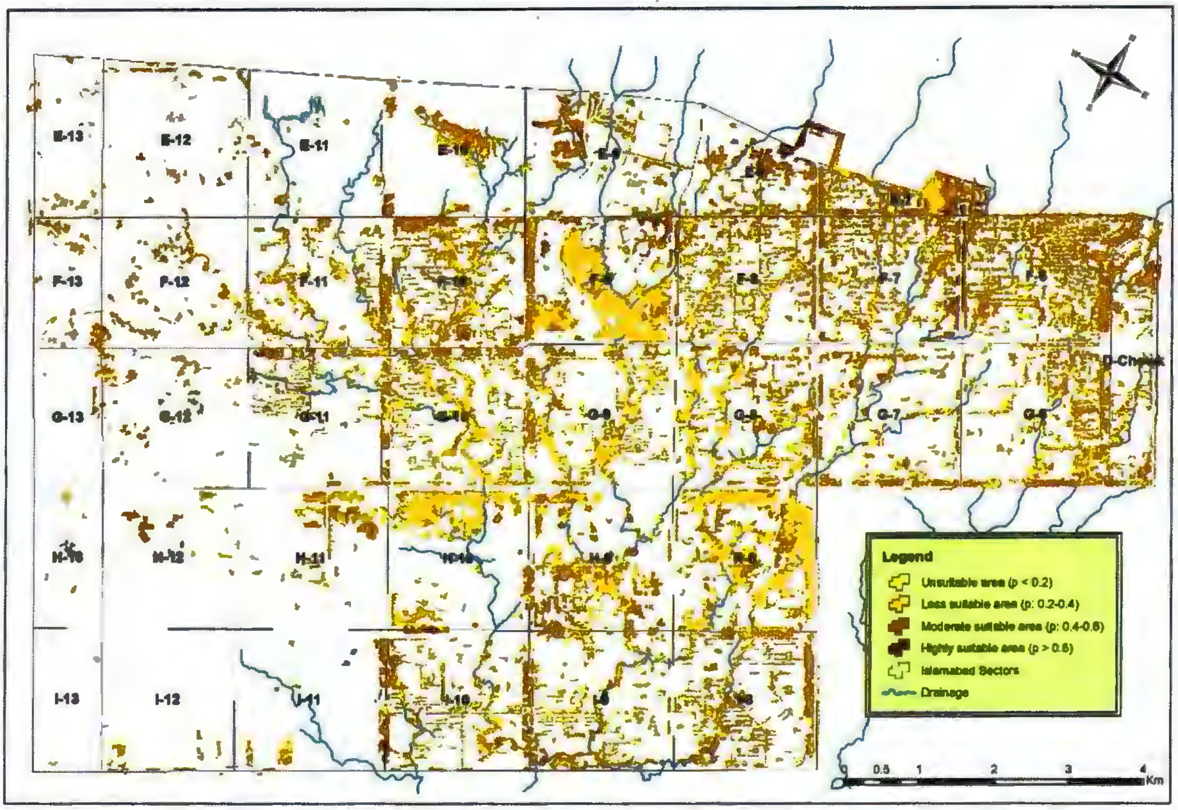


Figure 4. 38: Predicted probability of presence from MAXENT model for *Terminalia arjuna*

Table 4. 19: Suitability of *Terminalia arjuna* in the study area (hectare)

Suitability ↓ Sector →	E-13	E-12	E-11	E-10	E-9	E-8	E-7
Unsuitable	0	0	0	0	0	0	0
Less suitable	0.83	0.83	2.13	16.18	9.82	9.21	24.59
Moderately suitable	5.95	12.04	6.08	25.52	45.64	42.15	44.72
Highly suitable	0.48	2.2	0.38	0.82	2.9	12.68	4.69

Suitability ↓ Sector →	F-13	F-12	F-11	F-10	F-9	F-8	F-7	F-6	D-Chowk
Unsuitable	0	0	0	0	0	0	0	0	0
Less suitable	1.99	5.04	27.15	57.61	113.4	48.29	41.84	60.41	22.06
Moderately suitable	11.89	19.66	33.97	67.02	46.96	59.34	77	109	39.04
Highly suitable	0.51	3.57	0.22	1.2	6.49	0.47	3.02	3.43	1.3

Suitability ↓ Sector →	G-13	G-12	G-11	G-10	G-9	G-8	G-7	G-6
Unsuitable	0	0	0	0	0	0	0	0
Less suitable	0.63	2.76	15.45	75.76	70.36	73.53	32.38	55.24
Moderately suitable	2.71	12.48	28.38	43.13	35.66	44.51	42.38	56.83
Highly suitable	0.05	1.33	1.47	0.15	0.17	0.89	1.09	0.81

Suitability ↓ Sector →	H-13	H-12	H-11	H-10	H-9	H-8
Unsuitable	0	0	0	0	0	0
Less suitable	0.66	2.33	19.42	63.72	54.77	121.7
Moderately suitable	2.03	6.52	17.51	14.06	49.85	36.68
Highly suitable	0.93	1.6	0.47	0.71	1.62	0.38

Suitability statistic	
Min:	0
Max:	121.7

Suitability ↓ Sector →	I-13	I-12	I-11	I-10	I-9	I-8
Unsuitable	0	0	0	0	0	0
Less suitable	0.19	1.68	5.19	30.02	34.79	31.96
Moderately suitable	0.3	4.5	10.65	46.66	42.47	61.08
Highly suitable	0.02	0.37	2.21	3.5	1.78	0.76

Total	Total	Min	Max
Unsuitable	0	0	0
Less suitable	1134	0.19	121.69
Moderately suitable	1204	0.3	109.03
Highly suitable	64.67	0.02	12.68

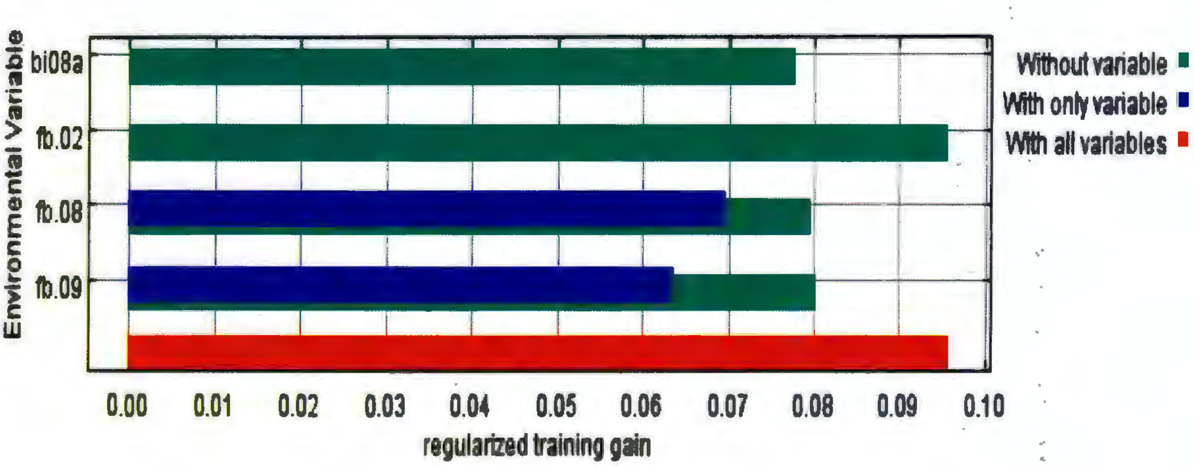
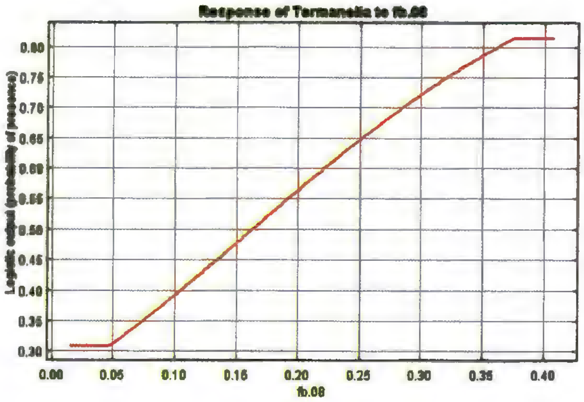
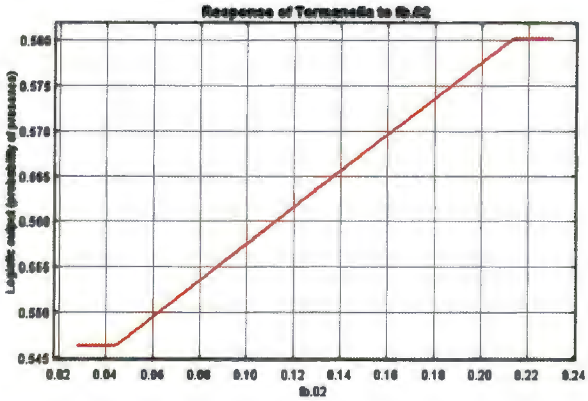


Figure 4. 39: Jackknife of regularized training gain for *Terminalia arjuna*

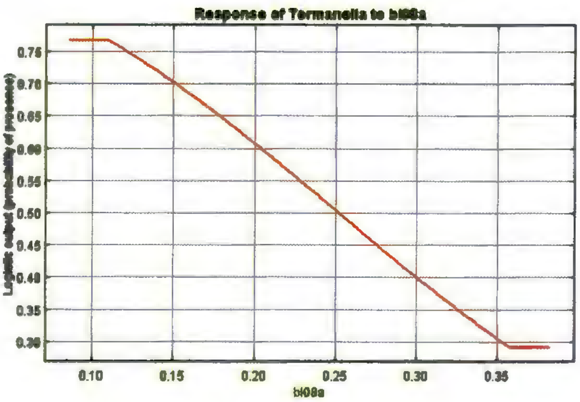
Response curves of important variables for *Terminalia arjuna*



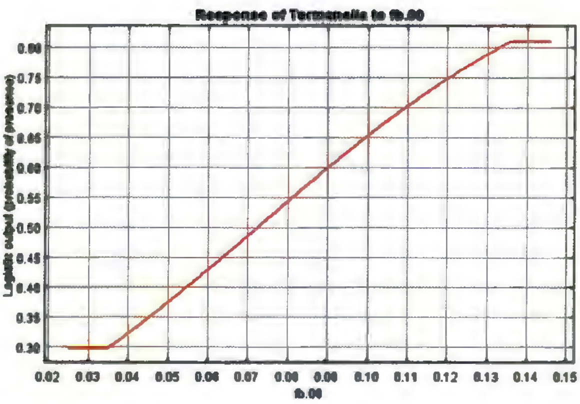
(a)



(b)



(c)



(d)

(a) The variable fb.08 (band 08 of February) have highest gain about 0.07 and shows positive correlation with highest probability of presence at 0.37 threshold. (b) The second most contributing variable is fb.02 (band 02 of February) also shows positive correlation. (c) Variable bi08a (band 08a of May) shows negative correlation in above graph. (d) Variable fb.09 (band 9 of February image) is also showing positive correlation with highest probability at 0.13 threshold.

4.4 Species-wise largest sectors

According to the results of probability of presence of different species, it is assessed that with different classes of suitability species distribution varies in different sectors. For example, *Acacia sp.* with highly suitable and moderately suitable class dominantly found in sector H-8. While, with less and unsuitable class sector F-6 shows dominant cover of *Acacia sp.*

Further detail of each species is given below (Table 4. 20)

Table 4. 20: Sectoral wise distribution of tree species with suitability classes

Sr #	Species name	Maximum tree cover			
		Highly Suitable	Moderately Suitable	Less suitable	Unsuitable
1	*Acacia sp.*	H-8	H-8	F-6	F-6
2	*Albizia lebbeck*	F-6	F-6	H-8	F-9
3	*Alstonia scholaris*	I-9	I-9	I-9	F-9
4	*Bischofia javanica*	F-6	F-6	F-6	F-9
5	*Broussonetia papyrifera*	H-8	H-8	H-8	F-9
6	*Callistemon citrinus*	I-9	I-9	F-6	F-9
7	*Cedrela serrata*	I-9	G-6	G-6	F-9
8	*Celtis australis*	F-6	F-6	F-6	F-9
9	*Citharexylum spinosum*	I-9	G-6	G-6	F-9
10	*Dalbergia sissoo*	G-10	F-10	F-10	F-6
11	*Eucalyptus camaldulensis*	F-6	F-6	F-6	F-9
12	*Ficus elastica*	I-9	H-8	F-9	F-12
13	*Jackaranda mimosifolia*	G-6	F-6	H-8	F-9
14	*Pinus roxburghii*	F-6	F-6	F-6	F-9
15	*Pongamia pinnata*	G-11	I-8	I-8	F-9
16	*Populus ciliate*	F-9	F-9	H-8	F-6
17	*Sapium sebiferum*	G-11	G-11	I-8	F-6
18	*Terminalia arjuna*	E-8	F-6	H-8	

4.5 Discussion

The study deals with the characterization of vegetation of urban Islamabad by using machine learning methods. Remote sensing data are widely used in the literature for landuse/landcover and tree species general. Multiple types of remotely sensed data, including multispectral, hyperspectral, and LiDAR data, have been used in recent studies (Xie *et al.*, 2008). Hyperspectral and hyper spatial imagery is now facilitating and serving the mapping of tree species spatial distribution modeling (Culvenor, 2002).

To classify the landcover of urban areas of Islamabad by using recent images of Sentinel-2 data, the landcover of different sectors was calculated with almost more than 91 percent accuracy. In previous studies land covers and tree species classification were carried out in different parts of the World. Recently, (Immitzer, *et al.*, 2016) used sentinel-2 imagery, to derive different crop type and tree species maps were analyzed in Austria and Germany for forests studied. In both case studies, only single cloud-free Sentinel-2 imagery of August 2015 was used. By using mono-temporal datasets, they applied a random forest classifier with 10 spectral bands of Sentinel-2 resampled to 10 m resolution. The achieved classification results were satisfactory but not extremely high.

Different machine learning methods including support vector machines (SVM) and random forests were used, but the results of RF were more satisfactory, because it can deal with the issues related to classification like unbalanced, multi-class and small sample data without data preprocessing procedures (Liu *et al.*, 2013). So, in present study Random forest classification method was used for multi seasonal/temporal data to reduce the out-of-bog (OOB) error and to improve the accuracy. It was successful in achieving the satisfactory result.

The accurate classification of land cover and tree species distribution in urban areas is an important task as it can drive the exploitation and management policies of forests. Furthermore, it is concluded by the maximum entropy result for species prediction of occurrence that the species diversity decreased from open green areas to residential areas along drains route. It is the result of construction and development activities at residential sites (Ali & Malik, 2010).

Techniques used for the predicting spatial distribution by combining presence only data occurrence records with climatic or environmental variables show much potential for application across a range of biogeographical analyses. In Madagascar, (Pearson *et al.*, 2007) evaluated two different models for 13 species of secretive leaf-tailed geckos that were endemic, for which available sample sizes vary from only 4 to 23 occurrence records. 20 different environmental layers were used by two modelling approaches: maximum entropy (MAXENT) and a genetic algorithm (GARP). According to statistical significance in jackknife tests they assessed that the MAXENT model was more successful with small sample size (only five samples). So, MAXENT model was used to predict the maximum entropy regarding individual tree species. Species prediction about their occurrence was calculated at different level of suitability.

Receiver operating characteristic (ROC) show the range of accuracy for different species, the area-under-curve (AUC) varies from 83 to 99 percent. Species like *Bischofia javanica, Citharexylum spinosum, Cedrela serrata and Sapium sebiferum* shows 99 percent accuracy, while, species like *Terminalia arjuna* showed 83 percent accuracy. It is assessed that with different classes of suitability species spatial distribution varies in different sectors.

Conclusion

The current study noted that Sentinel-2 data provides a great opportunity for global landcover and vegetation monitoring due to its enhanced spatial, spectral and temporal characteristics. The use of multi-temporal Sentinel-2 data and resampling of low spectral bands of sentinel-2 have potential to produce better classification results.

The landcover classes extracted by random forest classification of Sentinel-2 data were compared by the OOB estimation. It has been observed that combined images of seasonal variation produce more accurate results. It is concluded, that urban build up makes up the largest class with 40 percent of the land cover followed by Grass/weed (25percent), trees (20 percent), agricultural land (11 percent) and shrubs/scattered trees class (3 percent) in the study area.

The results of this study are vital for the governmental organizations, non-governmental organizations (NGO's), stakeholders and the general public in order to be able to respond faster and pinpoint the problem faced by urban community of Islamabad, primarily with regards to environmental degradation as landcover classification shows alarming condition in some sectors. The problem here is not only with Islamabad's vegetation alone, but all other major cities of the country as well.

Based on the results and analysis of the landcover classes (tree) data the prediction of different tree species was carried out by using MAXENT model. Species prediction of occurrence was calculated by different levels of suitability (unsuitable, less suitable, moderately suitable and highly suitable) shows good accuracy, receiving operating characteristics (ROC) shows that the finds accuracy varies from 83 percent to 99 percent. Species like *Bischofia javanica, Citharexylum spinosum* and *Cedrell serrata* show maximum (99 percent) accuracy.

The results of species prediction of occurrence assessed *Acacia sp.* as the most abundant species with 275 hectare landcover, *Albizia lebbeck* is the second most occurring species with 243 hectare cover of the study area and third largest predicted species is *Broussonetia papyrifera,* which is predicted to be present on 195 hectare of urban Islamabad.

Recommendations

The following recommendations can be made

- Present study can be used for monitoring the landcover and urbanization pattern of Islamabad.
- For further research multi-temporal Sentinel-2 data can be used for a large study area.
- Findings of this research can be used as a support for the sustainable development.

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