DECISION SUPPORT SYSTEM TO ASSESS REGIONAL BIOMASS ENERGY POTENTIAL

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ABSTRACT

Biomass is a renewable source that accounts for nearly 33% of a developing country's energy needs. In India, it meets about 75% of the rural energy needs and the rural population constitutes 70% of the total population. Sustainable management of these resources requires better and timely decisions, which can lead to increased cost--efficiency and productivity. This would help in regional energy planning and conservation through appropriate decision interventions. To assist in strategic decision--making activities, considering spatial and temporal variables, Spatial Decision Support Systems (SDSS) are required. SDSS is an interactive computerized system that gathers data from a wide range of data sources, analyze the collected data and then present it in a way that can be interpreted by the decision maker to deliver the precise information needed to make timely decisions. DSS framework is designed and implemented to ease and speed up the use of environmental systems. In this regard, to assist planners to plan and manage bioresources in a sustainable way, Biomass Energy Potential Assessment (BEPA) decision support system is designed and is being implemented at regional levels through proper training. Overall objective of this DSS is the development of a set of tools aimed at transforming data into information and aid decisions for bioresources.

This paper outlines the design and implementation of DSS for assessment of biomass energy potential of a region considering the resources available and the demand. It is designed with user friendly GUI's (Graphic User Interface) using VB (Visual Basic) as frontend with Microsoft Access database as the backend. This helps to build executive information systems and reporting tools that tap vast data resources and deliver information in the context of daily processes. This tool can be used to form a core of practical methodology that will result in more resilience in less time and can be used by decision--making bodies to assess the impacts of various scenarios and to review cost and benefits of decisions to be made. It also offers means of entering, accessing and interpreting the information for the purpose of sound decision making.

Keywords: Biomass, Bioenergy, DSS, Sustainable management, Regional energy planning.

INTRODUCTION

Biomass refers to solid carbonaceous material derived from plants and animals. The energy resulting from biomass is bioenergy. Although bioenergy use is predominant in rural areas, it also provides an important fuel source for the urban poor and many rural, small and medium scale industries. In order to meet the growing demand for energy, it is imperative to focus on efficient production and use of bioenergy to meet fuel requirements [1]. At present, a comprehensive approach to biomass exploitation is required for regions where other kinds of energy are difficult to exploit or where the use of biomass could decrease environmental pollution and enhance regional welfare, e.g., by providing local employment opportunities or improving environmental preservation. The amount and complexity of information relating to the development of bioenergy systems increases and so does the problem of how to handle the information in a manner is helpful for decision making. In this respect, decision support systems (DSS) have been designed to assist in bioresource management at a regional level [2]. Computer models are often complex to use so there has been much effort to develop DSS, which provides the user with an accessible interface with the computer and where the results are presented in a form, which is readily understandable by the user [3]. It is an interactive system that is able to produce data and information and in some cases, even promote understanding related to a given application domain in order to give useful assistance in resolving complex and ill--defined problems [4]. DSS analyzes the collected data and then presents it in a way that can be interpreted by the decision maker. Decision analysis programs can assist the user to create a decision tree of possible decisions and then predict the probabilities and costs of different outcomes. DSS allows ad--hoc enquiries and can assess the probable consequences of decisions before they are made. The DSS analysis tool disintegrates a problem into multiple series of decisions that could be made. Ultimately, the principal distinctive feature of these tools is to enlighten the probability of different outcomes and the expected outcomes. The result of design and execution of DSS for environmental systems, which generate energy, are prolific.

Decision Support Systems (DSS) focus on providing flexible tools for policy analysis, than providing models to answer structured problems [5]. DSS would present the results of a model in a lucid, easily understandable manner to enable policy makers in taking hierarchical sequence of decisions. Most decision support systems are actually based upon mathematical models. Indeed, modelling tools are only a part of DSS, which comprises three component subsystems, namely,

a) *The Database Management:* Manages an integrated database to drive all models.

b) *The Model Management:* Helps in creating new models, cataloging and editing existing models, and inter--relates models by links through the spatial and attribute database and integrates small models (building blocks) into larger model systems.

c) *The Dialogue Management*: Using consistent and familiar interface (like spreadsheet or word processing programs), this design is guided by various methodological considerations, such as,

   i). *Scenario Approach*: Simulates alternative energy and economic futures under different assumptions,

   ii). *Integrated Resource Planning*: Stresses the importance of integrating the analyses within a comprehensive planning while emphasizing on a disaggregated approach,

   iii). *Flexibility and User Friendliness:* Designed as a set of flexible, expandable and comprehensive modules.

Energy assessment across sectors, through time and localities (region) requires a wide range of information available through a reliable, consistent source. Good information can help to assess various outputs under multiple schemes. Improved technology and growing user acceptance are fueling increased usage demand of DSS for assessment of energy from bioresources. Scope for wide spread use of DSS for bioresources management is its ease of query, reporting, online analysis of both simulated and observed data and speed of processing the data. DSS provides flexible tool for decision makers to assess the effectiveness of the decision through querying and visualisation. Energy savings potential can be observed across different regions.

The world's energy markets rely heavily on fossil fuels such as coal, petroleum, crude oil and natural gas as sources of energy, fuels and chemicals. Since millions of years were required to form fossil fuels in the earth, their reserves are finite and subject to depletion as they are consumed. The only other naturally occurring, energy--containing carbon resource, that is large enough to be used, as a substitute for fossil fuels is biomass. Compared to these, bioresources are renewable with a cycling time less than 100 years. It is the most developed renewable energy source providing 35% and 3% of the primary energy needs of developing and industrialised countries respectively [6]. With 70% of India’s population still in rural areas, there is tremendous demand on resources such as fuelwood, agricultural residues, etc. to meet the daily fuel requirements. About 13.01% of the energy in India is derived from bioresources [7]. Dependence on bioresource to meet the daily requirement of fuel, fodder, etc. in rural areas is more than 85% while in urban area the demand is about 35%.

Biomass is all non--fossil organic materials that have intrinsic chemical energy content. They include aquatic and terrestrial vegetation and all waste biomass such as municipal solid wastes, municipal bio--solids and animal wastes, forestry and agricultural residues and certain types of industrial wastes. Unlike fossil fuels, biomass is renewable in the sense that only a short period of time is needed to replace what is used as an energy resource. Biomass is a renewable energy source because the energy it contains comes from the sun. Through the process of photosynthesis, chlorophyll in plants captures the sun's energy by converting carbon dioxide from the air and water from the ground into carbohydrates, complex compounds composed of carbon, hydrogen and oxygen. When these carbohydrates are burned, they turn back into carbon dioxide and water and release the sun's energy they contain. Bioenergy is regarded as "green" energy for several reasons. Recent study on energy utilisation in Karnataka considering all types of energy sources and sector wise consumption reveals that traditional fuels such as firewood (7.440 million tonnes of oil equivalent--43.62%), agro residues (1.510 million tonnes of oil equivalent--8.85%), biogas and cow dung (0.250 million tonnes of oil equivalent--1.47%) account for 53.20% of total energy consumption [8].

Assessment of available bioresources is helpful in revealing its status and helps in planning a sustained supply to meet the energy demand. Assessment of bioenergy potential can be theoretical, technical or economic. Natural conditions that favor the growth of biomass determine the theoretical potential. Technical potential depends on the available technologies that can be exploited for the conversion of biomass to more flexible forms and so is subjected to change with time. Of all the three potential estimates, the economic potential is subjected to high variability, as economic conditions fluctuate drastically over space and time [9]. To cater these requirements an integrated decision support system is designed that combines sound scientific methods of analysis and assessment of biomass energy (location wise), which can be exploited to meet the regional energy demand in a decentralised way. The assessment also necessitates the validation of DSS with the data compiled for the particular region.

Biomass energy potential assessment (BEPA) Decision Support System provides an integrated framework for easy access of data analysis and the design and evaluation of biomass energy assessment strategies with a unified user interface, comprising of fully menu--driven symbolic/graphic user interface, with a built in context sensitive help features. The distinctive feature of the database is its handling, display and analysis of observation time series data, with a linkage to real time data acquisition and monitoring. It supports realistic analysis and practical simulations of energy assessment.

LITERATURE REVIEW

A hypertext based DSS was developed to aid deployment of bioenergy systems. These approaches are discussed with reference to a short rotation forestry production information system and DSS for harvesting wood for energy from conventional forestry and short rotation forestry. Existing models and DSS were linked together to produce an integrated biomass electricity model, to investigate the interface between supply and conversion and to assess the impact of different feedstocks and conversion processes on the costs of generating electricity [3].

GIS based DSS was developed, which provides the tools to identify the geographic distribution of the economically important bioresources. The procedure introduces a four level analysis to determine the theoretical, available, technological and economically exploitable potential. The DSS handles all possible restrictions and candidate power plants are identified using an iterative procedure that locates bioenergy units and establishes the needed cultivated area for biomass collection. Electricity production cost is used as a criterion in the identification of the sites for biomass based power generation [10].

DSS was developed to assess the possibility of biomass exploitation for both thermal and electric energy production in a given area, while relating this use to an efficient and sustainable management of the forests within the same territory. In the proposed approach, geographic information system based techniques are integrated with mathematical programming methods to yield a comprehensive system that allows the formalization of the problem, decision taking and evaluation of effects. This DSS helps in identifying the optimal location for plants as well as computation of their optimal sizing (specifying energy types for the specific area), taking into account several aspects (economic, technical, regulatory and social) and deciding how to plan biomass collection and harvesting [2].

Using GIS, spatial mapping of the resources has been done for assessing the bioenergy potential for Karnataka state. Bioresource availability analysis shows that horticulture constitutes the major share of 43.6%, followed by forests (39.8%), agricultural residues (13.6%), animal residues (3.01%) and plantations (0.15%). Talukwise demand analysis shows that taluks such as Thirthahalli, Sirsi and Sagar have surplus bioresource compared to taluks such as Anekal, Malur, Gudibanda and Sidlaghatta. The computation of bioenergy availability, demand and talukwise status shows that Siddapura taluk in Uttara Kannada district has the highest bioenergy status of 2.004. Anekal taluk in Bangalore Urban district has the least status of 0.004 [8].

A spatial decision support system with algorithms specific for bioresources assessment and conservation was designed incorporating routines for forest mapping and monitoring changes at landscape level. It also provides inputs to decision--makers to deal with global issues such as global warming and understanding of carbon flux. Integration of biomass assessment and productivity models offered rapid and customized methods for resource estimation [11].

STUDY AREA

Kolar district is located in the southern plains of Karnataka State, India. It lies between 77° 21' to 78° 35' east longitude and 12° 46' to 13° 58' north latitude and extends over an area of 8,225 sq. km. The population was 2.523 million (as per 2001 census report). For administrative purposes, the district has been divided into 11 taluks. There are 15 towns and 3,345 inhabited villages in the district. Figure 3 shows the study area. Kolar belongs to the semi arid zone of Karnataka. In the semi arid zone apart from the year--to--year fluctuations in the total seasonal rainfall, there are also large variations in the time of commencement of rainfall adequate for sowing as well as in the distribution of drought periods within the crop--growing season. Kolar district depends on the rainfall during southwest and northeast monsoon. Out of about 2,800 sq. km of land under cultivation, 35% is under well and tank irrigation. There are about 951 big tanks and 2934 small tanks in the district. The average population density of the district is 2.09 persons/hectare (rural) and 2.69 persons/hectare (rural and urban). The population density ranges from 1.44 (Bagepalli), 1.69 (Gudibanda), 1.70 (Srinivasapur) to the maximum of 2.55 (Kolar). While, the population density in taluks is as follows: Bangarpet (2.52), Malur (2.38), Gauribidanur (2.36), Sidlaghatta (2.16), Chintamani (2.10), Mulbagal (2.04) and Chikballapur (1.92).

The average livestock density of the district is 0.81. It ranges from 0.68 (Bagepalli, Malur), 0.70 (Kolar) to a maximum of 1.09 (Gauribidanur). Extent of forest cover in the district (as per Forest Department records) is about 6.5%. It ranges from 1.71 % (Bangarpet), 2.3% (Malur), 2.78% (Kolar) to 15% (Srinivasapur) and 20% (Chikballapur). Taluks are grouped into three categorizes based on percentage of forest cover (<10 %, 10--20% and >20% cover). Chikballapur and Bagepalli have forest cover > 20%, Gudibanda and Srinivasapur are in the range 10--20%, while remaining taluks have forest cover < 10% [12].

Karnataka State is situated between 11° 40' and 18° 27' north latitude and 74° 5' and 78° 33' east longitude in the center of western peninsular India, covering an area of 19.1 Mha and accounts for 5.8% of the country's total geographic area. It has a 350 km long coastline, which forms the western boundary. According to the 2001 provisional census the population of the State is 52.6 million (26.8 million males and 25.8 million females), with a rural population of 66.02% and an urban population of 33.98%. Physiograpically, the State can be divided into two distinct regions, Malnad or Hilly region comprising of mainly the Western Ghats and the Maidan or Plain region comprising of the inland plateau of varying heights. The forest types prevalent in the State are; Tropical Wet Evergreen, Tropical Semi Evergreen, Tropical Moist Deciduous, Tropical Dry Deciduous and Tropical Thorn forests. Karnataka is divided into 10 agroclimatic zones taking into consideration the rainfall pattern--quantum and distribution, soil types, texture, depth and physio--chemical properties, elevation, topography, major crops and types of vegetation.

METHODOLOGY

The DSS of biomass energy assessment (figure 1) provides an user friendly Graphic User Interface (GUI), developed using Microsoft Visual Basic 6.0 as frontend with Microsoft Access database as backend. This GUI Environment helps in entry, edit or update of database along with the options to compute biomass energy potential spatially. Various sub--modules are Database, Database Management System (DBMS), GIS, level of analysis, land cover analysis, land use analysis, productivity, power and energy, and forecasting.

i). Database module helps in compilation of the data required for bioresource energy assessment. The data collected from secondary sources (Government offices, etc.) as well as primary (field measurements) are stored in the database. Data entry, Retrieval and Edit are the options provided in the module. Data redundancy is minimized through normalized data tables.

ii). GIS module with GRAM++ (Spatial analysis software developed by Indian Institute of Technology, Mumbai) provides the user with capabilities such as spatial and temporal analysis, querying and visualisation. The flexibility to enrich the database with spatial aspects helps to identify and quantify the local constraints in the resource management.

iii). Level of analysis module helps in hierarchical data input and analysis--state, district, taluk, village and town.

iv). Land cover analysis module calculates the extent of vegetation cover in a region using remote sensing data. Land use module helps in mapping the extent of different land use pattern (agriculture, forest, plantation, etc.) in a region.

v). Bioresource yield module computes sectorwise resource yield based on spatial extent (forest, agriculture, plantation, etc.) and productivity.

vi). Energy module computes the available energy for the selected bioresource.

vii). Forecasting module helps in predicting the resource status considering various scenarios.

As a case study, the DSS was implemented for energy assessment using the data of bioresources done at different--scale mapping of land use pattern in Kolar district. The data sets needed to develop the bioresource database included village maps, Survey of India toposheets (1:50000, 1:250000), satellite images (multispectral and panchromatic sensor data) and information from field surveys (training data) using Global Positioning System (GPS). Figure 2 shows the methodology for assessment of regional bio--resources potential. Landuse analyses were carried out using Geographical Information System (GIS), GPS and remotely sensed data (IRS--1C) covering the district. GIS is used to map spatially the resource availability and demand. It integrates common database operations, such as query and statistical analysis, with the spatial data (maps). It helps to efficiently store, manipulate, analyse and display spatial data according to the user specifications. GPS helps in collecting the ground data (spatial and attribute data), which is required for interpreting the remote sensing data for land cover and land use analyses.

Land cover and land use analysis was based on IRS--1C (Indian Remote Sensing Satellite--1C) LISS III and PAN (Panchromatic) data of November 2000 and November 2003. Spatial resolution of LISS--III data in multi spectral bands (G, R and NIR bands) is 23.5 m and that of PAN is 5.8 m. By merging LISS--III multispectral bands with PAN helps in determining the spectral response patterns of vegetation at species level (or crop type). Merging helps in retaining the spectral advantage of multispectral bands while taking advantage of PAN's spatial resolution. This helps in mapping bioresources at pixel levels (covering an area of few square meters).

The methodology developed for landscape analyses (landscape classification) at disaggregated levels provides an up--to--date land characteristic database and a model for further research. Taluks located in northern part of Kolar (Gudibanda, Gauribidanur, Bagepalli and northern part of Sidlaghatta) have lesser vegetation compared to southern part of the district. The landscape of mixed vegetation is of deciduous and scrub species. Plantations of Eucalyptus and *Acacia auriculiformis* are found in most parts compared to natural vegetation.

Land cover analysis was done with the computation of the vegetation indices namely NDVI (Normalized Difference Vegetation Index) and TSAVI (Transformed Soil Adjusted Vegetation Index) from the LISS--III bands (RED and NIR) of IRS--1C. This helps in identifying observed physical cover--vegetation and non--vegetation. It roughly indicates the extent of the vegetation cover in the region. NDVI is defined as

$$NDVI = (NIR-RED) / (NIR+RED) \text{--------------------} (1)$$

The index normalizes the difference between the bands so that the values range between -1 and +1. The negative value represents non--vegetated area while positive value represents vegetated area. Kolar district being in semi--arid region, vegetation cover is poor and sparsely spread. Pixels (remote sensing data) contain a mixture of vegetation and soil background. Hence to cancel the effect of soil brightness, Transformed Soil--adjusted Vegetation Indices (TSAVI1 and TSAVI2) were computed. These indices are slightly less sensitive to changes in vegetation cover than NDVI at low levels of vegetation cover. These indices are also more sensitive to atmospheric variations than NDVI. TSAVI1 assumes that the soil line has arbitrary slope and intercept and it makes use of these values to adjust the vegetation index and is written as:

$$TSAVI1 = a (NIR - a*RED - b) / (RED + a*NIR - a*b + X(1+a^2))$$ -----------------(2)

Where, NIR: reflectance in near infrared band,

RED: reflectance in red band,

a: slope of the line,

b: intercept of the soil line,

X: adjustment factor that is set to minimize soil noise.

Red band is taken as independent variable for regression analysis. Ratio value less than -9.0 is taken as non--vegetation while greater than -9.0 is taken as vegetation. With some resistance to high soil moisture, TSAVI1 proves to be a very good candidate for use in semi--arid regions. TSAVI1 was specifically designed for semi--arid region and does not work well in areas with heavy vegetation. TSAVI2 is modified version of TSAVI which was readjusted with an additive correction factor of 0.08 to minimize the effects of the background soil brightness and is given by,

$$TSAVI2 = a (NIR - a*RED - b) / (RED + a*NIR - a*b + 0.08(1+a^2))$$ -------------(3)

Land use analysis for Kolar district was done through supervised classification approach using multi spectral data of IRS--1C. The Maximum likelihood classification method is found to be more appropriate (based on confusion matrix analyses) compared to other classification approaches.

Bioenergy status assessment was done taluk--wise and aggregated for the district. This is based on compilation and computation of bioresource supply (forests, agriculture, plantations, etc.) and sector--wise bioenergy requirement (domestic, agriculture, industry, etc.). Bioresource supply from agriculture (residues), forest, horticulture, plantation and livestock is considered to assess the energy status taluk wise. This data is compiled from the agriculture, horticulture, forest and veterinary departments of the State apart from land use analyses using remote sensing data. The talukwise potential is evaluated using maps of administrative boundaries (taluk boundaries) along with remote sensing and statistical data.

Bioresource supply is based primarily on land use data, yield of various crop residues (agriculture and horticulture) and plantation and forest biomass productivities. Data on the historical land use pattern were collected from the Directorate of Economics and Statistics, Government of Karnataka. The major source of information on forest lands is the Karnataka Forest Department (KFD), which maintains a variety of records like the annual administration reports, working plans, forest inventory reports, which gave information on the growing stock, current status of the forests, the management practices adopted, plantations maintained and their prescribed felling cycle. The inventory of forest resources published by the Forest Survey of India was also referred [13]. The forest area by types, given division wise in the forest records, was used to compute the forest type at the taluk level. The biomass potential of the forests is dependent on the type of forest and its distribution.

Above ground standing biomass of trees is the weight of trees above ground, in a given area, if harvested at a given time. The change in standing biomass over a period of time is called productivity. The standing biomass helps to estimate the productivity of an area and also gives information on the carrying capacity of land. It also helps in estimating the biomass that can be continuously extracted. The standing biomass is measured using the harvest method or by using the biomass estimation equations. In the harvest method, vegetation in the selected sample plots is harvested and the weight is estimated in fresh and dry form to measure biomass. For trees, this method is inappropriate, as it requires their felling or destructive sampling. However, this could be computed by the knowledge of its height and girth (at 130 cm). Standing biomass (in kg) is given by

$$\text{Tree biomass} = b + (a\ D^2 H) \text{ ---------------(4)}$$

Where D is the diameter at 130 cm, H is the height of the tree, a and b are constants. Equations involving the basal area are used for all tree species and therefore are used to estimate the standing biomass of mixed forests. Productivity, which is the increase in weight or volume of any biomass over a period of time, can be estimated when the standing biomass estimates are available for two consecutive years. It can also be calculated by knowing the age of the forest stand in addition to the litter available annually. Productivity is equal to standing biomass per hectare/age of a tree or the trees per forest stand. Using the low, high and average productivity values, the annual biomass production from each forest type was computed at the taluk level. Energy equivalent of 4000 kcal/kg was taken for ever green, semi--evergreen and moist--deciduous forest types, while for the dry deciduous and scrub type vegetation 4800 kcal/kg and 3400 kcal/kg respectively were taken. Total bioenergy from forest (Bio_1) is computed by:

Bio_1 = Bioenergy from forests (kcal) = Forest area * Productivity * (Energy equivalent) ------ (5)

BEPA requires inputs such as forest types (i.e. Deciduous, Evergreen, etc.), respective spatial extent, annual productivity (tonne/hectare) and energy equivalent (kcal/tonne). Outputs of the DSS are annual bioenergy--forest type wise, regionwise, etc. (Note: Forest plantation inputs and outputs are similar to forest).

Plantation inventory involves the assessment of spatial extent of plantation, annual productivity, mean annual increment and cycling time. Based on an average productivity of 5 t/ha/year, the biomass production of plantations was calculated. The area of plantations raised by the forest department under various schemes was obtained from the State forest department and updated using latest remote sensing data (species wise extent). The details of plantations raised on different sites like canal side, roadside, institutional premises, etc., available with the forest department, were also used for computation. The biomass that could be obtained was calculated assuming that 30% of them were adult plantations (30% of the land is planted and also adult plantation about 30% is harvested annually by the forest department). Energy from plantations (Bio_2) is computed by

Bio_2 = Bioenergy from plantations (kcal) = Area * Productivity * (Energy equivalent) -------- (6)

The area under the horticulture plantations at the taluk level was obtained from the State horticulture department for the previous 4 years. The average yield figures of the district were used to compute the production at the taluk level. For the computation of number of trees in the given area, tree counts of 150/hectare and 800/hectare were assumed for Coconut and Arecanut plantations.

BEPA requires input data such as crop type (i.e. Coconut, Arecanut etc.), spatial extent, number of trees per hectare, residues (leaf, shell, husk) actual count, anticipated use percent, conversion to weight (kg) and energy equivalent (kcal/kg), while output of the DSS is annual energy--horticulture crop wise, regionwise, etc. Energy from horticulture (Bio_3) is computed by

Bio_3 = Bioenergy from horticulture (kcal) = Area * Productivity * (Energy equivalent) -------- (7)

The taluk--wise agriculture area of the dominant crops cultivated in each taluk was collected from the State agriculture department for the last 10 years. The yield of a crop (season and variety wise) across an agroclimatic zone was obtained by averaging the yields of the previous 10 years. Crop yields were also verified considering the area sampling frame (ASF) methodology. It involves the delineation of long-term sampling segments from satellite imagery. These were then used as sampling frames for subsequent agricultural surveys. The crop residues are surveyed during both the Kharif and Rabi season. Field sampling is carried out within one week before harvest to ensure that crop yield and residue measurements are related to fully mature crops.

Area under cultivation was not variety specific for a crop at the taluk level. The proportion of the area under high yielding variety and the traditional variety of a crop at the district level was used to segregate the area by variety at the taluk level. The grain yield and production figures for each crop were available only at the district level, which were used to compute the grain production at the taluk level.

The ratio of the main product to the by--product for each crop grown under local conditions along with their energy equivalents was used to compute the agro residues production. The energy equivalent of these residues was taken based on what would be obtained if they were subjected to the most energy efficient transformation processes. Apart from this, the actual availability of residues as energy supplements would also depend on other factors like efficiency of collection, mode of transportation and storage. Considering these, in the computation of bio residue from agriculture only 50% is accounted for fuel. Bioenergy from agriculture residues (Bio_4) is computed by:

Bio_4 =Bioenergy from agriculture (kcal)

= (Productivity of waste * Crop area* Energy equivalent)-----------(8)

To compute bioenergy from agricultural crops, BEPA requires inputs such as crop type (i.e. Cotton, Green grams, etc.), spatial extent, crop yield or productivity, residue to crop ratio, energy equivalent (kcal/tonne), while outputs are annual energy--crop wise, regionwise, etc.

The livestock population of cattle, buffalo, sheep and goat was collected from the State veterinary department. The field survey shows that quantity of dung yield varies from region to region. It was taken as 12--15 kg/animal/day for buffalo, 3--7.5 kg/animal/day for cattle and 0.1 kg/animal/day for sheep and goat. The total dung produced annually was calculated by multiplication of the animal dung production per year and the number of heads of different animals taking the lower and higher dung yield. Assuming 0.036--0.042 m^3 of biogas yield per kg of cattle/buffalo dung, the total quantity of gas available was estimated. Total bioenergy from livestock (Bio_5) is computed by:

Bio_5 =Bioenergy from livestock (kcal) = (Biogas * Energy Equivalent)-------------(9)

Where, Biogas (m^3) = Biogas yield * Dung * 1000 and

Dung (tonnes) = Dung yield * Population * 365 (for annual energy computation).

Data input for BEPA to compute energy from livestock are livestock type (i.e. Buffalo, Cattle, Goat, etc.); population, dung yield (kg/animal/day), biogas yield (m^3/kg) and energy equivalent (kcal/m^3), and output would be biogas (m^3) and annual energy.

Total bioenergy available from various sectors is computed by aggregating the energy computed from individual sectors (forestry, plantation, horticulture, agriculture, livestock) and is given by,

$$\text{Bioenergy availability} = \sum_{i=1}^{5} (Bio_i)\text{---------------------}(10)$$

Where i=1, 2…5 and Bio_1: Bioenergy from forest, Bio_2: plantation, Bio_3: horticulture, Bio_4: agriculture and Bio_5: livestock.

Estimation of rural energy demand for domestic purposes was based on the State rural population, which was obtained from the provisional population total, Census of India 2001, Karnataka. Bioresource demand is the sector--wise bioenergy requirement that was computed based on the statistics of earlier energy surveys from a sample of 3500 households covering various agro--climatic zones in Karnataka. Energy--demand survey results reveal that 80--85% of the rural population is dependent on bioenergy and hence the demand was projected taking into account the entire rural population. Domestic fuel consumption depends on the size of the family. Energy consumption patterns are seen to vary across geographical, agroclimatic zones, seasons and the different economic strata of the society. Hence, analysis was done for agro--climatic zones in Karnataka. Per Capita Fuel Consumption (PCFC) is computed to

i). Determine the fuel consumption pattern in various agro-climatic zones,

ii). Find the various parameters involved in the variation and level of consumption,

iii). Estimate the daily per capita consumption of fuel wood in traditional and improved stoves for cooking and water heating.

The per capita fuel consumption is given by

PCFC=FC/P------------------------- (11)

Where *FC* is the fuel consumed in kg/day and *P* is the number of adult equivalents, for whom the food was cooked. Standard adult equivalents of 1, 0.85 and 0.35 for male, female and children (below 6 years) respectively, were used.

Bioresource demand for domestic activity in a region is given by,

Bioresource demand (domestic) = (average PCFC) * Population * 365----------------(12)

Where *PCFC*=Per Capita Fuelwood Consumption.

Bioresource Status for a particular region is computed by,

Bioresource Status = Bioenergy availability/ Bioresource demand (Domestic)---------(13)

RESULTS AND DISCUSSIONS

The flowchart for navigating DSS is given in figure 4. This DSS is implemented and the results are discussed for Kolar district, Karnataka State. An Executable file is provided for this application and by executing this, a form with Login, Level of Analysis and Resources Menu options are displayed.

After logging with the user information, the Level of Analysis option is enabled for hierarchical administrative levels of analysis such as state, district, taluk, town and village levels. This option also enables user to either append data to the database or browse the data. Figure 5 shows the form enabling the data entry of forest type, productivity, year of estimate and spatial extent of the forest. Similar options are available for computing bioenergy from agriculture, horticulture and livestock sectors.

Total forest area in Karnataka State is 38,284.30 sq. km, of which 74.93% is reserved forest, 10.26% is protected forest, 0.32% is village forest, 13.66% is unclassified forests and 0.805% private forests. Provisions to modify or delete or add new forest type with biomass productivity values to the database are provided. Figure 6 displays the computed cover percentage, productivity, biomass yield, and energy equivalent values. User can visualize biomass situation for three cases namely high, low and medium productivity values.

The vegetation cover in Kolar district as per NDVI and TSAVI analyses is about 52.5 %, while 47.5% is not under vegetation. Land use analyses using Maximum likelihood classifier indicate that 46.69% is agricultural land, 42.33% is wasteland (barren land), 4.62% is built up, 3.07% plantation, 2.77% natural forest and 0.53% water bodies. Overlaying district layer with taluk boundaries on the classified district image, talukwise land use details were obtained. Table 1 shows land use details of Kolar district and corresponding percentage share is given in Table 2.

Figure 7 shows data entry of agriculture bioresource for the selected taluk (Chikballapur), district (Kolar) and State (Karnataka). User is provided with options to append, edit and delete agriculture resource details. For appending user has to provide year, season and crop type, production, and area details. A new agriculture crop type, if not present in the database, can be appended with an add/append option. There are options to calculate vegetation cover percentage, productivity and energy equivalent for appended and existing data of a selected taluk. Aggregation of bioresources from various sources (forests, agriculture, horticulture, plantations, animal residues, etc.) represents the bioresource availability.

The ratio of availability to the demand (bioresources) gives an idea of its status in a region. Ratio less than one gives the scarcity of bioresource in that region. The demand was calculated by considering the per capita consumption as 1.3 kg/person/day. Analysis shows that bioresource status in Srinivasapur taluk is higher compared to all other taluks in Kolar district. Table 3 gives the bioresource status talukwise for Kolar district.

Bioresource status ratio (resource to demand) showed that more than 95% villages have very less value (0--0.2), while very few villages have average value (>0.6).

Based on bioresource availability and demand, Kolar can be categorized as bioresource deficit district. Kolar depends mainly on non--commercial forms of energy. Non commercial energy constitutes 84%, met mainly by sources like firewood, agricultural residues and cow dung, while commercial energy share is 16%, met mainly by electricity, oil etc.

Plantation and forest area is very less in Kolar district, which causes scarcity of bioresource, specially fuel wood and imbalance of environment. To maintain the environmental balance and to meet the bioresource demand there should be tree plantations in waste lands and some alternative energy source should be found for cooking need.

Availability of animal residues for biogas generation gives a viable alternative for cooking and lighting fuel and fertiliser. However, to support the present livestock population fodder from agricultural residues is insufficient in this district. Various alternatives such as fuel--efficient stoves, biogas and energy plantations are proposed for improved utilisation of bio resources and to enhance bioresource. Also renewable energy sources such as solar could be viable alternatives for cooking and lighting.

The bioresource potential (from forests, plantations, agriculture, horticulture and animal residues) and demand (domestic, agriculture, industry, etc.) were computed across the agro--climatic zones for Karnataka. Bioresource status computed for various zones shows that the value ranges from 0.23 to 3.8. Bioresource status in north eastern dry zone is 0.23, 0.48 in north eastern transition zone, 0.58 in northern dry zone, 0.46 in northern transition zone, 1.4 in central dry zone, 0.4 in eastern dry zone, 0.93 in southern dry zone, 3.12 in southern transition zone, 3.79 in hilly zone and 3.4 in coastal zone. These values reveal that among the ten agro--climatic zones, the central dry zone, the southern transition zone, hilly zone and the coastal zone are bioresource surplus, while the north eastern transition zone, north eastern dry zone, northern dry zone, eastern dry zone, southern dry zone and northern transition zone are biomass deficient zones.

CONCLUSION

The role of bioresources in meeting a region's requirement of fuel, food, fodder and timber has increased the interest for quantifying the amount of biomass available in a region. In addition to the many environmental benefits, biomass offers many economic and energy security benefits. The estimation of biomass of tropical forests has continually been refined over the past decade or so as the methodologies, knowledge and the technology available for such methods and for such estimation have improved. The technologies and methods used to develop and deploy DSS to aid in biomass energy assessment make work easier for a decision maker. The possibility of quickly accessing and processing large spatial databases over high speeds offers a tremendous improvement. In spite of rapidly advancing computer technology and the proliferation of software for decision support, relatively few DSS have been developed for assessment of biomass energy. This DSS is a User--friendly GUI, which provides user with all needs to estimate and calculate biomass energy at different locations with different conditions. The entire framework is designed in such a way that, user is provided with helpful tips and context--sensitive help options.

The bioresource status analysis shows that Kolar is a bioresource deficit district. Kolar depends mainly on non--commercial forms of energy. Non--commercial energy constitutes 84%, met mainly by sources like firewood, agricultural residues and cow dung, while commercial energy share is 16%, met mainly by electricity, oil, etc.

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Table 1: Land use details of Kolar district

Taluks	Land Use (in Sq. Km)					
	Built--up	Agriculture	Plantation	Vegetation	Wasteland	Water body
Bagepalli	78.26	302.59	1.651	9.058	541.04	6.725
Bangarpet	23.04	495.75	37.29	50.56	258.31	9.125
Chikballapur	18.01	314.45	15.46	30.6	252.46	8.665
Chintamani	50.74	428.91	4.983	1.048	409.68	2.989
Gauribidanur	51.58	325.85	0.715	5.231	511.82	2.924
Gudibanda	8.027	62.343	0.109	1.028	154.36	1.538
Kolar	25.78	406.98	17.4	14.5	330.18	3.233
Malur	10.76	414.67	47.11	3.53	168.51	4.283
Mulbagal	49.81	428.68	15.27	6.358	321.25	4.72
Sidlaghatta	33.95	320.4	35.15	4.731	276.3	2.08
Srinivasapur	32.94	480.4	32.52	57.45	262.81	3.118

Table 2: Talukwise percentage share of land use

Taluk	Land use (%)					
	Built --up	Agriculture	Plantation	Forest	Wasteland	Water body
Bagepalli	8.33	32.21	0.18	0.96	57.60	0.72
Bangarpet	2.69	39.76	8.81	10.46	37.93	0.35
Chikballapur	2.82	49.16	2.42	4.78	39.46	1.36
Chintamani	5.65	47.74	0.56	0.12	45.60	0.33
Gauribidanur	5.74	36.28	0.08	0.58	56.99	0.33
Gudibanda	3.07	44.30	3.28	2.82	45.74	0.79
Kolar	3.23	50.99	2.18	1.82	41.37	0.41
Malur	1.66	63.91	7.26	0.54	25.97	0.66
Mulbagal	6.03	51.89	1.85	0.77	38.89	0.57
Sidlaghatta	5.05	47.63	5.23	0.70	41.08	0.31
Srinivasapur	3.79	55.27	3.74	6.61	30.23	0.36
District %	4.62	46.69	3.06	2.77	42.33	0.53

Table 3: Talukwise bioresource status for Kolar district

Taluk	Bioresource (Lakh kWh)	Demand (Lakh kWh)	Status
Bagepalli	1011.58	3539.57	0.29
Bangarpet	1079.22	9408.85	0.11
Chikballapur	1675.45	4105.63	0.41
Chintamani	860.55	5718.40	0.15
Gauribidanur	1624.47	5825.25	0.28
Gudibanda	310.88	1110.97	0.28
Kolar	768.83	6891.82	0.11
Malur	413.03	4217.88	0.10
Mulbagal	790.05	4922.23	0.16
Sidlaghatta	781.81	4081.81	0.19
Srinivasapur	2904.39	3959.17	0.73

Note: 0.1 Million kWh = Lakh kWh

Figure 1: Design of Decision support system for Bioresource assessment

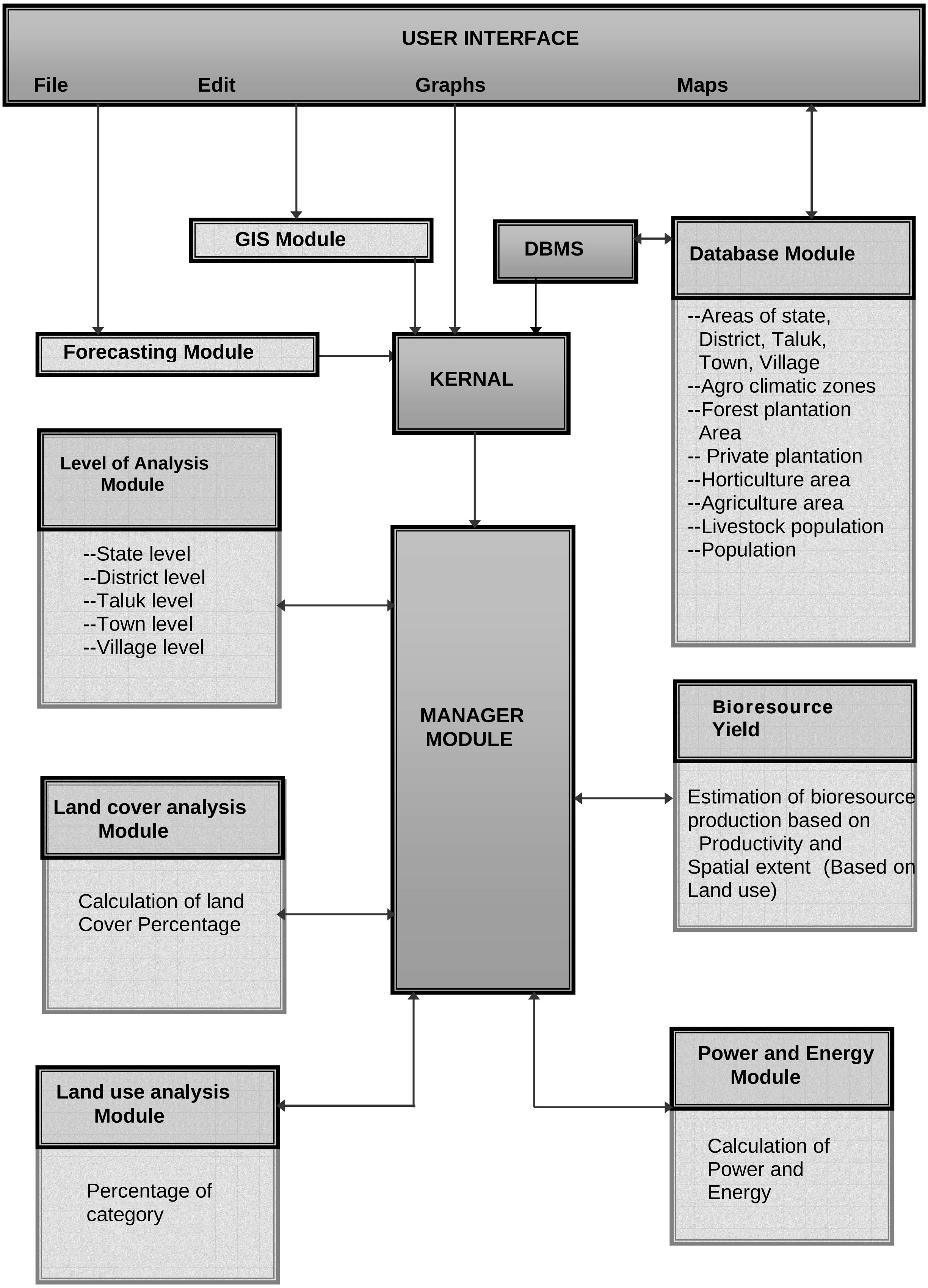

Figure 2: Methodology for assessment of regional bio--resources potential

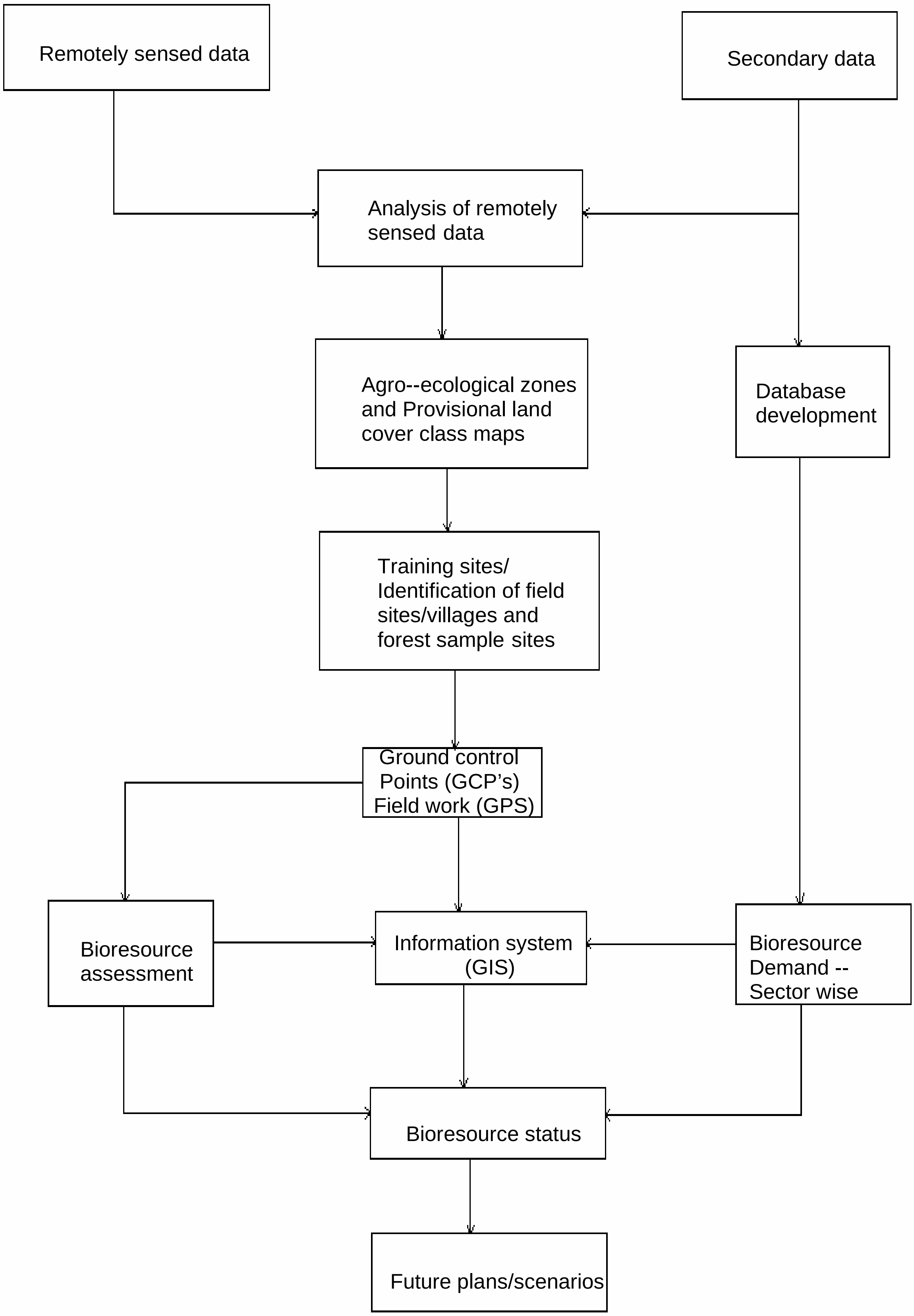

Figure 3: Study area

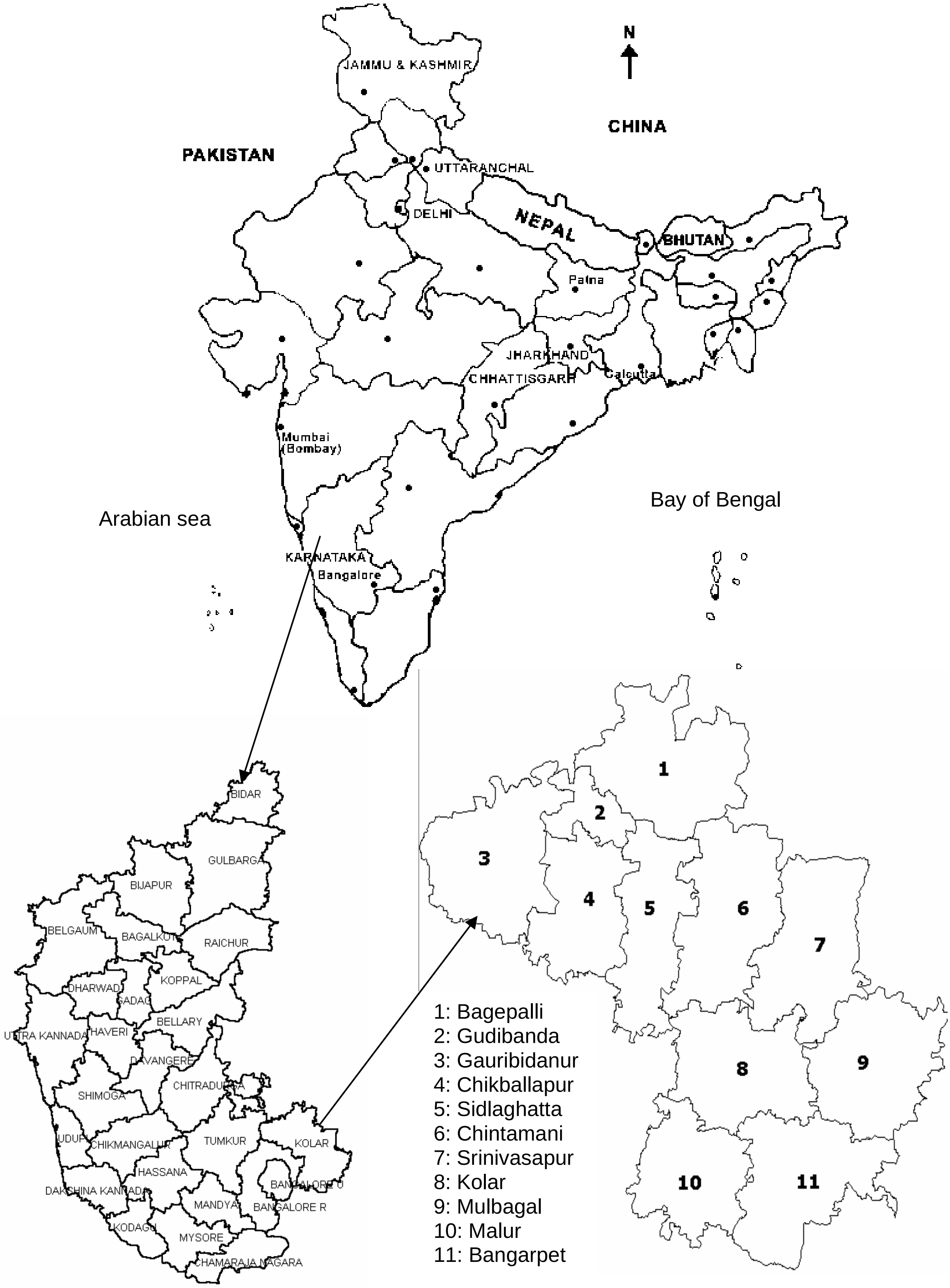

Figure 4: Navigation of DSS

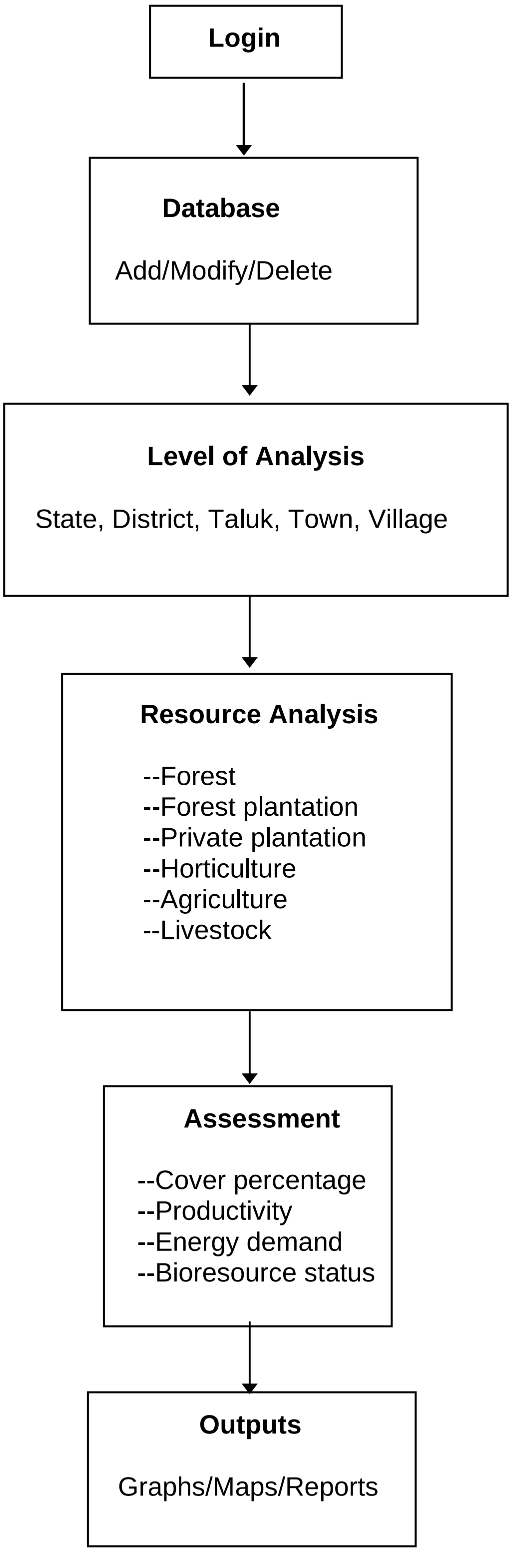

Figure 5: Bio--resource from forests

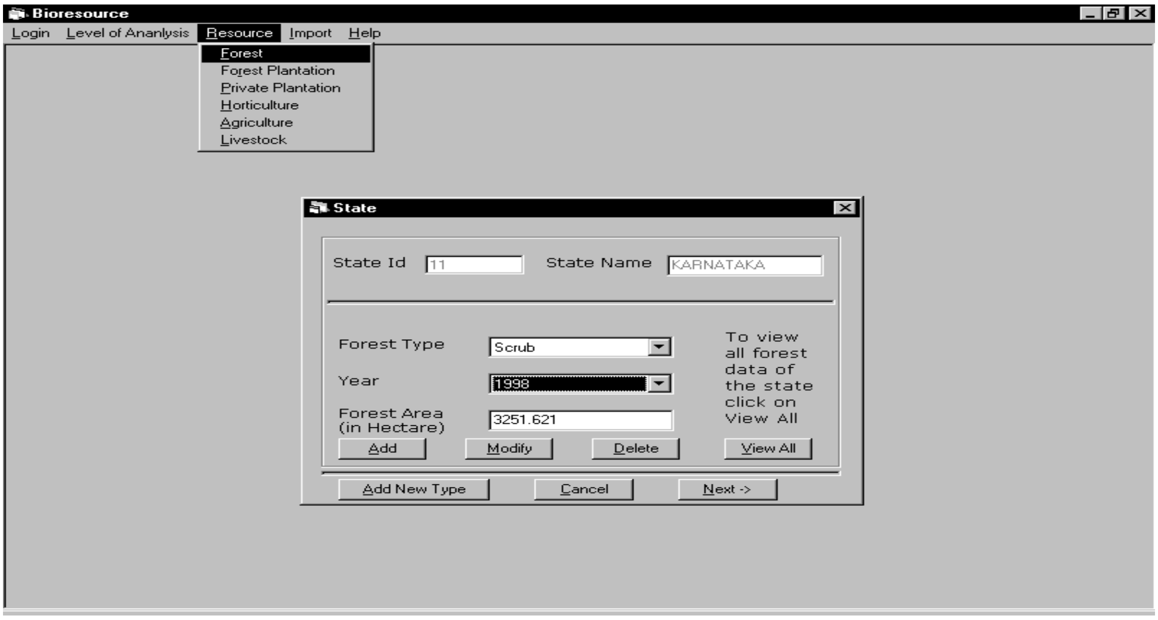

Figure 6: Forest bio--resource, cover percentage, productivity, energy analysis

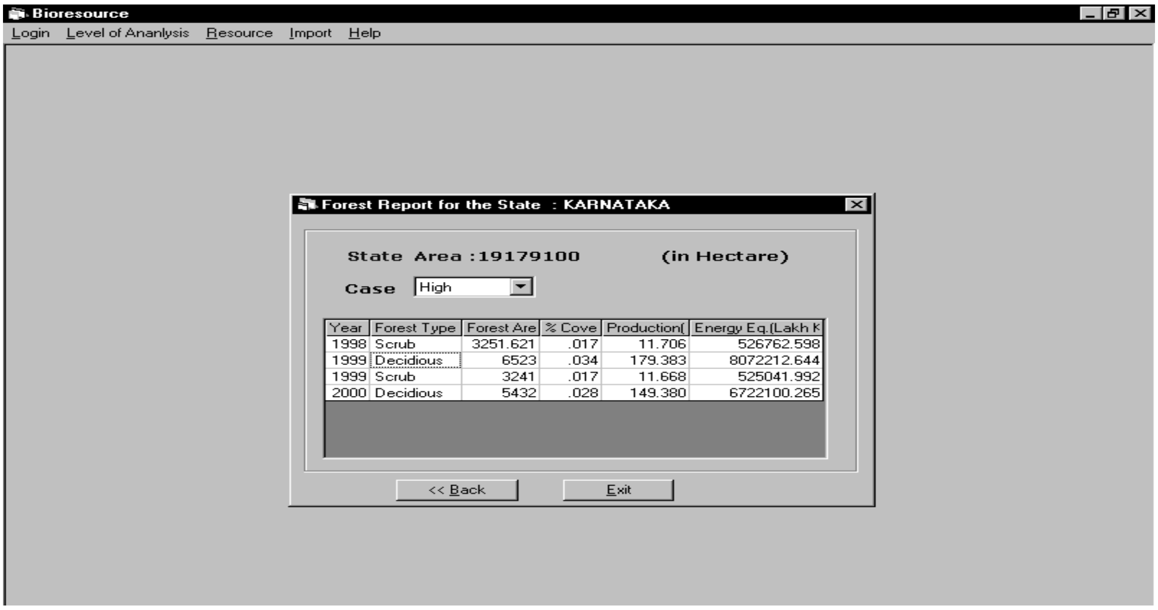

Figure 7: Land use analysis--agriculture bio--resource for Chikballapur taluk