

# Creativity and Cognition in Art and Design



*Edited by*

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B L O O M S B U R Y

# Web Based Spatial Decision Support System for Sustenance of Western Ghats Biodiversity, Ecology and Hydrology

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## ABSTRACT

The Western Ghats with spatial extent of 1,64,280 km<sup>2</sup> (<5% of India's geographical area) is a chain of hills with undulating terrains running in the North-South direction for about 1600 km parallel to the Arabian Sea from river Tapti (22°26'N) to Kanyakumari (about 8°0' N). The region with exceptional biodiversity of endemic flora and fauna: 4,600 species of flowering plants with 38% endemics, 330 butterflies with 11% endemics, 156 reptiles with 62% endemics, 508 birds with 4% endemics, 120 mammals with 12% endemics, 289 fishes with 41% endemics and 135 amphibians with 75% endemics ([http://wgbi.ces.iisc.ernet.in/biodiversity/pubs/ces\\_tr/TR122/index.htm](http://wgbi.ces.iisc.ernet.in/biodiversity/pubs/ces_tr/TR122/index.htm)), is one among 35 global biodiversity hotspots. The rich biodiversity coupled with higher endemism is due to the humid tropical climate, topographical and geological characteristics, and geographical isolation (Arabian Sea to the west and the semiarid Deccan Plateau to the east). The Western Ghats forms an important watershed for the entire peninsular India, being the source of 37 west flowing rivers and three major east flowing rivers and their numerous tributaries. These fragile ecosystems are extremely important for the existence of humankind from the point of productivity, revenue generation, employment potential and subsistence. This necessitates sustainable natural resources management by considering ecological, hydrological, climatic, economic, and social perspectives. An interactive web-based spatial information with the decision support system by integrating heterogeneous spatial information with attribute details aids in good governance while ensuring transparency and dissemination of decisions to all stakeholders. Geovisualization of natural processes and phenomenon through synthesis and integration of information would meet scientific and societal needs through real world knowledge construction. Web based spatial decision support system (WSDSS) is designed by integrating free and open source softwares (Geoserver, PostgreSQL, GeoTools, Openlayers) and integration of spatial information of Open Geospatial Consortium (OGC) standards to carry out a multiple criteria analysis. Features such as Web Map Service (WMS), Web Feature Service (WFS) and Web Coverage Service (WCS) would help in accomplishing effective knowledge dissemination with ecological, socio, economic and environmental perspectives. Integration of spatio-temporal information data with algorithmic techniques facilitate visualization in order to analyze decision problems through exploratory analysis based on multiple criteria to obtain historical, statistical analysis and aid by enabling a detailed comparative analysis of the alternatives. Geo visualization enables enumerating current scenario, visualizing alternate scenario, while predicting likely changes with different agents, which is essential for effective decision making towards sustainable management of natural resources.

**Keywords:** *Geo-visualization, Web Based Spatial Decision Support System, Western Ghats, Biodiversity, Ecology*

## INTRODUCTION

Natural resource management and decision making has become increasingly important with the growing population and changing consumption patterns. The consumption rate of natural resources has increased considerably to about 60 billion tons of raw materials a year during the last 30 years [1]. Unplanned developmental activities coupled with the uncontrolled resource exploitations has stressed the resource availability, biodiversity and ecosystem [2, 3], evident from barren hill tops, and the decline in quantity and duration of water flow in streams and rivers. Natural resources management would be effective with the active participation of all stakeholders with formalize and rationalize decisions. This has necessitated integrating heterogeneous data, making them available to the various stakeholders to allow them to make more informed decisions. Systematic conservation planning is a vital tool for protecting the nature around the world. Ecosystem based management (EBM) of land resources integrating ecological, social, and economic objectives [4], recognizes human dimensions as key functional components of the ecosystem and natural resource management [5, 6]. Integration of multiple criteria considering spatio-temporal aspects would help in the effective decision making. Multiple criteria decision analysis (MCDA) offers structured and systematic decision support through consideration of multiple factors and their value judgements and relative importance of factors [7, 8], which are essential for sustainable management of natural resources. However, non-spatial MCDA with large volumes of complex data has limitations in dynamic applications, which necessitates the design of spatial decision support system with the support for exploration, evaluation and optimal management. Spatial decision support systems (SDSS) aid in organizing, analyzing, modifying, and re-evaluating spatial information for planning activities.

Geovisualization with capabilities of geographical information system (GIS) based MCDA [9] helps in providing dynamic links among maps, tables, and statistical charts to discover new relationships in the data which seeks to dynamically synthesize spatial and non-spatial information in integrated [10]. It focuses on improving public access to geospatial data and maps, providing possibilities for participatory learning and analysis by the general public, in planning and decision making. Use of thematic or topographic maps as background information aid in spatial decision making [11, 12] and also landscape visualization for communicating spatial scenarios for effective understanding of a decision problem [13]. Integrating SDSS with Geo-visualization helps in visualizing the spatial decisions for conservation planning and natural resource management requires ecological, economic, and social perspectives [14]. A web based spatial decision support system (WSDSS) helps in identification and framing of a problem, exploratory development of alternatives, selection of evaluative criteria,

aggregation and weighting of impacts of decision options. The recent advancement to explore future options via 2D mapping (GIS), 3D spatial visualization (WSDSS) and scenario development allows people to link web GIS to a realistic 3D model for visualizing environmental effects of land use changes [15]. The objectives of this communication are:

- (a) To design a web based spatial decision support system (WSDSS), which supports an exploration and visualization of spatial decision making with free and open source tools.
- (b) Integrating exploratory analysis and evaluation phases in the decision making process to attain transparent and interactive system with MCDA.

## STUDY AREA

Western Ghats with spatial extent of 1,64,280 km<sup>2</sup> (<5% of India's geographical area) is chain of hills and undulating terrain running in the North-South direction for about 1600 km parallel to the Arabian Sea from river Tapi (22°26'N) to Kanyakumari (about 8°0' N) is a repository of endemic flora and fauna. It is one of the 35 hotspots of the world having diverse social, religious, and linguistic group. The region harbors very rich flora and fauna and there are records of over 4,000 species of flowering plants with 38% endemics, 330 butterflies with 11% endemics, 156 reptiles with 62% endemics, 508 birds with 4% endemics, 120 mammals with 12% endemics, 289 fishes with 41% endemics and 135 amphibians with 75% endemics ([http://wgbis.ces.iisc.ernet.in/biodiversity/pubs/ces\\_tr/TR122/index.htm](http://wgbis.ces.iisc.ernet.in/biodiversity/pubs/ces_tr/TR122/index.htm)). Uttara Kannada district is located in central Western Ghats with 76% of its 10,291 sq.km area covered with forests has the distinction of having highest forest area. This is the northernmost coastal district of Karnataka State (13.9220° N to 15.5252°N and 74.0852°E to 75.0999°E), topographically the district can be divided into three zones – the narrow and relatively flat to low hilly coastal along the west of Karwar, Ankola, Kumta, Honnavar and Bhatkal taluks; the precipitously rising main range of Western Ghats towards the eastern interior of these taluks, the crestline zone composed of Sirsi, Siddpur Supa and Yellapura taluks and Haliyal and Mudgod taluks towards the north-east flattening and merging with the Deccan Plateau. The district can be divided broadly into five vegetation zones namely: Coastal, Northern evergreen, Southern evergreen, Moist deciduous and Dry deciduous. The evergreen to semi-evergreen forests form major portion of the district especially towards the rainier western parts. Towards the eastern rain-shadow portion, the forests change rapidly into moist and dry deciduous types. Web based SDSS designed with various spatial information related to land, water, biodiversity, ecology and hydrology helps in identifying local hotspots of biodiversity.

## METHOD

The approach includes (i) designing WSDSS, (ii) evaluation through MCDA.

## System Design

Figure 1 outlines the architecture of WSDSS design with open source. The configuration of CentOS operating system with the associated software such as Geoserver, Apache Tomcat 8, Postgresql and Postgis. Apache Tomcat 8 web server enabled to connect and communicate, Postgresql and Postgis was used for spatial database management with PgAdmin interface. Postgresql is an object-relational database management system (ORDBMS) server to store securely spatial data, while allowing retrieval at the request of other software applications. It can handle workloads ranging from small single-machine applications to large Internet-facing applications with many concurrent users. The integration of information reference is done through GeoServer with Open Geospatial Consortium (OGC) standards. GeoServer is an open source server allows users to share, process and edit geospatial data, supports interoperability using open standards. GeoServer connects existing information to web-based maps such as OpenLayers, Google Maps and Bing Maps for effective layer visualization. GeoServer reads a variety of data formats: PostGIS, Oracle Spatial, ArcSDE, DB2, MySQL, Shapefiles, GeoTIF, GTOPO30, ECW, MrSID, JPEG2000. It produces KML, GML, Shapefile, GeoRSS, PDF, GeoJSON, JPEG, GIF, SVG, PNG and more. GeoServer functions as the reference implementation of the Open Geospatial Consortium Web Feature Service standard (WFS), Web Map Service (WMS), Web Coverage Service (WCS) and Catalog Service Web (CSW). WFS Standard provides an interface allowing requests for geographical features across the web using platform-independent

### Western Ghats Spatial Decision Support System Architecture

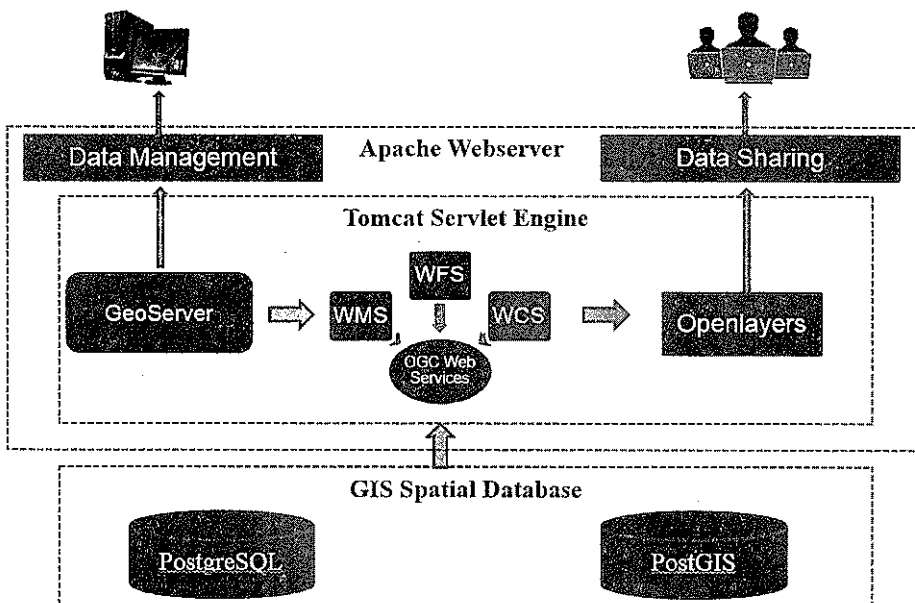


Fig. 1: The Architecture for WSDSS

calls. WFS allows querying and retrieval of features. WMS is a standard protocol for serving (over the Internet) georeferenced map images which a map server generates using data from a GIS database. WCS Interface Standard defines Web-based retrieval of coverages – i.e., digital geospatial information representing space/time-varying phenomena. CSW is a standard for exposing a catalogue of geospatial records in XML on the Internet (over HTTP). The catalogue is made up of records that describe geospatial data (e.g. KML), geospatial services (e.g. WMS), and related resources. The Styled Layer Descriptor (SLD) is an XML-based markup language using for styling both vector and raster data. Quantum GIS (QGIS) is used for SLD creation.

### Spatial MCDA for Prioritization

The spatial MCDA process has been applied to prioritize ecological sensitive regions (ESR) by (1) identification and visualization of individual variables; (2) exploratory development of aggregation and weighting of criteria; and (3) selection and decision. Figure 2 illustrates how each stage of the process can be supported with maps. Map use can be threefold; (1) to communicate spatial information to stakeholders; (2) as analysis tools for spatial evaluation of decision alternatives; and (3) as input for interactive tools for decision support. Map based visualization tools with effective user-friendly interfaces allows to evaluate each criteria and considering biological (terrestrial and aquatic flora and fauna, estuarine biodiversity), ecological (diversity, endemism, conservation reserve), geo-climatic (altitude, slope, rainfall), renewable energy prospects (bio, solar, wind), social (population, forest dwelling communities) (Table 1) [16]. The study area is divided in to  $5' \times 5'$  equal area grids (168) covering approximately  $9 \times 9 \text{ km}^2$  (Figure 3) for prioritizing ESR. The weightages were assigned iteratively across the landscape with varied themes for a development solution and monitoring. The data has been collected from various studies under the specified themes [17, 18, 19, 20, 21, 22, 23, 24, 25, 26]. The criteria were ranked based on Eq. (1) variables generate real time output to support negotiated spatial decisions. Assigning weightages based on the relative significance of themes [27] for prioritizing eco-sensitive regions provides a transparent mechanism for combining multiple data sets together to infer the significance. The weightage is given by,

$$\text{Weightage} = \sum_{i=1}^n W_i V_i \quad \dots 1$$

Where  $n$  is the number of data sets (variables),  $V_i$  is the value associated with criterion  $i$ , and  $W_i$  is the weight associated to that criterion, ranked between 1 and 10. Value 10 corresponds to highest priority for conservation whereas 7, 5 and 3 corresponds to high, moderate and low levels of prioritization. Assigning weightages based on individual proxy based extensively on GIS techniques, has proved to be the most effective for prioritizing ESR. These decision weightages dynamically explore the spatial outcomes of planning alternatives and to quantify real-time changes in terms of indicators of relative suitability. A very important

phase of spatial MCDA consists in the aggregation of the scores related to the different criterion maps useful for the decision [28]. The combined metric score of aggregation operation is a generalization of the Boolean overlay operations and the Weighted Linear Combination (WLC) method used as a technique for ranking criteria and addressing the uncertainty from their interaction.

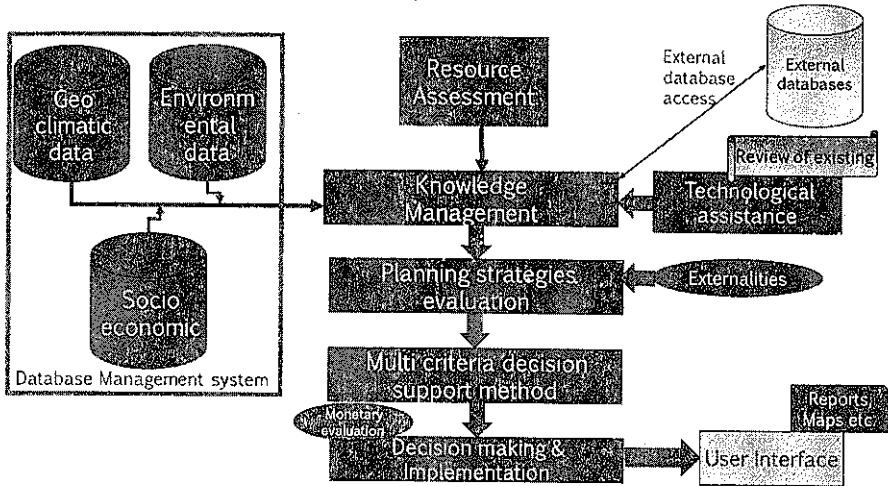


Fig. 2: Flow of WSDSS

Table 1: The Various Themes Considered and their Weightages

| S. No. | Themes                     | Ranking  |                     |                     |                     |                                                                   | Theme        |
|--------|----------------------------|----------|---------------------|---------------------|---------------------|-------------------------------------------------------------------|--------------|
|        |                            | 1        | 3                   | 5                   | 7                   | 10                                                                |              |
| 1      | Land use                   | FC < 20% | 20 < FC < 40%       | 40 < FC < 60%       | 60 < FC < 80%       | FC > 80%                                                          | LAND         |
|        | Interior forest            | IF < 20% | 20 < IF < 40%       | 40 < IF < 60%       | 60 < IF < 80%       | IF > 80%                                                          |              |
| 2      | Flora                      | NEND     | END < 30%           | 30 < END < 50%      | 50 < END < 70%      | END > 70%                                                         | ECOLOGY      |
|        | Fauna                      | -        | NEND                | -                   | -                   | END                                                               |              |
|        | Conservation reserves (CR) | -        | -                   | -                   | -                   | National parks, Wild life reserves, Myristica swamps, Sanctuaries |              |
|        | Biomass (Gg)               | BM < 250 | 250 < BM < 500      | 500 < BM < 750      | 750 < BM < 1000     | BM > 1000                                                         |              |
| 3      | Slope                      | -        | -                   | -                   | Slope > 20%         | Slope > 30%                                                       | GEO-CLIMATIC |
|        | Precipitation              | -        | 1000 > RF > 2000 mm | 2000 > RF > 3000 mm | 3000 > RF > 2000 mm | RF > 4000 mm                                                      |              |

| S. No. | Themes                               | Ranking  |                |                                                                                         |                                 |                                   | Theme                  |
|--------|--------------------------------------|----------|----------------|-----------------------------------------------------------------------------------------|---------------------------------|-----------------------------------|------------------------|
|        |                                      | 1        | 3              | 5                                                                                       | 7                               | 10                                |                        |
| 4      | Stream flow                          | WA < 4   | 4 < WA < 6     | 6 < WA < 9                                                                              | 9 < WA < 12                     | WA=12                             | HYDRO-<br>LOGY         |
| 5      | Solar                                | -        | -              | < 5 KWh/<br>m <sup>2</sup> /day                                                         | 5-6 KWh/<br>m <sup>2</sup> /day | 6-6.5 KWh/<br>m <sup>2</sup> /day | ENERGY                 |
|        | Wind                                 | -        | -              | 2.4 to 2.55<br>m/s                                                                      | 2.5 to 2.6<br>m/s               | 2.6 to 2.7<br>m/s                 |                        |
|        | Bio                                  | SD < 1   | SD > 1         | 1 > SD < 2                                                                              | 2 < SD < 3                      | SD > 3                            |                        |
| 6      | Population density (PD)              | PD > 200 | 100 < PD < 200 | 100 < PD < 150                                                                          | 50 < PD < 100                   | PD < 50                           | SOCIAL                 |
|        | Forest dwelling communities (Tribes) | -        |                | Tribes are present then assigned 10; if no tribal population exists, then assigned as 0 |                                 |                                   |                        |
| 7      | Estuarine regions                    | -        | low            | moderate                                                                                | high                            | very high                         | ESTUARINE<br>DIVERSITY |

FC-forest cover; IF-interior forest cover; END-endemic; NEND-non-endemic; BM-biomass; SD-supply to demand ratio; WA-Water availability

## RESULTS

The WSDSS provides and integrate framework for easy access of information and evaluation with a unified user interface, comprising fully menu-driven graphical user interface, with a built in context sensitive help features, designed by incorporating web technologies and open source tools special feature of the database is its handling, display and analysis of observation time series data, with a linkage to real time data and monitoring with comparative analyses of various scenarios and effective graphical outcomes. The user interface is as outlined in Fig. 3. Multiple options are visualized (state/district wise) with the Western Ghats as backdrop (OpenStreetMap or Bhuvan) is shown in Fig. 4. The selected district is highlighted with various variables information (Figs. 5-8). The Uttara Kannada region is considered for visualization and WSDSS evaluation. The user has option to select and query variables under each theme to evaluate (Fig. 9). The querying is allowed to generate user defined maps, for example population density map generated based on the query. The aggregated rank corresponding to biological, ecological, geo-climatic, renewable energy and social variables is analyzed to prioritize ecologically sensitive regions (ESR) and graded as ESR 1, ESR 2, ESR 3 and ESR 4 respectively (Fig. 10). Uttara Kannada district has 209 panchayats and among these, 102 panchayats are in ESR 1, 37 panchayats in ESR 2, 33 panchayats in ESR 3 and 37 in ESR 4. Sahyadri and eastern part of coastal regions represents highest ecological sensitivity.

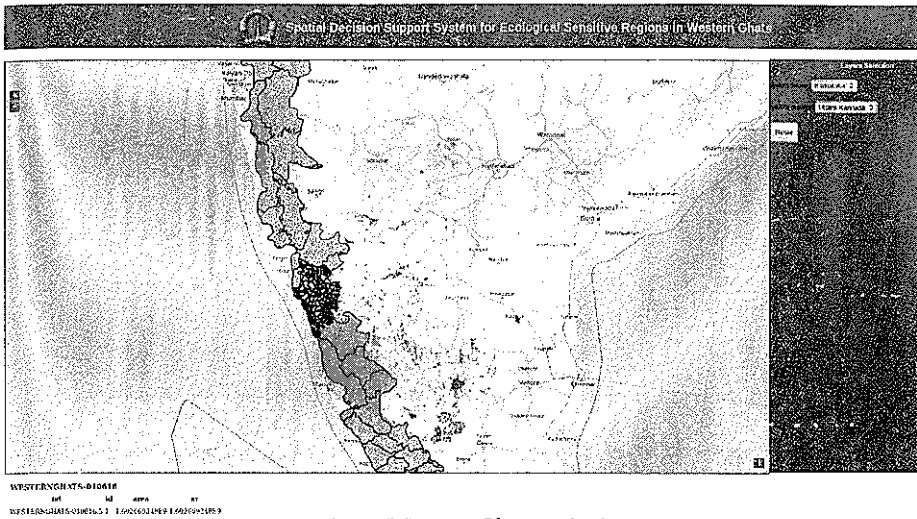


Fig. 3: Western Ghats WSDS

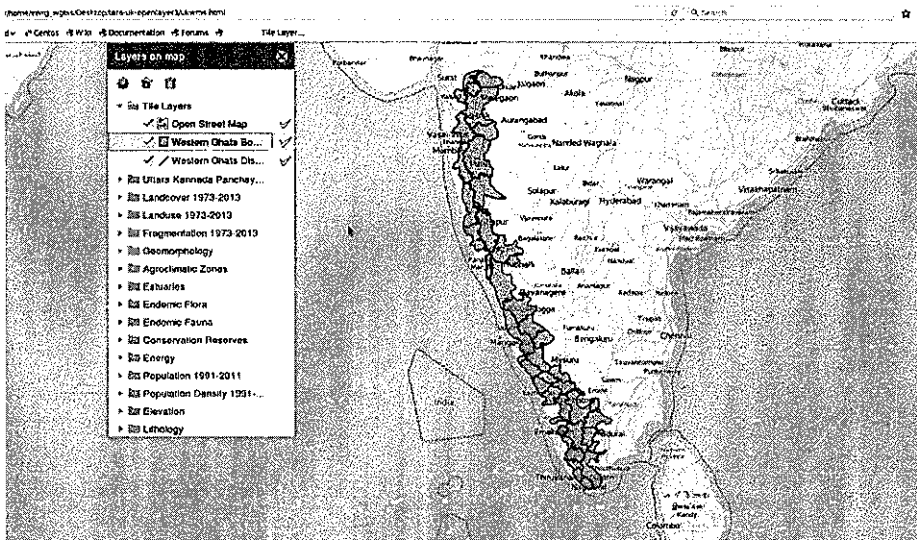


Fig. 4: The Western Ghats as Shown in OpenStreetMap Backdrop (WMS)

The ESR 1 represents ecologically highly sensitive requiring strict conservation measures with sustainable management involving VFCs (Village forest committees). ESR 2 is as good as ESR 1, except degradation of forest patches in some localities. ESR 3 represents moderate conservation region and only regulated development is allowed in these areas. ESR 4 represents less ecological sensitiveness. The non-spatial data also been provided for the better understanding of region's status in terms of reports. The regulated and restricted activities in ESR also provided as a report form to further aid in decision making. The sustainable developmental framework has provided for the management of ESR with improvement of environment by public



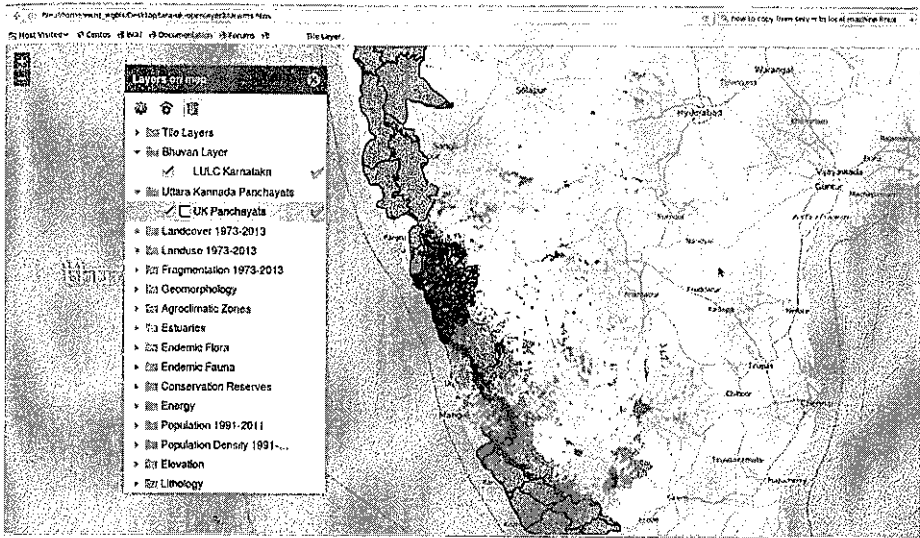


Fig. 8

Figs. 5–8: The Selection of Region in Western Ghats Based on User Input

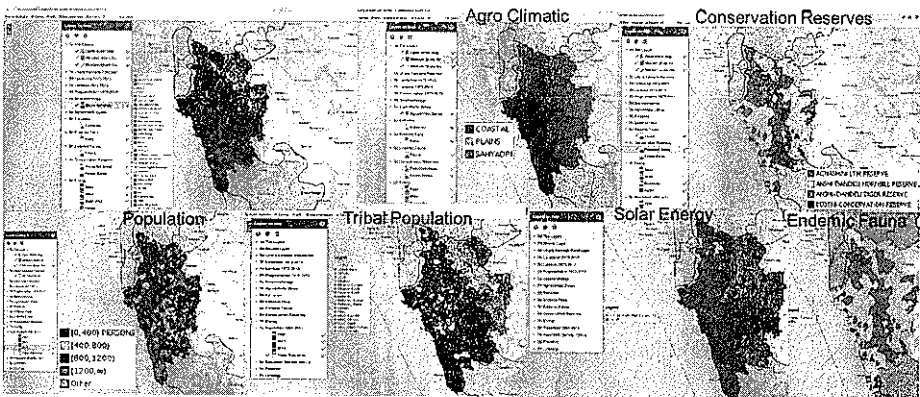


Fig. 9: The Thematic Maps of Various Variables Considered and their Information

private partnership and distributed development. This also points out to establish a well ordered decision making process by regulatory authorities, which include stake holder's involvement and their priorities for livelihood. Moreover, maps can be integrated with real-time analysis and visualization tools into collaborative environments to support group decision-making.

## CONCLUSION

WSDSS with MCDA designed to prioritize ecologically sensitive regions based on biological, ecological, geo-climatic, renewable energy and social variables. The designed WSDSS provides an integrate framework for easy access of data comprising fully menu-driven graphical user interface, effective database

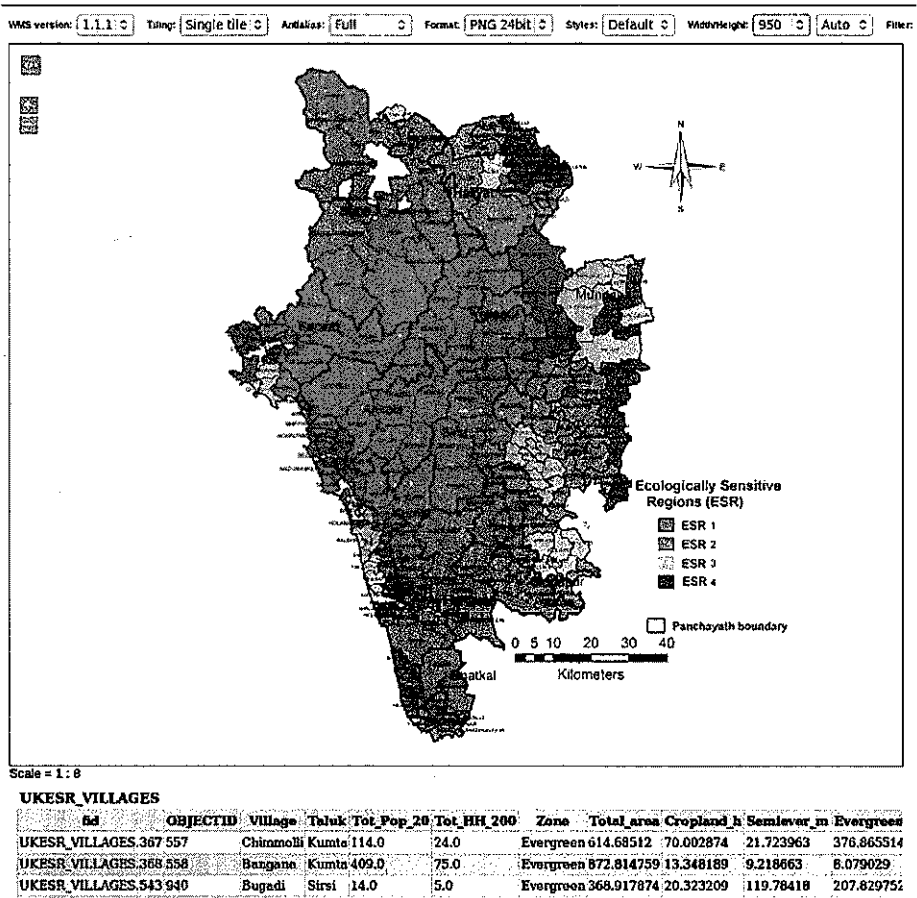


Fig. 10: Ecologically Sensitive Regions of Uttara Kannada Based on MCDA

handling, display and analysis of observations with a linkage to real time data. Web based Spatial decision support system aids in decision making through effective visualization and querying through integration of multiple information. The comparative analyses of various scenarios and effective graphical outcomes enables end user to effectively analyze specific information. The external support services have been integrated to enhance the capability with a variety of data sources, formats for effective decision making. The attributes include geo-climatic features, the biological features and the social relevance of a locality. The results highlight the prioritized ecologically sensitive regions in Uttara Kannada region at panchayat level. Uttara Kannada district has 209 panchayats and among these, 102 panchayats are in ESR 1, 37 panchayats in ESR 2, 33 panchayats in ESR 3 and 37 in ESR 4. The Resource managers and policy decision makers can use this information for effective management and conservation in relation to the environmental status of the region.

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'Creativity' is a topic of immense interest to Researchers and Practitioners of multiple domains working towards understanding the process of Creative application as well as in the workings of Mind and Brain in creative endeavors. This book contains papers that showcase the multivariate aspects of creativity as is practiced, researched and is applied in education. This book will give invaluable information and insight into the current avenues of research and innovative ways of application into practice of creativity.

This book contains unique research studies undertaken under four sections of Practice of Creativity, Science & Understanding of Creativity and Education of Creativity. Each paper showcases the multidisciplinary aspect of creativity and the particular challenges faced in the research study.

**Prof. Aneesha Sharma** is affiliated with National Institute of Design (NID), Bangalore, India. Aneesha holds research expertise in Creativity, especially in the domains of Art and Design with a special focus on self-transformative experiences during creative processes.

**Prof. Jamuna Rajeswaran** is affiliated with Department of Clinical Psychology and heads of the Clinical Neuropsychology Unit at National Institute of Mental Health and Neuroscience (NIMHANS), Bangalore, India. She is a pioneer in EEG Neurofeedback Training and has worked in cognitive neuroscience of creativity especially the Brain Correlates of Creativity.



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