INTEGRATED ADVANCED REMOTE SENSING GIS STUDY FOR BAMBOO BASED LIVELIHOOD ANALYSIS AND RURAL DEVELOPMENT PLANNING IN NHAMATANDA, DONDO DISTRICTS OF SOFALA PROVINCE, MOZAMBIQUE

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SUMMARY

Mozambique has undergone substantial changes in its natural resources since its independence, largely in response to changing economic and political setting. As a result several polices have been approved and adopted on renewable natural resources and regulation of their use to guide sustainable development in the country.

Of the existing natural resources, forest resources play an important role in the economy of Mozambique. They are a significant source of livelihood and food security for rural people. However, with the annual change in forest cover estimating to 50,000 hectare, deforestation and land degradation are becoming a major problem. Hence, this calls for re-evaluation of the institutions and policies, which guide an integrated approach for rural development planning with a focus on Sustained Secured Livelihoods (SSL) generation based on optimal utilization of forest resources.

In this context present study had been taken up jointly by FAO, IUCN, and INBAR with a technical support from RMSI Private Limited, India. The study broadly aimed at establishing a pilot model of integrated approach of remote sensing system and GIS and tests its utility in Mozambican context for livelihood development.

Base layers representing terrain (elevation, slope and aspect), physiography (soil texture, soil porosity, drainage pattern etc.), climate (rainfall, temperature) and infrastructure (road, power line, railway line and village location) were prepared from available maps and satellite data. Mapping of land use land cover features, forests distribution and wastelands was also carried out using satellite data.

Primary analysis were carried out for soil erosion, agriculture zonation, watershed delineation, stock mapping for bamboo and timber using the information contained in base layers. Output maps were used further for secondary /conditional analysis in GIS by giving probabilistic weightage and field data inputs.

The parts of Africa and Central Asia are recognized as being particularly vulnerable to adverse climate change brought about by global warming. In this context carbon emission and carbon sequestration mapping at tier-1 level were carried out in the present study. Vulnerability analyses for flood risk and forest fire were also taken up and priority villages for mitigation have been suggested.
To meet specified criteria e.g. suitable locations for bamboo nursery, plantations, ANR and industry setup for active carbon plant, gasifier plant and charcoal plant based on availability and distribution of bamboo and timber resources, site suitability analysis were carried out for forest and bamboo resource planning.

Human resource development is an essential component for ensuring sustainable development. The study therefore presented GIS based analysis for locating potential markets for several commodities such as bamboo poles, handicrafts and mats along with the potential rural markets and industrial site location based on input database created in the project and those made available by partner agency (CEF).

Use of GIS for deriving various output layers would help the planners in judicious utilization of the valuable natural resources of the region and livelihood development for local inhabitants. The modeling framework can be further improved by incorporating more exhaustive data on livelihood pattern, resource usage/dependency and socio-economic fabric of the rural communities. The information derived hence can be used for devising more practical and integrated approach for resource planning and development in Mozambique.

1. INTRODUCTION

Mozambique, situated in the eastern coast of African Subcontinent, is spread over an area of 799390 Km$^2$ and the total population of the country is approximately 17 million. The country has vast land, water resources and good forest cover. Agriculture in a shifting cultivation mode is the main source of livelihood to the rural household of Mozambique. However, crop failure due to drought, flood, pests etc. is a common phenomenon. In such situations forests remains the main off-farm source of income. Forestry sector also plays an important role in the economy of the country by contributing 18% of the GDP and supplying about 80% of the energy demands (Nakala and Cuemba, 1998). Forests in Mozambique falls under 4 major zones (adapted from de Campos Andrada 1951);

- Moist (hygrophile) forests in Milange, Gurue, Tacuane, etc. The forest in this moist environment used to be thick and well developed but now openings promote fire events.
- Mesophile forest at medium altitude characterized by a habitat, which is neither very moist nor very dry. Vegetation is composed principally of Brachystegia and Julbernardia globiflora and it is commonly open with frequent meadows where grass grows tall and thick.
- Low altitude dry (xerophile) vegetation is found relatively close to the littoral zone where the habitat is characterized by intense droughts. The timber rich forest in places such as Derre and Buzi is deciduous.
- Dry to arid forest of Colophospermum mopane and/or Acacia spp. is associated with low and scarce to non-existing annual grass.

Food, shelter and energy needs of people in many rural areas are met from these forests. Timber industries in the country contribute to the economic development by exploiting and trading valuable timber resources. Therefore, by and large forests provide food security, employment and income to the people. However resource conflicts are also common due to limited availability of forest over its utilization among the various stakeholders viz. i.e. the government, private owners and the communities each having their own set of priorities i.e. conservation, exploitation and livelihood respectively. This has accelerated the activities such as deforestation, illegal felling, manmade fires and encroachments that in turn have resulted in fragmented forests and low species diversity.

The effective solutions to this problem could be achieved by laying down an integrated approach for rural development planning with a focus on Sustained Secured Livelihoods (SSL). In the existing situation bamboo, a vastly available resource in north and central parts of the country could be used as a supplement to meet the emerging demands in a sustainable way. Bamboo, the fastest growing woody plant in the world, is
considered as the most valuable resource because of its diversified utility. It is already a source of income, food and housing to over 2.2 billion people worldwide and is known worldwide to meet the global challenges.

Bamboo is widely used for various purposes. It can act as a medium for construction, source of energy, food, industrial use, paper manufacturing etc. It can also be effectively utilized for arresting soil erosion and riverbank cutting. It grows very fast and holds the soil particles together. Even after cutting the bamboo culms, bamboo roots holds the soil together and again new culms germinate from the roots. Bamboo is very light in weight and therefore it can be planted on high slopes to protect the slope failure. Livelihood options based on bamboo and bamboo-based products not only provide livelihood to the people but in a long run would also help in reducing pressure on forest.

Serious attempt are being made in the direction of making bamboo as a contributing factor in the sustainable development. For micro-level development and sustainable exploitation of this locally available bamboo resource, its quantification and assessment becomes mandatory. In order to utilize the locally available resource in sustainable and effective manner micro-level studies are required. For such a detailed action plan several factors are required to be analyzed. Therefore creation of base line information becomes mandatory which could be collected from various sources from topographical maps, satellite images, existing maps, census data, field survey etc. However, the information alone does not help in understanding the problem in an effective manner.

Holistic approach and proper planning are very important components for developmental activities. Remote sensing and Geographical Information System (GIS) are widely used tools for resource inventory, planning, monitoring and evaluation. The basic advantage associated with satellite remote sensing and GIS derived outputs, once created this data can be readily updated and used. For the present study all the data were brought to one platform and one coordinate system. Information thus collected were converted into digital form through digitization and image interpretation into various GIS layers for further analysis. In nature there are several factors that influences and make certain areas more suitable for a particular use than in comparison to other uses. Identification of such areas can be done through conditional analysis using GIS. Based on the pre-conditions identified for setting up bamboo-based industries, set of rules were prepared and thus applied to input layers (map). This resulted in the output locations that are best suitable for particular industry. Several iterations/calibrations are generally required to get the optimal result. In the process several new conditions were incorporated for various analysis based on the inputs collected by the experts during fieldwork. Once the analysis completes; then starts the monitoring phase. The monitoring part become very easy once all the data model is put one system. The basic layers can be updated in future with recent information from the field or from satellite imageries for monitoring and evaluation purposes in time and cost effective manner.

2. Goals / objectives

The main goals of this project were to;

- Establish a Rapid bamboo resource assessment model to address emergencies of bamboo flowering
- Establish a pilot model of Advance Remote sensing system and test its utility in Mozambican Context for livelihood development based on natural resource utilization

A resource inventory of bamboo, forest resources, base maps, infrastructure maps, socio-economic and climatic data in terms of GIS and non-GIS database for the project area (Nhamathanda, Dondo and parts of Gorangosa district of Sofala Province of Mozambique) were created using information available from various maps, satellite imagery (classification, matching of the signature of bamboo with ground truthing), and other non-GIS sources. These were a regional level database where information on natural resource for the Nhamathanda, Dondo and parts of Gorangosa district were generated and incorporated into the database. Brief outline of the work carried out is as follows:
• Remote Sensing based bamboo and forest resource inventory
• Ground truthing and collection of GPS points
• To provide multiple user GIS (natural resource inventory, base map and infrastructure maps) database.

3. STUDY AREA

The project area consists of 5000 sq kms of the area that includes Nhamatanda and Dondo and parts of Gorangosa districts of Mozambique (Fig.1).

![Location map of the study area](image)

Figure 1: Location map of the study area

4. DATA AND SOFTWARE USED

Following data inputs were used by for this study:

• Topographical maps produced by Não disponivel na carta at 1:200,000
• Landsat-7, IRS Resourcesat LISS-IV (5 scenes for sample sites) and MODIS (Moderate Resolution Imaging Spectroradiometer) satellite images covering the study area.

Details of satellite images are given below:

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Swath (K m)</th>
<th>No. of Bands</th>
<th>Spatial Resolution (m)</th>
<th>Area Coverage (sq km)</th>
<th>Path/Row</th>
<th>Date of Acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>Resolution</td>
<td>Spectral bands</td>
<td>Date of Acquisition</td>
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<tr>
<td>Landsat TM</td>
<td>185 X 185</td>
<td>7 Multi Spectral 1 Pan</td>
<td>30</td>
<td>(1) 167/73 (2) 167/74 (1) 30 December 2000 (2) 7 May 2001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRS LISS-IV</td>
<td>23 X 23</td>
<td>Visible and Near Infra Red</td>
<td>5.8 m</td>
<td>(1) 102/18 (2) 202/16 (3) 202/17 (4) 202/18 (5) 202/17 (1) 01 September 2005 (2) 13 October 2005 (3) 13 October 2005 (4) 13 October 2005 (5) 31 August 2005</td>
<td></td>
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</tr>
<tr>
<td>MODIS</td>
<td>2330X 2330</td>
<td>36 bands</td>
<td>250</td>
<td>54,28,900</td>
<td>Two images</td>
<td>(1) 20 August 2003 (2) 13 August 2003</td>
</tr>
</tbody>
</table>

- **Base Maps** –
  o Forest Cover – Saket maps (Natural Vegetation Cover of Mozambique produced by Saket, 1994)
  o Administrative boundary map provided by CEF
  o Soil maps provided by CEF

- **Climatic Data**
  o Rainfall map
  o Temperature map

- **Socio-economic data**
  o Village information like village location (latitude/longitude), name, population, density, habitation etc. provided by CEF Mozambique.

- **Infrastructure maps**
  o Road networks: Road network map was updated using satellite images (Both Landsat TM and IRS LISS-IV). The vector file received from CEF was having planimetric error (shift of feature from its original location), therefore, road network was corrected in terms of planimetric accuracy by capturing the road features from satellite images and also with reference to GPS locations collected during field work.

- **Forest inventory data**: Forest resource inventory was carried out using Landsat satellite images of year 2000-01 and in order to accurately map the bamboo distribution areas IRS LISS-IV scenes of selected areas of bamboo wherever available with reference to the field knowledge in consultation with CEF.

- **Average carbon sequestration**: Land use land cover based average carbon sequestration map was generated using well-defined factors for different land use land cover units.

For satellite image based forest/bamboo resource inventory ERDAS Imagine image processing software was used. For base layers creation and GIS analysis Arc View 3.2/ArcGIS were used. MS-Office has been used for preparation of reports and data tables.

5. **METHODOLOGY**

Methodology adopted for mapping required thematic layers and subsequent analysis for bamboo based livelihood development is given in detail in the following diagram.
6. RESULTS

As part of this study below given thematic maps were prepared.

<table>
<thead>
<tr>
<th>Thematic Maps Prepared for the Study</th>
<th>Use and Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DEM (Digital elevation model)</td>
<td>Digital Elevation Model is a 3-dimensional surface. Free DEM database was collected/downloaded (Shuttle Radar Topography Mission) SRTM website. For Mozambique SRTM is available at a resolution of 90m. This was utilized for all topographical studies.</td>
</tr>
<tr>
<td>2. SLOPE</td>
<td>Slope is the rate of change in elevation from a point to nearby point. In GIS terminology also slope is the maximum rate of change in value of elevation from each cell to its neighbors. Slope map was generated from the SRTM DEM.</td>
</tr>
<tr>
<td>3. Drainage (Perennial and seasonal)</td>
<td>Drainage map was created from topographical maps at 1:50,000 scale and updated using Landsat satellite imagery.</td>
</tr>
<tr>
<td>4. Soil Type</td>
<td>Soil type map provided by CEF was used for various analyses.</td>
</tr>
<tr>
<td>5. Climatic data (rainfall, temperature)</td>
<td>Climatic maps were prepared using interpolation technique.</td>
</tr>
<tr>
<td>6. Socio-economic maps</td>
<td>Socio-economic data supplied by CEF in digital format (MS-Excel and Access) was used for various scenario based GIS analysis.</td>
</tr>
<tr>
<td>7. Base maps</td>
<td>Base map includes village location points, captured from topographical maps.</td>
</tr>
<tr>
<td>8. Infrastructure maps</td>
<td>Infrastructure map includes road, rail network and power lines. Major road and rail features were captured from topographical maps and realigned from satellite images. In case of Landsat image it was difficult to discriminate and precisely mark railway line with planimetric precision, therefore, LISS-IV satellite images (high resolution) were used for the same. Power lines were captured from topographical maps.</td>
</tr>
<tr>
<td>9. Land use/Land cover (LULC)</td>
<td>Land use/ Land cover (LULC) is the distribution of natural as well as man-made features on earth surface. LULC map for the study area was generated through image processing and classification of satellite imageries.</td>
</tr>
<tr>
<td>10. Forest distribution map</td>
<td>Forest distribution map was prepared using satellite imageries, ground truths and topographical maps.</td>
</tr>
<tr>
<td>11. Timber species map</td>
<td>Timber species distribution map was generated through satellite based classification using GPS based ground information.</td>
</tr>
<tr>
<td>12. Bamboo distribution map</td>
<td>Bamboo distribution map was generated through satellite based classification using GPS based ground information. This was digitally classified using successive masking technique and knowledge based classification.</td>
</tr>
<tr>
<td>13. Bamboo stock map</td>
<td>Bamboo density map was generated based on the density of bamboo clumps as inferred from the field survey. The density map was further classified through Hybrid</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td>14. Shifting cultivation area</td>
<td>Approach using satellite image and GPS based field information. Current shifting cultivation areas were clubbed together in wasteland map itself as one of the class.</td>
</tr>
<tr>
<td>15. Erosion area mapping</td>
<td>Erosion prone areas were mapped using NDVI index generated from satellite imageries that was further overlaid over DEM and slope to demarcate various categories of erosion susceptibility.</td>
</tr>
<tr>
<td>16. Degraded land mapping</td>
<td>Degraded land mapping was done using satellite images and ground-based information. The output was clubbed together with Wasteland map.</td>
</tr>
<tr>
<td>17. Wasteland Map</td>
<td>Wasteland mapping was done through satellite interpretation and ground based information.</td>
</tr>
<tr>
<td>18. Carbon emissions</td>
<td>MODIS satellite images were used to map the forest fire areas (fire anomaly pixels). The map was further processed (using forest biomass and carbon emission factor, source – Trozzi and Vaccaro, 2002) to derive total amount carbon emission from the fire sites. This was a regional analysis to understand the scenario and future planning and advancement.</td>
</tr>
<tr>
<td>20. Industrial locations</td>
<td>Potential sites for Bamboo based industries require technical specification related to the terrain, transportation, socio-economic set-up, resource availability etc. For suggesting/recommending sites for industrial activities RMSI undertook a GIS analysis based on the guidelines set by expert committee from organization like CEF/INBAR whose inputs were essential and critical.</td>
</tr>
<tr>
<td>Some additional analysis that were carried out based on available and derived information is as follows:</td>
<td></td>
</tr>
<tr>
<td>21. Mapping of Degraded areas for Assisted Natural Regeneration (ANR) of forest</td>
<td>This map was created with the basic aim of cost efficient way of regenerating forest, to provide job opportunities for communities, to contribute to strengthening biodiversity, to provide hunting areas and to increase carbon sequestration and carbon sinks which contribute to climate change mitigation.</td>
</tr>
<tr>
<td>22. Low and High Value forest</td>
<td>The forest maps were classified as per the importance</td>
</tr>
<tr>
<td>23. Potential Agriculture area</td>
<td>This analysis was carried out for agriculture development</td>
</tr>
<tr>
<td>24. Potential Bamboo poles production and enterprise area with sustainable</td>
<td>It helped in identification of potential sites for bamboo pole production and sustainable harvesting schemes</td>
</tr>
<tr>
<td>25.</td>
<td>Potential Bamboo charcoal production &amp; enterprise area with sustainable harvesting</td>
</tr>
<tr>
<td>26.</td>
<td>Potential Bamboo Mat production and enterprises area with sustainable harvesting</td>
</tr>
<tr>
<td>27.</td>
<td>Potential Bamboo handicrafts production and enterprise area with sustainable harvesting</td>
</tr>
<tr>
<td>28.</td>
<td>Locations suitable for establishing Bamboo Nursery</td>
</tr>
<tr>
<td>29.</td>
<td>Potential Bamboo plantation area</td>
</tr>
<tr>
<td>30.</td>
<td>Potential Timber charcoal production &amp; enterprise area with sustainable harvesting</td>
</tr>
<tr>
<td>31.</td>
<td>Potential Active carbon production and enterprise with sustainable harvesting</td>
</tr>
<tr>
<td>32.</td>
<td>Potential Gasifier enterprise area with sustainable harvesting</td>
</tr>
<tr>
<td>33.</td>
<td>Optimal human settlement areas</td>
</tr>
<tr>
<td>34.</td>
<td>Vulnerability analysis</td>
</tr>
<tr>
<td>35.</td>
<td>Allied agriculture development activities</td>
</tr>
<tr>
<td>36.</td>
<td>Allied Forest activities</td>
</tr>
<tr>
<td>37.</td>
<td>Regular Development activities</td>
</tr>
</tbody>
</table>
- Optimal rural market location
- Other industrial potential like food processing, cold storage etc

and suggested with proper management schemes like storages and transportation.

Below given figures – 2 to 4 shows the maps generated for the above mentioned analysis.
Figure 2: Advance use of GIS in Livelihood planning and decision making

Figure 3: Base maps prepared for the study
7. Conclusion

As bamboo is a very useful resource and its growth and regeneration takes lesser time as compared to tree therefore the need of the hour is to use it in a much more scientific manner for sustainable development at micro level. The use of GIS and remote sensing for such resource based livelihood development is immense. GIS not only provides a platform for analyzing various set of conditions based on physical attributes but its capability to query the database is enormously helpful for planners. In addition, because of its ability to link into remote sensing, it is possible to monitor and assess progress of resource growing activities in a shorter time period, undertake monitoring in areas that are not easily accessible by road or road access is not available, and perhaps reduced costs. The ability to map the earth surface from the sky through satellites and the intelligent queries through GIS, not only helps in planning and monitoring the projects but in channelising the expenditure on the developmental process in an effective manner.

For any GIS based study the most important pre-requisite is the collection and compilation of accurate and authentic data. The data should be complete in most of the respect. Inadequate data layers means that the analysis will not be very authentic as there is every possibility that the layer which is missing from analysis might be the one of the important layers that puts constraints for particular analysis. This will eventually lead to some amount of in accuracy in the data. In order to overcome the lacuna of shortage of information about certain GIS layers, validation
of the results from the field becomes mandatory. The field-based validated information can be incorporated in the refinement of the analysis to achieve maximum results with high accuracy. In the present study all care was taken to validate the data as per the field information. The suggested locations and the analysis are based on the constraints put for selection of suitable locations from the data supplied. The suggested analytical outputs may change based on the ground and social condition.

Monitoring is the important aspect for the assessment of the developmental work undertaken in the area. GIS helps in maintaining the database where quick updation is possible. As the main criterion between successful and failure of any developmental project is based on quantifiable change in the socio-economic life of the people, therefore, use of GIS becomes imperative.

After implementation of plan its benefits can be evaluated through GIS. The socio-economic condition is a parameter of development. With the help of GIS the socio-economic development of the region can be analysed and coupled into the model to evaluate the change in condition, which will be capable to answer questions like where, how, and how much? Similarly the progress of certain industries and the locations for plantations suggested with the help of GIS can be evaluated after certain duration. It is expected to identify possible reasons for success and failure from the data. For example, it is possible that a given household enterprise succeeded because the bamboo resource was upstream or on the slope above the enterprise and hence there was a transportation advantage that gave an added economic benefit to the enterprise. In another instance, a similar enterprise might have failed or not succeeded due to reason, the resource was downstream or on the hill slope below the enterprise, resulting in greater expenditure on resource procurement. But it is also possible that ultimately both had a similar level of success because the latter was located closer to the road and had better market access. Such analyses would likely become possible once the system has a threshold data resource base.

8. References:

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