



## Review article

# Predicting suitability of tree species in various climatic conditions

Sharad Tiwari<sup>1</sup> and Rajesh Kumar Mishra<sup>2\*</sup>

<sup>1</sup>Institute of Forest Productivity, Lalgutwa, Ranchi, Jharkhand

<sup>2</sup>Tropical Forest Research Institute, P.O. RFRC, Mandla Road, Jabalpur, Madhya Pradesh

\*Corresponding Author: [rajeshkmishra20@gmail.com](mailto:rajeshkmishra20@gmail.com)

[Accepted: 04 February 2016]

**Abstract:** Climate is a key factor shaping the forest environment; thus changes in the climate are likely to strongly affect forest ecosystems by altering the physiology, growth, mortality and reproduction of trees, the interactions between trees and pathogens, and ultimately the disturbance regimes (winds, wildfires, insect attacks, etc.). The sensitivity to such changes depends on the level that is considered (landscapes vs. forest, stands vs. single trees) and on the specific site conditions. These complex influences indicate that a changing climate may lead to non-linear responses, tipping points, etc., particularly since the longevity of trees implies that many individuals present today will experience substantial changes of the climate before they will be replaced by the next generation. Thus, the question arises to what degree current trees and forest ecosystems are able to cope with a changing climate. In the present work a user-friendly package “PLANTPAK” has been developed and tested successfully to evaluate the climatic suitability of forestry species in central Indian region. The package can be used to store, retrieve and display information based on simple key strokes. The package provides query on textual as well as map basis. The package is tested with 15 data records and all the features including data entry, information retrieval based on species name, location wise, climatic as well as edaphic fields are working properly. Further the package is also successfully tested for providing map based retrieval of information of suitable species.

**Keywords:** Forest ecosystem - Central India - Climatic suitability - PLANTPAK.

[Cite as: Tiwari S & Mishra RK (2016) Predicting suitability of tree species in various climatic conditions. *Tropical Plant Research* 3(1): 18–32]

## INTRODUCTION

The world's rapidly rising population requires most countries to make the best possible use of their land resources for agriculture, horticulture, forestry and conservation. Being able to predict where and how well particular plants are likely to grow in different regions is vital for land use planning. Linking GIS and modules can help to answer these questions, but decision makers and researchers in developing countries have limited access to these technologies. Climate has an important influence on tree growth it is particularly useful as a means to predict where particular tree will grow, as mean climatic condition can now be reliably estimated for most locations around the world. Being able to identify where particular trees (or plants) will grow is useful, but many people need to know how well they will grow on particular sites. Generally they do not require highly precise predictions of yield, but they do need to know whether growth will be good, fair, poor or useless. Therefore the development of interactive and user friendly decision support system is being proposed, which will help in predicting suitability of important forestry species of central India in varied climatic and edaphic conditions.

Dr. Michael Hutchinson (Center for Resource and Environmental Studies, Australian national University) has developed a package known as ANUSPLIN, which uses Laplacian smoothing splines to interpolate spatially between data recorded at meteorological stations (Hutchinson 1989, 1992). As part of ACIAR project 9127 mean monthly data were collated from meteorological stations in a single area including China, Thailand, Vietnam, Laos, Cambodia and Peninsula Malaysia (Zuo *et al.* 1996). A digital elevation model was prepared by Zuo *et al.* (1996) and monthly mean values for all five climatic factors were estimated for a 1/20<sup>th</sup> of a degree

grid (*ca.* 5 km) of approximately 400 000 points across China and mainland South east Asia. As part of ACIAR Project 9127 climatic mapping programs were prepared at the CSIRO Division of Forestry for China (100 000 grid points) and Latin America (66000 grid points – interpolated climatic data kindly supplied by Dr. Peter Jones, CIAT, Colombia).

Most of the programs have been developed for the MS-DOS environment, which is the most common operating system on PC's used in the developing world. However, a version of the THAI program has recently also been developed for the Windows environment. Windows allows multitasking which makes it easy to compare maps produced by different descriptions on the computer's screen, as well as providing built-in support for hundreds of different printers. Significant progress has been made in the development of climatic mapping software in recent years (Hackett 1988, Booth 1990, Hackett 1991, Booth 1996a, b).

## METHODOLOGY

For the present work climatic and edaphic data for entire central region has been collected. Basic database structure and data retrieval algorithm has been developed. Initially records for 15 selected species with reference to their climatic and edaphic suitability has been collected. All the forms including Main form, user management form, data entry and edit form, query shell form has been designed and tested successfully. The package has been developed and tested successfully for all the operations including data entry, data modification and retrieval of information.

### Requirement analysis

The brief study of the areas involved including the potential of the work, target user group, infrastructure requirement and other related issues. It was attempted to create an easy to use and user friendly package, which not only allows maintaining records but also provides for data retrieval, data entry, search for any specific data among the entire database. It was decided that this database package will be made available to entire institute and to others interested in deriving information or consultation. The field or parameters of input of information were discussed at large and at various levels. The database structure was suitably modified to incorporate the suggestions made to widen the applicability and usefulness of the package. Table 1 containing information about species was designed for entering species records. Table 2 is also depicted the location details from the fields.

**Table 1.** Species information.

Species Id
Species Botanical Name
Genus
Vernacular Name
Family
Uses
Combination
Soil- Poorly suitable
Soil- Moderately Suitable
Soil- Most Suitable
Temp Mean Min- Poorly suitable
Temp Mean Min- Moderate suitable
Temp Mean Min- suitable
Temp Mean Max- Poorly suitable
Temp Mean Max- Moderate suitable
Temp Mean Max- suitable
Rainfall- Poorly suitable
Rainfall- Moderate suitable
Rainfall- Most Suitable
Remark

**Table 2.** Location details and climatic conditions.

Location ID
Location name
Soil Type
Temp min
Temp max
Rainfall min
Rainfall max,
Suitable Species
Remark

**Database structure**

The database should be prepared as showed in tables 3–6.

**Table 3.** Species master.

<b>Field name</b>	<b>Data type &amp; Width</b>
Species_ID	Number (7) Primary key
Species_Botanical_Name	Varchar2 (50)
Genus	Varchar2 (40)
Vernacular_Name	Varchar2 (40)
Family	Varchar2 (40)
Uses	Varchar2 (100)
Combination	Varchar2 (100)
Soil_Poorly_suitable	Varchar2 (100)
Soil_Moderately_suitable	Varchar2 (100)
Soil_Most_Suitable	Varchar2 (100)
Temp_Mean_Min_Poorly_l	Number (2)
Temp_Mean_Min_Moderate_l	Number (2)
Temp_Mean_Min_suitable_l	Number (2)
Temp_Mean_Max_Poorly_l	Number (2)
Temp_Mean_Max_Moderate_l	Number (2)
Temp_Mean_Max_suitable_l	Number (2)
Temp_Mean_Min_Poorly_u	Number (2)
Temp_Mean_Min_Moderate_u	Number (2)
Temp_Mean_Min_suitable_u	Number (2)
Temp_Mean_Max_Poorly_u	Number (2)
Temp_Mean_Max_Moderate_u	Number (2)
Temp_Mean_Max_suitable_u	Number (2)
Rainfall_Poorly_l	Number (4)
Rainfall_Moderate_l	Number (4)
Rainfall_Most_Suitable_l	Number (4)
Rainfall_Poorly_u	Number (4)
Rainfall_Moderate_u	Number (4)
Rainfall_Most_Suitable_u	Number (4)
Remark	varchar2 (100)
Preference	varchar2 (55)

**Table 4.** User master.

<b>Field name</b>	<b>Data type &amp; Width</b>
USERID	VARCHAR2 (25) primary key
PASSWORD	VARCHAR2 (20)
FNAME	VARCHAR2 (20)
LNAME	VARCHAR2 (20)
DESIGNATION	VARCHAR2 (25)
PREVILLAGE	VARCHAR2 (20)
REMARK	VARCHAR2 (50)

**Table 5.** Location master.

<b>Field name</b>	<b>Data type &amp; Width</b>
location_ID	Number (6) primary key
location_name	varchar2 (35)
soil_type	varchar2 (40)
temp_min	varchar2 (5)
temp_max	varchar2 (5)
rain_min	varchar2 (9)
rain_max	varchar2 (9)
suitable_species	varchar2 (35)
remark	varchar2 (50)

**Table 6.** Error master.

<b>Field name</b>	<b>Data type &amp; Width</b>
error_ID	Number (7) primary key
error_date	date
user_ID	varchar2 (25)
error_details	varchar2 (100)
error_status	varchar2 (15)
solution	varchar2 (100)
remark	varchar2 (100)

### Functional identification

The system consists of selections made by the user at different stages in application and the entries that the user makes. Different selections and entries that the user can make were finalized. It is usually very difficult to specify system characteristics accurately without actually doing much of the proposed work. Thus, a quick guess about the systems characteristics was all that was possible at this point. To systematically plan the output of the proposed system, thorough interaction with some potential target group had been done which resulted in finalization of procedure of the output display on monitor or printing as reports. The inputs required to produce the required outputs were listed and the sources of these inputs determined. A tentative, general schedule for developing the package was decided as follows:

1. User login ID and password.
2. User selects what he wants to do.
3. Data Entry: User enters the data regarding the database.
4. Editing: User can add, edit, species and location details.
5. Information Retrieval.
6. User can report an error.

### Data collection

Data were collected from various sources viz. literature, books and journals. The district wise climatic and edaphic data were collected from NIC site. The state maps were downloaded from state NIC website. Species data were collected through extensive review of relevant literature.

### Feasibility study

Feasibility study was conducted to select the best system meeting performance requirements. Once it was determined that the project was feasible, project specifications which finalize project requirements were prepared. Three key considerations were involved in feasibility analysis: Economic, Technical & Operational. Economic analysis also known as cost / benefit analysis, determined, whether the adoption of the system was cost justified or not. Technical consideration evaluated existing hardware and software and future requirement. Operational feasibility specified that whether the proposed system will meet the operating requirements of the organization.

### System design life cycle

In order to transform requirements into a working system both the customer/user and the developer has to be satisfied. The user/employee has to understand that what the system is suppose do and at the same time the system developer is to know as to how the system is to work.

### Conceptual design

The Conceptual Design tells what the system will do. The System is described in term of it's boundary, entities, attributes and relationship. In this phase it was determined that-

1. The Data comes from field level survey.
2. The Data is fed to the system.
3. The front end designed, links the user to the database.
4. The user is offered a number of choices like simple viewing of records searching for a particular record, record entry, deletion of record etc.
5. The format of reports output screen.

**Algorithms:****I. Algorithm for adding user**

1. START
2. INPUT:  
{USERID, PASSWORD, USERNAME, DESIGNATION, REMARK}
3. FORM LEVEL VALIDATION :
  - i. IF <data valid> THEN  
GO To NEXT STEP  
ELSE  
User is prompted to correct the entries / data in the field / fields.
4. DATABASE LEVEL VALIDATION:  
{As user ID primary key therefore two user's IDs can't be identical.}
  - i. IF <data valid> THEN  
GO To NEXT STEP  
ELSE  
User is prompted to correct the entries / data in the field / fields.
5. MESSAGE : RECORD ADDED.
6. END.

**II. Algorithm for Adding Species**

1. START
2. INPUT:
  - {
  - Species ID
  - Species Botanical Name
  - Genus
  - Vernacular Name
  - Family
  - Uses
  - Combination
  - Soil- Poorly Suitable
  - Soil- Moderate Suitable
  - Soil- Most Suitable
  - Temp Mean Min- Poorly Suitable
  - Temp Mean Min- Moderate Suitable
  - Temp Mean Min- Most suitable
  - Temp Mean Max- Poorly Suitable
  - Temp Mean Max- Moderate Suitable
  - Temp Mean Max- Most Suitable
  - Rainfall- Poorly Suitable
  - Rainfall- Moderate Suitable
  - Rainfall- Most Suitable
  - Remark
  - Preference
  - }
3. FORM LEVEL VALIDATION :
  - i. IF <data valid> THEN  
GO To NEXT STEP  
ELSE  
User is prompted to correct the entries / data in the field / fields.

4. DATABASE LEVEL VALIDATION:
  - i. IF <Data Valid> THEN  
GO To NEXT STEP  
ELSE  
User is prompted to correct the entries / data in the field / fields.
5. MESSAGE: RECORD ADDED.
6. END.

### III. Algorithm for adding location

1. START
2. INPUT :  
{LOCATION NAME, RAINFALL, TEMPERATURE, SUITABLE SPECIES, SOIL TYPE, REMARK}
3. FORM LEVEL VALIDATION :
  - i. IF <data valid> THEN  
GO To NEXT STEP  
ELSE  
User is prompted to correct the entries / data in the field / fields.
4. DATABASE LEVEL VALIDATION:
  - i. IF <data valid> THEN  
GO To NEXT STEP  
ELSE  
User is prompted to correct the entries / data in the field / fields.
5. MESSAGE: RECORD ADDED.
6. END.

### IV. Algorithm for search / query operations

1. START
2. INPUT:  
{BOTANICAL NAME, VARNACULAR NAME, GENUS, RAINFALL, TEMPERATURE, WHATEVER CARITERIA USER WANTS TO USE.}
3. FORM LEVEL VALIDATION:
  - i. IF <data valid> THEN  
GO To NEXT STEP  
ELSE  
User is prompted to correct the entries / data in the field / fields.
4. FORMING SQL QUERY AND SENDING IT TO RDBMS (ORACLE):
  - i. IF < Data Found > THEN  
GO To NEXT STEP  
ELSE  
User is prompted no records found try again.
5. DISPLAYING Message.
6. END.

### Design approach

Modular is the design approach. The entire system works due to the functionality of its component modules. Each module was designed to be complete in itself. It's the user action, however that decides the flow of control in the system since the entire programming is event based. For each action of the user, a particular module is associated to starts functioning generating the desired results.

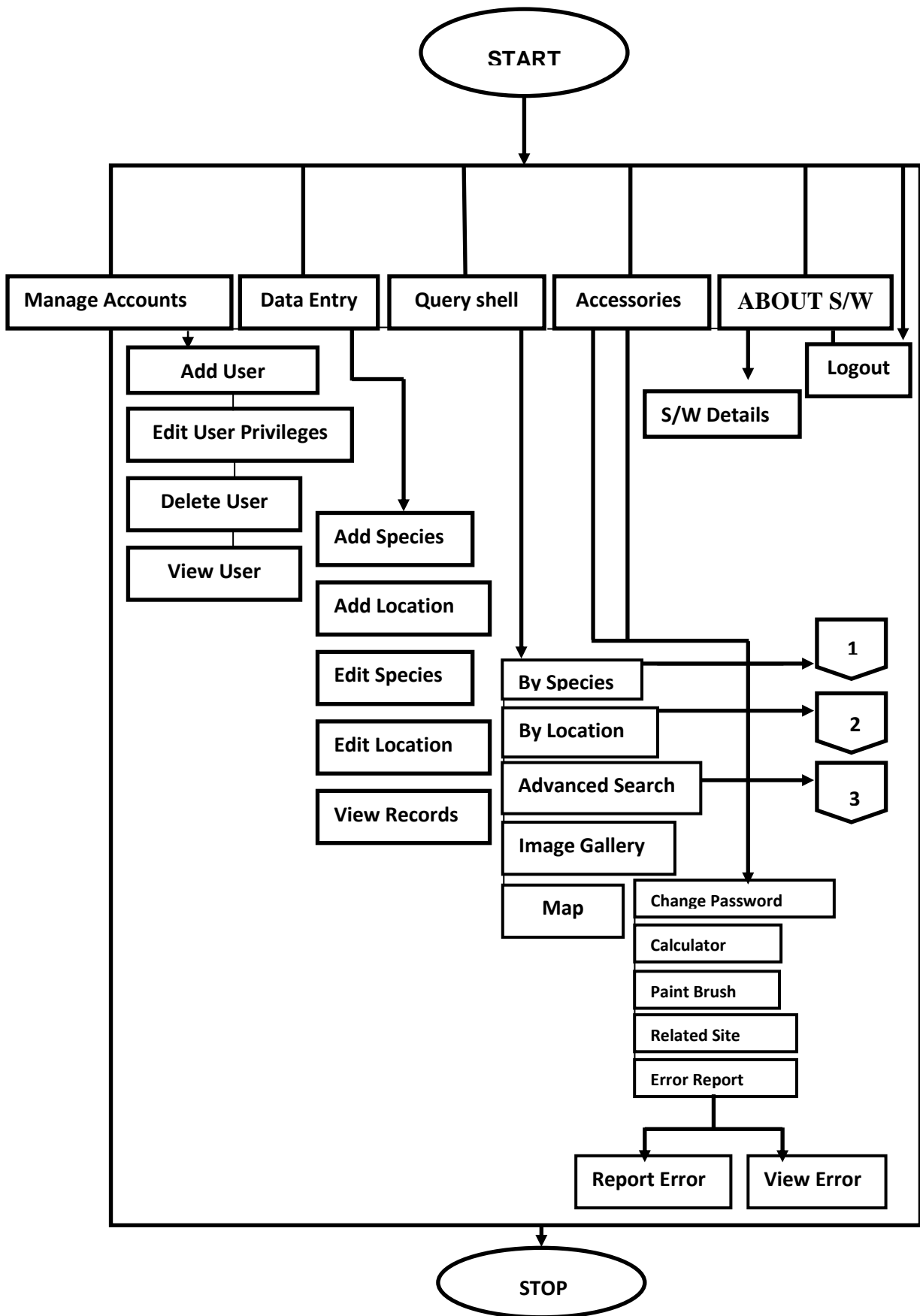
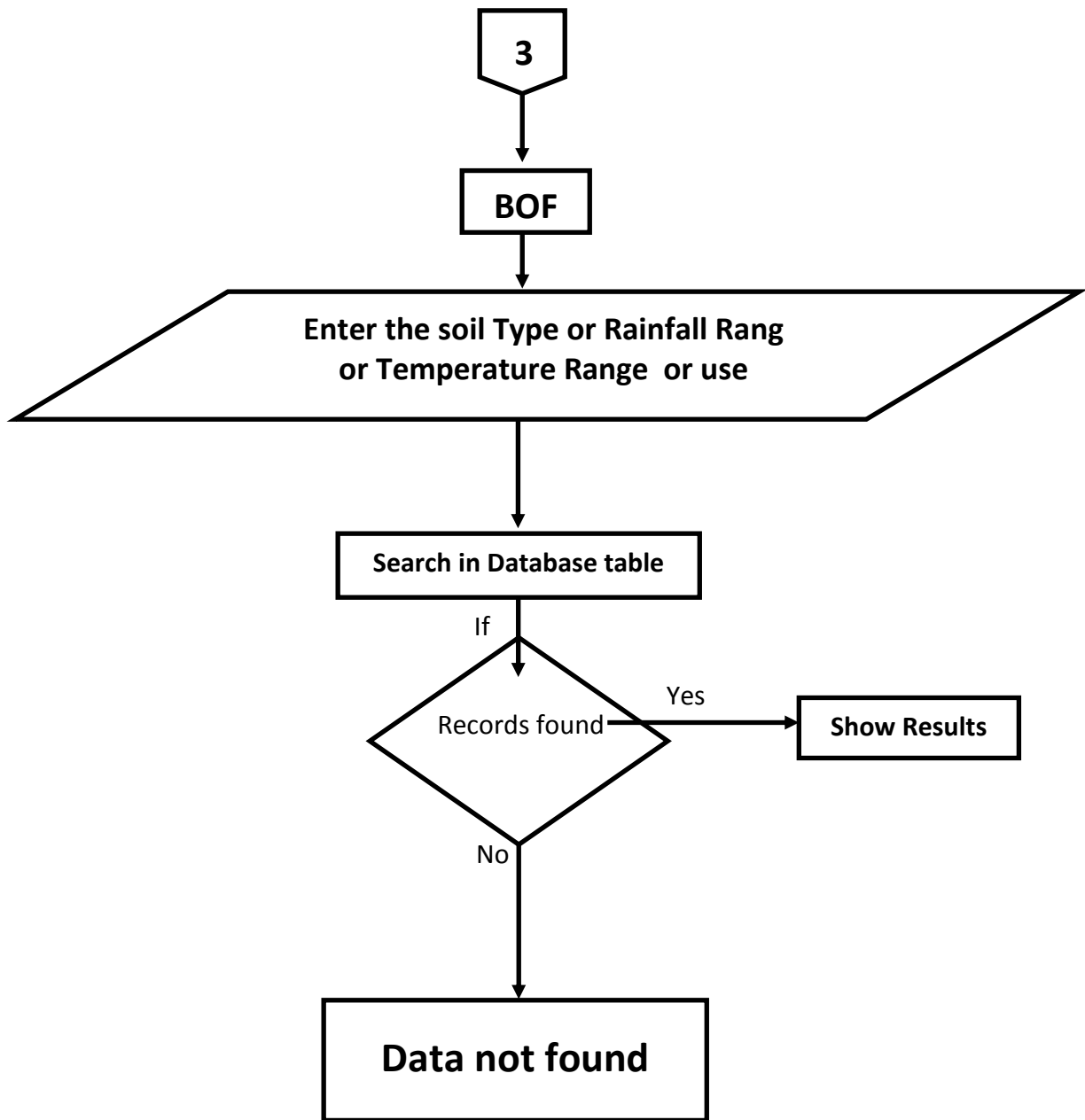
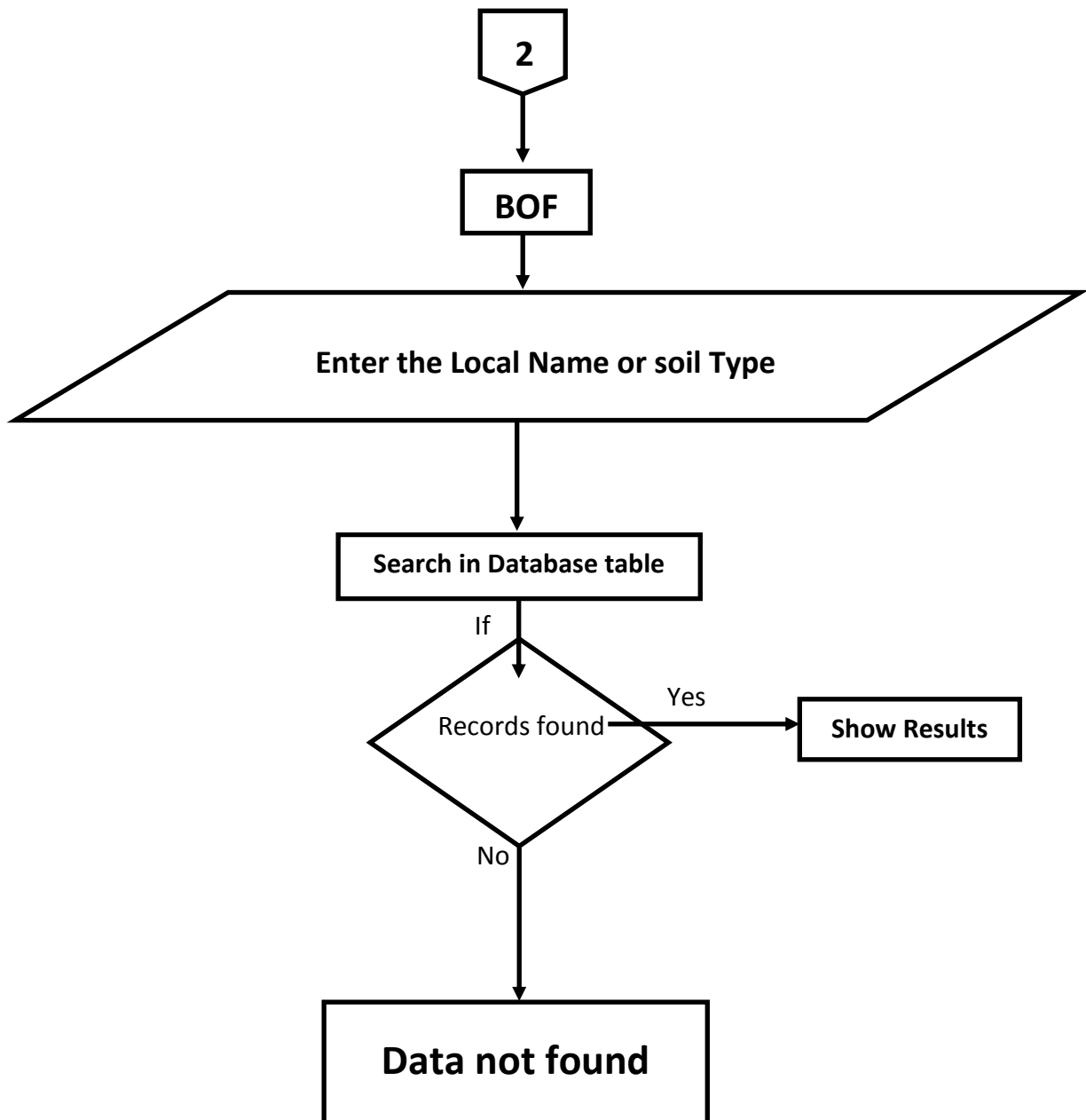


Figure 1. Flow chart of program.

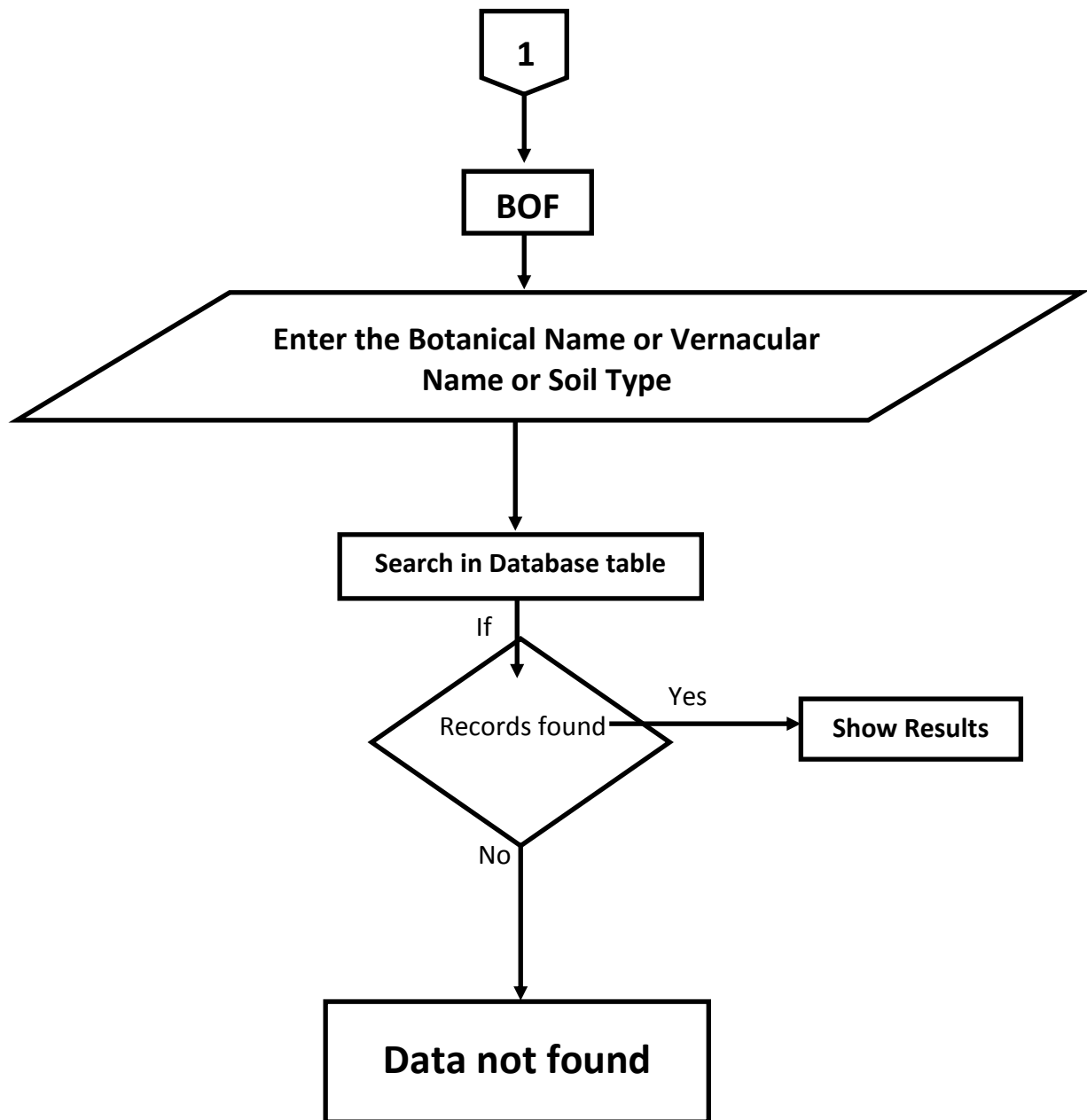


**Figure 2.** Flow chart for advance search.





**Figure 3.** Flow chart to search species by local details.



**Figure 4.** Flow chart to search by species details.

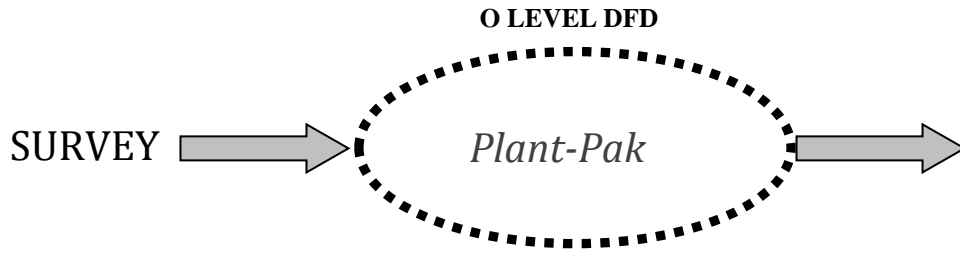


Figure 5. Flow chart of O level DFD.

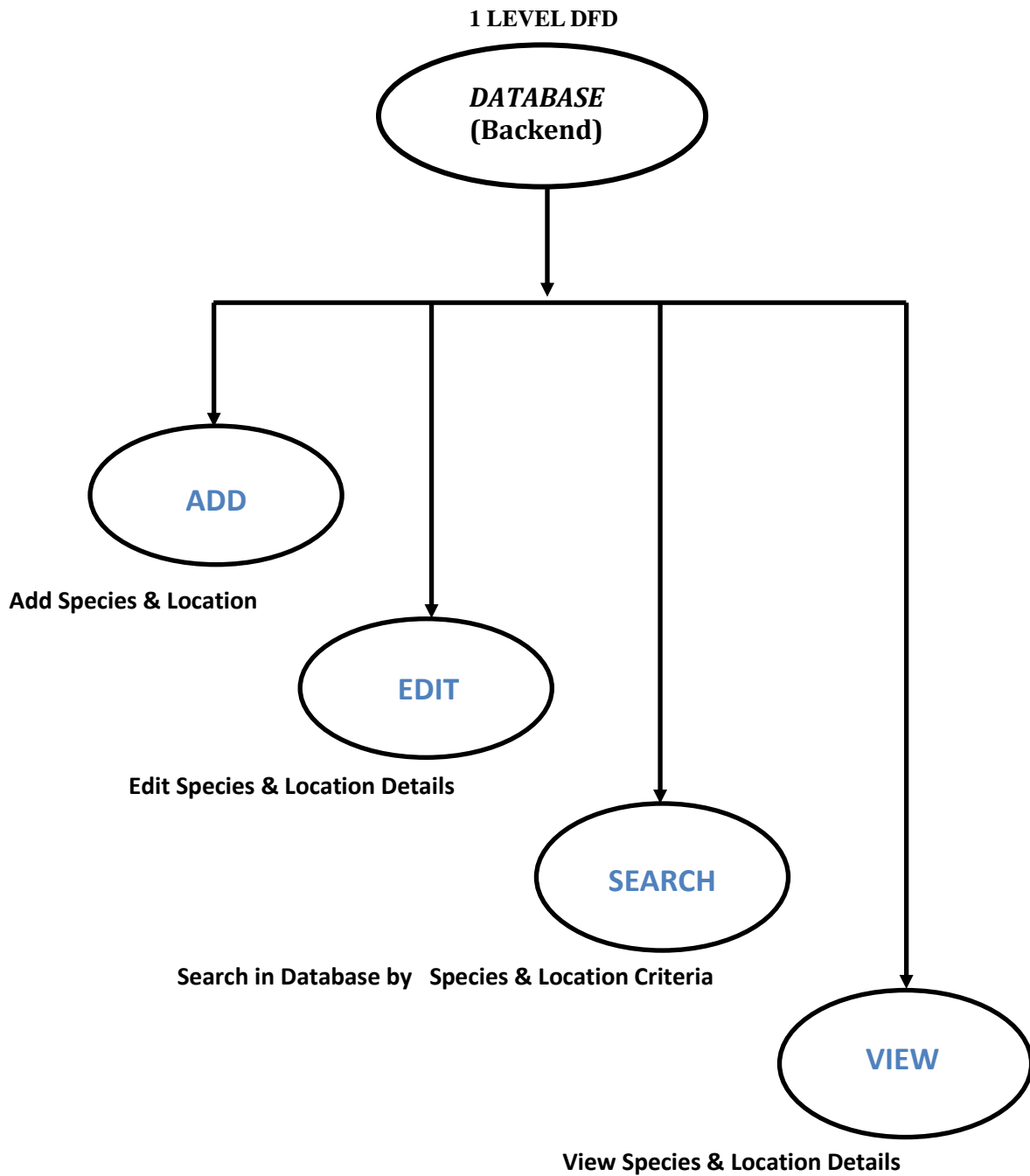
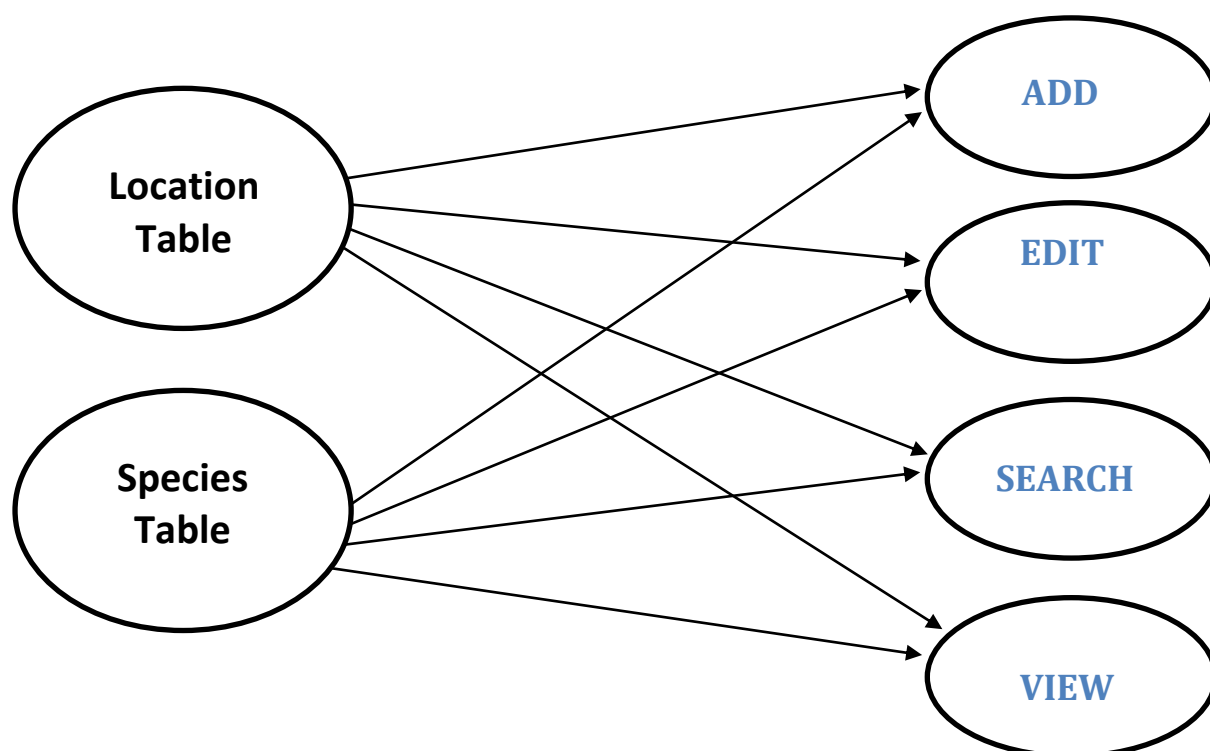


Figure 6. Flow chart of 1 level DFD.

## 2 - LEVEL DFD



**Figure 7.** Flow chart of 2 level DFD.

The database contains important new features that optimize traditional business applications, facilitate critical advancement for internet-based business, and stimulate the emerging hosted application market. New database features deliver the performance, scalability, and availability essential to hosted service software made available to anyone, anywhere. The database offers new transparent, rapid growth clustering capabilities, along with powerful and cost-effective security measures, zero-data-loss safeguards, and real-time intelligence to deliver the power needed in today's dynamic marketplace.

#### Data retrieval

The package provides retrieval of information based on following fields:

- **By Species Name:** User can get access to records by simply selecting the species either by
- **Local\_ Name** or by **Vernacular\_ Name:** On selection of this choice, a drop down menu containing all the available species stored in the database is displayed. User can select the species of his interest from the drop down menu.
- **By Family Type:** On selection of this option, all the species belongs to a particular family are displayed.
- **By Location Name:** On selection of this option, a window as containing list of all the locations stored in the database is displayed. User can select the location of his interest from the drop down menu.
- **By Climatic and Edaphic Condition:** On selection of this option, a user friendly window is displayed. User can enter the Soil type or climate range to retrieve information belonging to those climatic and edaphic conditions.
- **Through Map:** The package has the option to provide information also through the map. On selection of this option, the map of selected state is displayed. The user can browse through the map and can retrieve species suitable to a particular place by simply clicking at that place on the map).

The package has been successfully implemented and tested for 15 species (*Acacia catech*, *Albizia lebbec*, *Albizia procer*, *Ailanthus excels*, *Boswellia serrata*, *Gmelina arborea*, *Holoptelea integrifolia*, *Lagerstroemia parviflora*, *Madhuca latifolia*, *Moringa oleifera*, *Pongamia pinnata*, *Pterocarpus marsupium*, *Dalbergia latifolia*, *Sterculia urens*, *Embllica officinalis*) in Madhya Pradesh and Maharashtra region (Appendix I–IV).

The strength of this package is that it is very user friendly more intended to not only function to the best of user satisfaction but its workability also. It allows the users to not only retrieve data but also manage the

database by updating to whenever necessary. The user is provided with all the relevant option of adding, deleting, making changes to and also updating the records. The point of vulnerability of this application is that care has to be taken while feeding data to the database. The database incorporates two table and care should be taken that while one table is being fed the relevant filed of the second table also be fed at the same time otherwise it may cause inconvenience and irrelevant data retrieval.

This application on integration with GIS application can be enhanced to work like a Specialist Decision Support System. The structure of the database can be planned in a better and efficient way; there still is a scope to redefine it. This application was tested to work successfully with a fifteen tree species. The workability of the system has been checked from each and every aspect and was found to work fine generate the desired output.

The application of this model shows good results in the research resulted in satisfactory results for most of the species, but not for others. Hence, the need and justification that if further developed it can be proved as quite robust and applicable at any level and with high percentage of accuracy. The evaluation of the results can still be debated, and various experts will have a say regarding their respective field of expertise. However, this Decision Support System, with further improvement, i.e. providing more detailed information, will cover the gaps which can be seen here in some of the suitability maps for the species. The lack of “proved” mathematical formula is also the issue in this DSS; a formula was created which would grow more complex and accurate as further input is provided. This way of producing suitability maps for tree species purposes has not been carried out in the past in our country. The method needs a lot more input data in order for it to be deemed as absolutely reliable (or close to that). Such input would require implementing detailed species characteristics, detailed climate-vegetation data, habitat specifications, slope and aspect data, various constraint data (agricultural land, urban areas, industrial areas, and protected areas), etc. However, this research shows that this is a very good approach for creating suitability of tree species in different climatic conditions which provide satisfactory accuracy. That was the case in our research, where some of the suitability resulted in very good spatial distribution and accuracy, while other for some of the species deemed areas as suitable when in fact they aren't such. The tree species used in this paper has justified their choice, in terms of offering various possibilities for afforestation throughout the country. Finally, the approach used in this research resulted in the creation of a model which was carried out as such for the first time in our country, and with its development will prove to be robust enough to be used during the afforestation of any localities. In the end it can be concluded that the quality of the model is dependent on the quality of the input. Therefore, more research should be done in improving the theoretical background of the modelling process and the input parameters.

## Conclusion

The decision support systems make use of variety of technology and new technologies playing important role in decision making. PLANTPAK as this new decision support system has been named will be immensely useful for farmers, tree planters and entrepreneurs in the arena of plantation forestry to decide the suitability of tree species according to locality, climate and edaphic characteristics in central India. However, the package could easily be enriched by incorporation of other area and species. In the recent times, the need of site specific information along with geographical details has grown up immensely. The textual data coupled with geographic detail can provide a very clear picture of the object under consideration. Many areas of DSS application are concerned with geographic details. GIS based DSS can make use of spatial data processing. Clearly SDSS will be an important subset of DSS in future. The trend in the future is likely to be growth in the use of SDSS by users without any special skill in GIS applications. SDSS don't require in-depth commands to operate, yet allow users to negotiate very sophisticated geographic analysis. In the future, the use of SDSS will be extended to applications where the spatial information is only an interim stage. Users dealing with this broader set of applications need to be given control over the important variables in the decision, while other processing is performed without the need for extensive user interaction. With the development of such systems, new classes of decision and new class of users will be supported effectively.

## REFERENCES

- Anonymous (1993) *Plant Resources of South-East Asia*. No. 5 (1&2). Pudoc Sc. Publication, Wageningen.
- Booth TH (1990) Mapping regions climatically suitable for particular tree species at the global scale. *Forest Ecology & Management* 36: 47–60.

- Booth TH (1996a) The development of climatic mapping programs and climatic mapping in Australia. In: Booth TH (ed) *Matching Trees and Sites*. Proceedings of an International Workshop held in Bangkok, Thailand, 27–30 March 1995. ACIAR Proceedings No. 63, pp. 38–42.
- Booth TH (1996b) The development of climatic mapping programs and climatic mapping in Australia. In: Booth TH (ed) *Matching Trees and Sites*. ACLAR Proceedings No. 63.
- Brandis D (1971) *Indian Trees*. Bishen Singh Mahendra Pal Singh, Dehradun.
- Burley J & Styles BT (1976) *Tropical Trees: Variation, Breeding and Conservation*. Academic Press, London.
- Gamble JS (1984) *A Manual of Indian Timbers*. Bishen Singh Mahendra Pal Singh, Dehradun.
- Hackett C (1988) *Matching Plants and Land: Development of a broad scale system from a crop project for Papua New Guinea*. CSIRO Division of Water and Land Resources. Natural Resources Series no.11, Melbourne, 82 p.
- Hackett C (1991) *Plantgro: a software package for the prediction of plant growth*. CSIRO, Melbourne.
- Hutchinson MF (1989) *A new objective method for spatial interpolation of meteorological variables from irregular network applied to the estimation of monthly mean solar radiation, temperature, precipitation and wind run*. CSIRO Division of Water and Land Resources, Tech.Memo.89/5, CSIRO, Canberra 10 p.
- Hutchinson MF (1992) *Documentation for SPLINA and SPLINB- two programming the ANUSPLIN software package*. CRES, Australian, National University Canberra.
- Luna RK (1996) *Plantation Trees*. International Book Distributors, Dehradun.
- Maslekar AR (1996) *Foresters Companion*. Surya International Publications, Dehradun.
- McCann C (1985) *Trees of India*. Periodical Expert Book Agency, New Delhi.
- Prakash R & Hocking D (1986) *Some Favourite Trees For Fuel And Fodder*. Society For Promotion of Wasteland Development, New Delhi.
- PurKayastha SK (1996) *A Manual of Indian Timbers*. Sribhumi Publication Company, Kolkata.
- Seth SK, Raizada MP & Waheed Khan MA (1962) *Trees for Van Mahotsava*. FRI and Colleges, Dehradun.
- Singh RV (1982) *Fodder Trees of India*. Oxford and IBH Publication Company, New Delhi.
- Singhal RM & Khanna P (1991) *Multipurpose Trees and Shrubs*. ICFRE, Dehradun.
- Troup RS (1986) *The Silviculture of Indian trees*. International Book Distributors, Dehradun.
- Zuo H, Hutchinson MF, McMahan JP & Nix HA (1996) Developing a mean monthly climatic database for China and Southeast Asia. In: Booth TH (ed) *Matching Trees and Sites*. ACIAR Proceedings No. 63.

**Appendix I:** Classification of different districts of Madhya Pradesh according to rainfall (mm).

S. No.	Rain fall range	Districts
1.	800–1000	Gwalior, Bhind, Shivpuri, Morena, Sheopurkala, Khandwa, Burhanpur, Khargone, Jhabua
2.	800–1200	Mandsaur, Ratlam, Ujjain, Dewas, Indore, Sajapur, Rajgarh, Dhar
3.	800–1400	Chhattarpur, Datia, Tikamgarh,
4.	1000–1200	Betul, Chhindwara
5.	1000–1400	Rewa, Satna, Panna, Seoni, Katni
6.	1200–1400	Bhopal, Sehore, Raisen, Vidisha, Guna, Ashoknagar, Sagar, Damoh
7.	1200–1600	Balaghat, Shahdol, Anuppur, Sidhi, Mandla, Jabalpur, Narsinghpur, Hoshangabad, Harda

**Appendix II:** Soil types of different districts of Madhya Pradesh.

S. No.	Soil Type	Districts
1.	Shallow & medium black	Betul, Chhindwara, Seoni
2.	Deep medium black	Narsinghpur, Hoshangabad, Harda, Shahdol, Umaria, Jabalpur, Katni, Sagar, Damoh, Vidisha, Raisen, Bhopal, Sehore, Rajgarh, Ujjain, Dewas, Shajapur, Mandsaur, Neemach, Ratlam, Jhabua, Dhar, Indore, Khargone, Barwani, Khandwa
3.	Alluvial soil	Gwalior, Morena, Sheopurkala, Bhind
4.	Mixed red & black	Mandla, Dindori, Balaghat, Rewa, Satna, Panna, Chhatarpur, Tikamgarh, Shivpuri, Guna, Datia, Sidhi

**Appendix III:** Classification of different districts of Maharashtra according to rainfall (mm).

S. No.	Rain fall range	Districts
1.	500–800	Ahmednagar, Aurangabad, Akola, Beed, Buldhana, Dhule, Jalgaon, Jalna, Osmanabad, Pune, Sangli, Solapur
2.	800–1200	Amravati, Chandrapur, Hingoli, Latur, Nashik, Nanded, Parbhani, Washim, Wardha, Yavatmal
3.	1200–1500	Bhandara, Gondia, Gadchiroli, Kolhapur, Nagpur, Satara
4.	2500–3000	Sindhudurg, Thane
5.	3000–3500	Raigad, Ratnagiri

**Appendix IV:** Soil types of different districts of Maharashtra.

S. No.	Soil Type	Districts
1.	Black to red	Akola, Amravati, Beed, Buldhana, Jalgaon, Latur, Osmanabad, Solapur
2.	Light laterite, Reddish brown, Greyish black	Ahmednagar, Satara
3.	Brown to red	Bhandara, Gadchiroli
4.	Reddish brown to black, Greyish black	Kolhapur, Nashik, Pune, Sangli
5.	Coarse & shallow	Raigad, Thane
6.	Black soils, Black to red	Aurangabad, Jalna, Nanded, Parbhani, Yavatmal
7.	Laterite, light laterite & reddish brown	Ratnagiri, Sindhudurg
8.	Black Soils, Brown to red	Chandrapur, Nagpur, Wardha
9.	Black to red, Greyish black	Dhule