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Climate suitability evaluation for Poplar in Uttarakhand using GIS application

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ABSTRACT

The objective of this study was to evaluate the suitability of climate for poplar in Uttarakhand. The study area located between latitude 28º43'N and 31º27'N and longitude 77º34'E and 81º02'E. and covers approximately 53,485 sq km. The identified theme layers include temperature (maximum, minimum and average temperature), precipitation and soil properties. Those thematic layers with their associated attribute data were encoded in GIS database. Overlay operation was performed on those layers as the suitability model assigned. The model was a result of the crop requirement analysis. Models were applied to the overlay process and to formulate the suitability classes. The result indicated that 41.8%, 26.4%, 10.7%, 1.6% and 19.5% area of the total geographical area of the state, the most suitable, suitable, moderate suitable and less suitable, respectively for poplar plantation. On the basis of the results, it can be recommended that poplar can be grown on the larger area of Uttarakhand state, especially the wastelands can be utilized for cultivation of poplar which will not only be beneficial for socio-economic point of view but also sequester the carbon from the atmosphere.

Key words: Poplar, climate suitability, GIS

Poplar species occupy a unique and important position in the rural economy of India. They are known for their fast growth, easy vegetative propagation, capability to enrich surface soil by adding leaf litter and the ability to provide substantial production (10-30 $m^3ha^{-1}yr^{-1}$) on a short rotation of 6 to 12 years. The tree crown intercept rains, acts as wind breaks and thus checks soil erosion and minimizes the effects of wind on associated crops. Poplar species in India are winter deciduous and remain leafless for 3-4 months, thereby favouring intercultivation of agricultural crops throughout the rotation (Naithani *et al*. 2001). There are 35 species of poplar currently recognised in the world. Poplar is widely planted above 28 degree N latitude in India. Fast growth rate of poplar, high financial return and multiple utility, have become a very important species for cultivation both in the forest and farms. Poplar wood is widely used in plywood and match splints. Market has been developed for poplar in Haryana, Punjab and Uttar Pradesh (Naithani *et al*. 2001).

Geo-informatic technology which at present embodies geographic information system (GIS), remote sensing (RS) and global positioning system (GPS) has been further developed to provide greater efficiency. In particular, GIS has been used extensively for spatial analysis and land suitability as GIS functions could be employed for several forms of information including point, line and area. The system, therefore, possesses greater storage capacity for spatial information processed with identical standard. GIS also provides greater reliability with lesser time and cost compared with manual operation (Bera *et al.,* 2003). The geospatial technology can be very efficiently used in analyzing the suitability of agricultural crops, which will not only save the huge cost of experimentation but also save precious time (Harashah, 1994). Several attempts have been done for suitability classification (Al-Mashreki *et al.* 2011; WeiGuang *et al.* 2010; Ekanayake *et al.* 2003, Bhagat *et al*. 2009). Keeping this in view this study aimed to use GIS to classify the suitability of land with integrated information for poplar plantation. The spatial information resulted from this study could be utilized the wastelands for plantation which not only help to increased income of villages but also minimize environmental problems.

MATERIALS AND METHODS

The area of present study has been considered the state of Uttarakhand which is surrounded by Himachal Pradesh in the north-west and Uttar Pradesh in the south and shares its international borders with Nepal and China. This area is located between latitude 28º43'N and 31º27'N

Table 1: Table of PDI with suitability classes

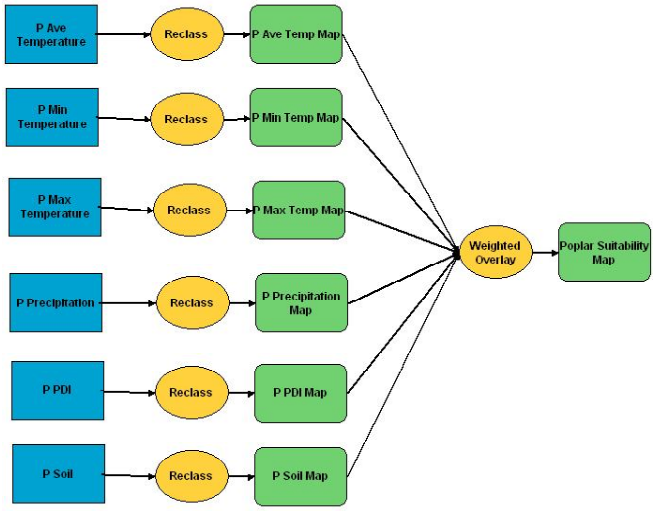
S.No.	PDI range (>0.3)	Suitability class
1	0.33-0.55	Less suitable
2	0.55-0.75	Moderately suitable
3	0.75-0.98	More suitable

Table 2: Weightage percentage given to the parameters

S. No.	Input Theme	% Info
1	Average temperature	40
2	Minimum temperature	5
3	Precipitation	20
4	PDI	25
5	Soil texture	10

and longitude 77º34'E and 81º02'E. The different geo-physical and climatic parameters viz., precipitation and temperature, topographic (elevation) and soil type were used for identifying suitable areas for poplar. The soil information and maps of the region were acquired from NBSSLUP, Nagpur. The climatic data of some meteorological stations were down loaded from the website, while some other stations data were taken from published IMD periodicals. The data of all weather stations falling within the geographical boundaries of Uttarakhand were collected. Additionally the data of meteorological observatories of adjoining states/ nations close to Uttarakhand were also used in the present study. For this study the optimum climatic requirement (*i.e.* maximum, minimum and optimum temperature, rainfall) and soil type for fast growing tree species are essential. This information was collected with the help of many publish data and literatures.

The methodology of suitability analysis included the digitization of the map. The soil unit boundaries of the map were digitized very carefully using the polygon feature. Then the soil attribute data were added to the project. The layers of different meteorological parameters were generated using the spatial analyst Extension of ARC-view. DEM provides a digital representation of a portion of the earth's surface terrain over a two dimensional surface (UNEP/GRID). The DEM was used for constructing temperature surfaces keeping in view the environmental lapse rate. The environmental lapse rate which describes that with increasing elevation by 1 km the temperature will decrease by 6-5ºC was used to correct the interpolated temperature surface using following equation.



Model 1: Poplar suitability model

T corrected = T interpolated- Elevation difference 0.0065*

Here, T corrected and T interpolated in °C and Elevation difference in m.

The precipitation distribution index (PDI) was calculated with the help of following formula (Nain *et al.*, 2010):

$$PDI = \frac{\Sigma\,(Months\ with\ value\ 1)}{12}$$

Where,

PDI = Precipitation distribution index

1 = the value of a particular month when the ration between P/PET is >0.3, the value of month is 0 when the ratio between P/PET is < 0

P = Precipitation (mm)

PET= Potential evapotranspiration (mm)

PET was calculated by using Thornthwaite (1945) method.

The PDI was computed on point data and later the spatial surface covering entire state of Uttarakhand was generated using inverse distance weightage (IDW) interpolation techniques enbeded in Arcview 3.2a. PDI surface was divided in 3 classes, which are more suitable, moderate suitable and less suitable (Table 1). If PDI value is high then it suitable for planting and if it is low then less suitable. Suitability model was developed using model builder module available in Arc-View 3.2a GIS. The interpolated data related to climate and soil is added in raster format. The reclass function is added and reclasses of data was done. Then all these reclass data were combined to the weighted overlay function and a weighted overlay map or suitability map model is developed. After model

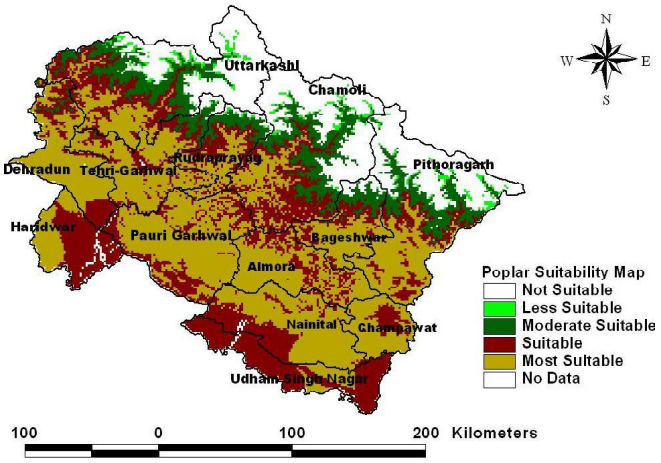


Fig. 1: Suitability map of Poplar

was run and suitability map were obtained. Weighted given to the different parameters are shown below (Table 2) on the basis of their effect on growth of tree. A suitability map with 5 classes: most suitable, suitable, moderately suitable, less suitable and not suitable was generated and most suitable class was found when all parameters weightage values are highest and other classes, classified on basis of descending weightage value.

RESULT AND DISCUSSIONS

Suitable areas for plantation of poplar were delineated by integrating various spatial information files (maximum, minimum and average temperature, PDI and soil types). The parameters are describing the specific requirements i.e. elevation, rainfall, temperature and soil type for poplar under study. Poplar requires rainfall ranging from 1000-1400mm, thrives best at temperature 15–25°C in clay loam or loamy soils. The potential land suitable areas for plantation of poplar have been worked out. The quantification of the area was based on the model builder module, which concerning the range of different parameters. The output (thematic maps) produced varying degree of suitability in terms of spatial maps presented in Figs. 1.

There is a high correspondence between climatic conditions of the area and the climatic requirements of poplar, *e.g.* temperature (optimum, maximum, minimum) elevation, annual rainfall and soil types in these regions are similar to the poplar requirement *i.e.* 15-25ºC, 600-3000m, 1000-1400mm and loamy clay, respectively. The most suitable category occupied the most of the area of studies having total area of 22346 km^2 or 41.8% of total geographical area of the study area. Most of central part of the state comes under this suitability class.

Although there is medium correspondence between climatic conditions and requirements of poplar in these areas compared to the first zone, *e.g.* temperature is not exactly in the optimum range of the temperature (15-25 ºC) required for poplar. There are some restrictions with minimum temperature. In these areas compared to the first zone. However, still occupies a considerable area of Uttarakhand. It covered 26.4% of the total geographical area of state.

A considerable region of the state has been classified as moderately suitable because more restriction was in passed by temperature and soil parameter on poplar plantation. This type of suitability class occupied the 10.7% of the total geographical area of the state. This class includes lower and middle Himalayan hilly regions.

There are more restriction in climatic conditions (optimum, maximum and minimum temperature) and soil requirement of poplar plantation. This zone is less suitable for poplar growth. The area 840 km^2 (1.6%) includes mostly upper hilly part of the study area.

The area of this suitability class was regarded as unsuitable for Poplar plantation. There are severe restrictions due to climatic parameters and soil types. The zone includes upper skeleton soil surface and the temperature of study area, which is 10453 km^2 or 19.5% of total area.

Poplar suitability map shows the mostly central part of state is most suitable, lower part suitable, lower and middle Himalayan hilly region moderate suitable and less suitable zone of the state. The map shows some temperate areas come under the suitable and moderate suitable zone. Though, the optimum climatic and soil requirements are present in the central part of the state, but it is possible that poplar species are not found in this region owing to the fact that mostly in central and upper part of state the vegetation is natural, and poplar is not found in natural forests as it is an exotic species in India. The farmers of this region have not also included poplar in the agro-forestry system. However, given some incentices and traning/demonstration, this species could be easily popularized in this region and can prove to be remunerative. Poplar has 25 to 30 species favouring various set of climatic conditions (like maximum temperature, minimum temperature, optimum temperature, precipitation and elevation), so the farmers

can choose any species for plantation at particular place depending upon the soil and climatic condition. Less suitable area cannot be not used for planting because there will be severe restrictions for growth of tree.

CONCLUSION

This study demonstrates an attempt to use the available spatial information for the identification of suitable areas for poplar plantations in Uttarakhand. According to the results of the study 41.8%, 26.4%, 10.7%, 1.6% and 19.5% of the total geographical area are classified as most suitable, suitable, moderate suitable, less suitable and not suitable respectively for poplar. On the basis of the suitability map; the wastelands can be used for poplar plantation. It will be not only beneficial for socio-economic point of view but also enhance the carbon sequestration potential of the land.

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