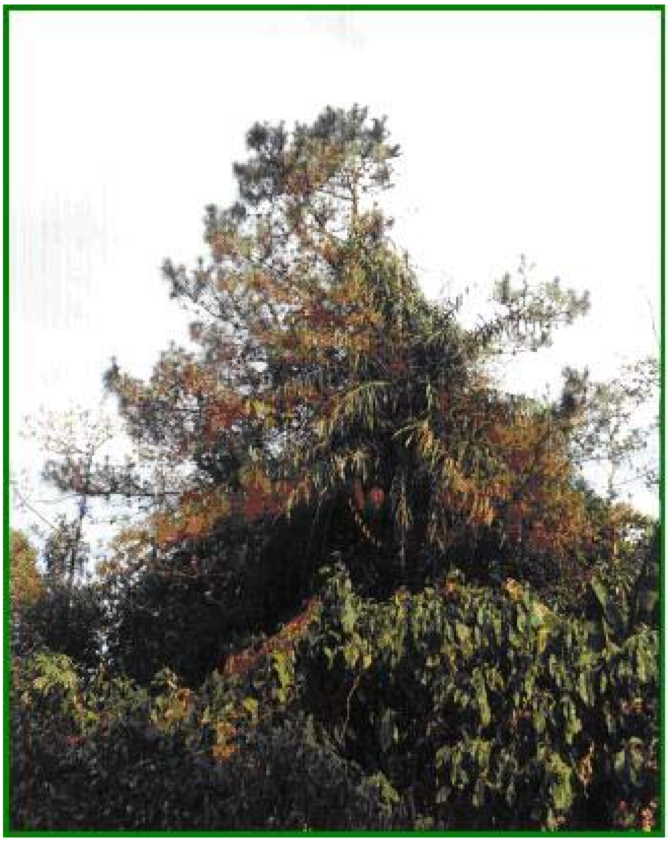
Integrated Advanced Remote Sensing GIS Study for Bamboo based Livelihood analysis and Rural Development planning in Nhamatanda, Dondo districts of Sofala province, Mozambique



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Implementing Agency

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Forest Research Centre (CEF)
Direccao Nacional De Florestas E Fauna Bravia (DNFFB)
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The project team from Government of Mozambique and FAO

- Mr. Muino Taquidir, Director CEF – Project holder,
- Mr. Jeevanandhan Duraisamy, FAO Mozambique, Team leader and Technical coordinator,
- Mr. Castelo Banze – Forest Inventory Unit, DNFFB

GIS team from RMSI Pvt. Ltd. India was involved in the present study. List of members is as follows:

- Dr. Siva Subramanian, DGM
- Mr. Shalabh P. Bharadwaj, Sr. GIS Specialist
- Ms. Stutee Gupta, Sr. GIS Engineer
- Mr. Raushan Kumar, GIS Engineer

Executive 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 has been taken up jointly by FAO, IUCN, and INBAR with a technical support from RMSI Private Limited, India. The study broadly aims 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 is carried out in the present study. Vulnerability analysis for flood risk and forest fire is 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 are carried out for forest and bamboo resource planning.

Human resource development is an essential component for ensuring sustainable development. The study therefore presents 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.

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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, man made 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 (Box. 1). 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.

Bamboo and Global Challenges

Bamboo is well placed to address four major global challenges:

Shelter security, through the provision of safe, secure, durable and affordable housing and community buildings

Livelihood security, through the generation of employment in planting, primary and secondary processing, construction, craft and the manufacture of value-added products

Ecological security, by conservation of forests through timber substitution, as an efficient carbon sink, and as an alternative to non-biodegradable and high-embodied energy materials such as plastics and metals

Food security through bamboo-based agro-forestry systems, by maintaining the fertility of adjoining agricultural lands, and as a direct food source – example, edible bamboo shoots

Source: www.nabard.org

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 unsustainable 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 output is that once created this data can be readily updated and used. For the present study all the data was brought to one platform and one coordinate system. Information thus collected was converted into digital form through digitization and image interpretation into various GIS layers. One layer contains details about one single theme only. Once all the information is ready it can be utilized for GIS based analysis. In nature there are several factors that influences and make certain areas more suitable for particular use than in comparison to other uses. Identification of such areas can be done through suitability analysis using GIS. Based on the pre-conditions identified for setting up bamboo-based industries a 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 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 is complete then starts the monitoring phase. The monitoring part become very easy once all the data is completed and put into one system. The basic layers are required to be updated with the recent information from the field or from satellite imageries.

Goals / objectives

1. Establish a Rapid bamboo resource assessment model to address emergencies of bamboo flowering
2. Establish a pilot model of Advance Remote sensing system and test its utility in Mozambican Context for livelihood development

1.1. Scope of work

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) to be created from information available from various maps, satellite imagery (classification, matching of the signature of bamboo with ground truthing), and other non-GIS sources. This will be a regional level database where information on natural resource for the Nhamathanda, Dondo and parts of Gorangosa district will be 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.

1.2. 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).

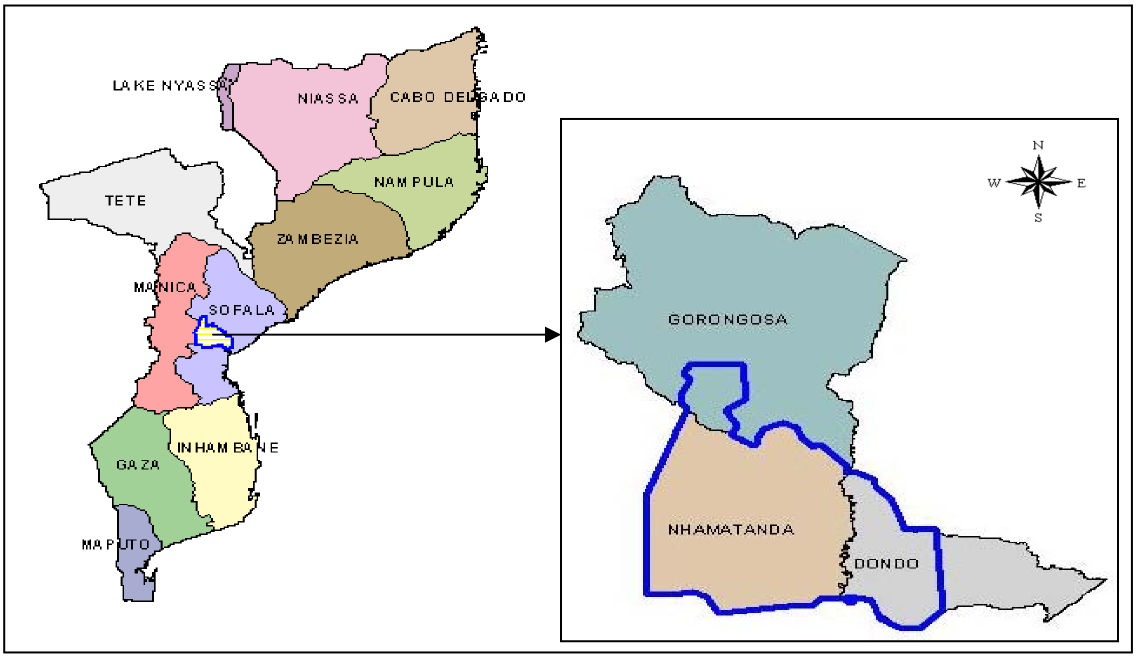


Fig 1: Location map of the study area

1.3. Data Input

Following data inputs were used by RMSI for the current project.

- 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. Salient features of the satellites are given below:

Satellite	Swath (Km)	No. of Bands	Spatial Resolution (m)	Area Coverage (sq km)
Landsat TM	185 X 185	7=Multi Spectral and 1=Pan	30	34,225
IRS LISS-IV	23 X 23	Visible and Near Infra Red	5.8 m	529
MODIS	2330X 2330	36 bands	250	54,28,900

- Details of the images used and the acquisition dates is given below:

S. No	Landsat TM Data		
	Path	Row	Date
1	167	73	30 December 2000
2	167	74	7 May 2001

S. No	MODIS Data	
	Resolution	Date
1	250m	20 August 2003
2		13 August 2003

S. No	IRS Resourcesat LISS-IV		
	Path	Row	Date
1	102	18	01 September 2005
2	202	16	13 October 2005
3	202	17	13 October 2005
4	202	18	13 October 2005
5	202	17	31 August 2005

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

  - Rainfall map in digital digitized format
  - Temperature map in digital digitized format
- Socio-economic data
  - Village information like village location (latitude/longitude), name, population, density, habitation etc. in digital format (MS-Excel, Access etc.) provided by CEF
- Infrastructure maps
  - 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 (constants) for different land use land cover units.

1.4. GIS layers/ Data deliverables and Data format

A. List of GIS layers is as following:

1. **DEM** (Digital elevation model) – Digital Elevation Model is a 3-dimensional round surface where apart from x & y coordinates, z (height) is also represented. Free DEM database was collected/downloaded from the net depending upon the availability of the same on the date of downloading. SRTM (Shuttle Radar Topography Mission) from National Aeronautics and Space Administration (NASA) and National Geospatial-Intelligence Agency (NGA) is available at global level for public use. For Mozambique SRTM is available at a resolution of 90m.
2. **SLOPE** – 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 available DEM.

3. **Drainage -**(perennial and seasonal with watershed boundaries) – Drainage map was created from topographical maps at 1:50,000 scale and updated using Landsat satellite imagery.
4. **Soil Type -** Soil type map provided by CEF was used for various analysis.
5. **Climatic data** (rainfall, temperature) maps supplied by CEF were used for GIS analysis.
6. **Socio-economic data –** Socio-economic data supplied by CEF in digital format (MS-Excel and Access) was used for GIS analysis.
7. **Base maps –** Base map includes village location points, captured from topographical maps.
8. **Infrastructure maps –** 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.
9. **Land use/Land cover (LULC**) – 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.
10. **Forest distribution map** – Forest distribution map was prepared using satellite imageries and topographical maps.
11. **Timber species map** – Timber species distribution map was generated through satellite based classification using GPS based ground information.
12. **Bamboo distribution map** (from satellite imageries and ground truthing) - Bamboo distribution map was generated through satellite based classification using GPS based ground information.
13. **Bamboo stock map** – 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 Approach using satellite image and GPS information.
14. **Shifting cultivation area** – Current shifting cultivation areas were clubbed together in wasteland map itself as one of the class.
15. **Erosion area mapping** – 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.

16. **Degraded land mapping** – Degraded land mapping was done using satellite images and ground-based information. The output was clubbed together with Wasteland map.
17. **Wasteland Map** – Wasteland mapping was done through satellite interpretation and ground based information.
18. **Carbon emissions** – MODIS satellite images were used to map the fire areas. The map was further processed to derive total amount carbon emission from the fire sites.
19. **Carbon Sequestration** – Satellite based land use land cover map alongwith information from available literature was utilized for estimation of carbon sequestration for different land use / land cover classes.
20. **Industrial locations -** 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.

Some additional analysis that were attempted based on available and derived information is as follows:

21. Degraded areas for ANR
22. Medium Value forest for timber with sustainable harvesting
23. Low Value forest
24. Potential Agriculture area
25. Potential Aided Natural regeneration area (with low density)
26. High value forest for Bamboo with sustainable harvesting
27. Medium value forest for Bamboo with sustainable harvesting
28. Potential Bamboo poles production and enterprise area with sustainable harvesting
29. Potential Bamboo charcoal production & enterprise area with sustainable harvesting
30. Potential Bamboo Mat production and enterprises area with sustainable harvesting
31. Potential Bamboo handicrafts production and enterprise area with sustainable harvesting
32. Locations suitable for establishing Bamboo Nursery
33. Potential Bamboo plantation area
34. High Value forest for Timber with sustainable harvesting
35. Potential Timber charcoal production & enterprise area with sustainable harvesting

36. Potential Active carbon production and enterprise with sustainable harvesting
37. Potential Gasifier enterprise area with sustainable harvesting
38. Optimal human settlement areas
39. Vulnerability analysis
    - Flood and disaster response priority villages
    - Forest Fire Mapping
40. Allied agriculture development activities
    - Ponds and Lakes based small irrigation
    - Potential Fish Farming Areas
    - Mapping Irrigation potential for agriculture areas
41. Allied Forest activities

    Conservation and Protected area mapping for forests
42. Regular Development activities
    - Optimal rural market location
    - Other industrial potential like food processing, cold storage etc

B. Data formats

The above-mentioned layers were created in Arc view 3.2 compatible format (Shape, Grid and Geotiff files) in UTM projection system, along with attributes.

C. Hardware and Software used

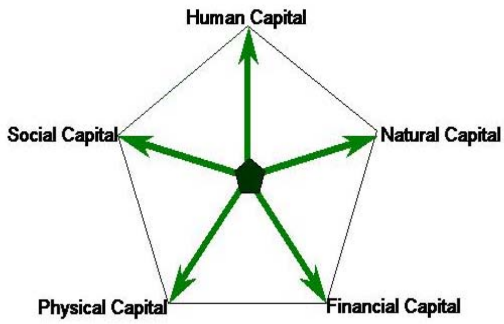
For satellite image based forest/bamboo resource inventory ERDAS Imagine 8.6 image processing software was used. For base layers creation and GIS analysis Arc View 3.2 was used. MS-Office has been used for preparation of reports and data tables

2.0 Overview of Methodology

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

2.1. Literature Review

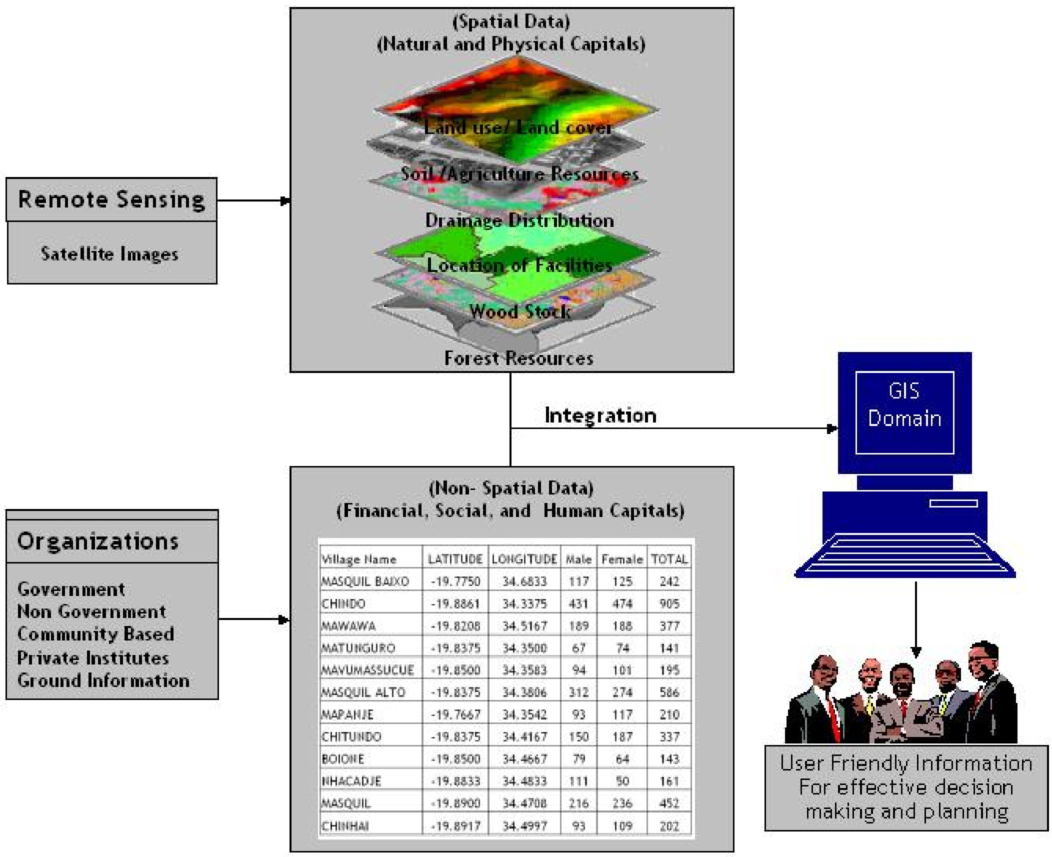
For any livelihood development planning it is essential to understand the various components that play a crucial role directly and indirectly in effecting a development study and a proposed development model. In this context study of livelihood capitals (DFID, 1998) was taken up (Fig 2.).



- **Human capital** – manpower, skills, knowledge & info, ability to work, health
- **Natural capital** – natural resources, land, water, wildlife, biodiversity, environment
- **Financial capital** – monitory resources, savings, credit, remittances, pensions
- **Physical capital** – facilities such as electricity, transport, shelter, dam, etc
- **Social capital** – linkages, networks, groups, trust, access to institutions

Fig 2. Livelihood Capitals

Information on three of the five capitals presented above i.e. Human, Financial and Social is collected from the various departments *viz*. government and private sector and represent the non-spatial data. Whereas the remaining two i.e. Natural and the physical capital can be assessed from the satellite Images using geo-spatial technique of remote sensing and GIS. The geo-spatial techniques further make it possible to integrate the non-spatial (Human, Financial and Social) and spatial information (Natural and Physical) so as to derive authentic and meaningful information and decision making for the planners and administrators (Fig 3).



Village Name	LATITUDE	LONGITUDE	Male	Female	TOTAL
MASQUIL BAIXO	-19.7750	34.6833	117	125	242
CHINDO	-19.8861	34.3375	431	474	905
MAWAWA	-19.8208	34.5167	189	188	377
MATUNGURO	-19.8375	34.3500	67	74	141
MAVUMASSUCUE	-19.8500	34.3583	94	101	195
MASQUIL ALTO	-19.8375	34.3806	312	274	586
MAPANJE	-19.7667	34.3542	93	117	210
CHITUNDO	-19.8375	34.4167	150	187	337
BOIONE	-19.8500	34.4667	79	64	143
NHACADJE	-19.8833	34.4833	111	50	161
MASQUIL	-19.8900	34.4708	216	236	452
CHINHAI	-19.8917	34.4997	93	109	202

Fig 3: Role of Remote Sensing and GIS in decision making and planning for livelihood development

Review of available literature on the socio-economic set-up of Mozambique, carbon sequestration and carbon emission phenomenon was also carried out as a part of desk study. In addition INBAR/FAO/IUCN rules and conditions were also thoroughly studied for the analysis.

2.2. Project & GIS Team involved

The project team from Government of Mozambique and FAO

Mr. Muino Taquidir, Director CEF – Project holder,

Mr. Jeevanandhan Duraisamy, FAO – Team leader and Technical coordinator,

Mr. Castelo Banzee – Forest Inventory Unit, DNFFB

GIS team from RMSI Pvt. Ltd. India was involved in the present study. List of members is as follows:

- Dr. Siva Subramanian, DGM
- Mr. Shalabh P. Bharadwaj, Sr. GIS Specialist
- Ms. Stutee Gupta, Sr. GIS Engineer
- Mr. Raushan Kumar, GIS Engineer

Apart from this a team of medium level technicians from the district, university and CEF assisted and obtained practical training on using GPS instruments and basics of data collection for remote sensing.

2.3. Preparatory activities

The major activities involved in the current project during initial stages of the project are listed as following:

- Downloading/Procurement of Satellite data
- Image Processing: Image processing is the process of making images ready for interpretation /classification. Some of the Image processing features are described below:

  Georefrencing: It includes geo-rectification of the images. All images were georefrenced in UTM projection. Datum and spheroid are WGS 84, Zone 36 and southern orientation. Images were georefrenced with the help of Landsat images using image-to-image georefrencing method. Adjacent images were also matched to each other. This helped in maintaining the homogeneity of Land Use Land Cover Classification.

Image Enhancement: Image enhancement is required to enhance interpretability of the image through contrast stretching, histogram adjustment etc.

- Collection of secondary data (spatial and non-spatial)

2.4. GIS database creation

Information related to physical resource, socio-economic conditions, cultural values and human resource are of prime importance for any GIS based analysis. The required information was generated from topographical maps, satellite imageries, census data and field information (Fig. 4). Each theme was captured as a separate layer – such as road/rail network, drainage, village locations, boundary map etc. For each layer attributes were assigned to each entity in GIS environment. Details like length, distance etc. were calculated and stored with each spatial entity. Satellite images were used to update the information for GIS layers and for bamboo inventory. Updated layers were further utilized for suitability and overlay analysis based on the requirement.

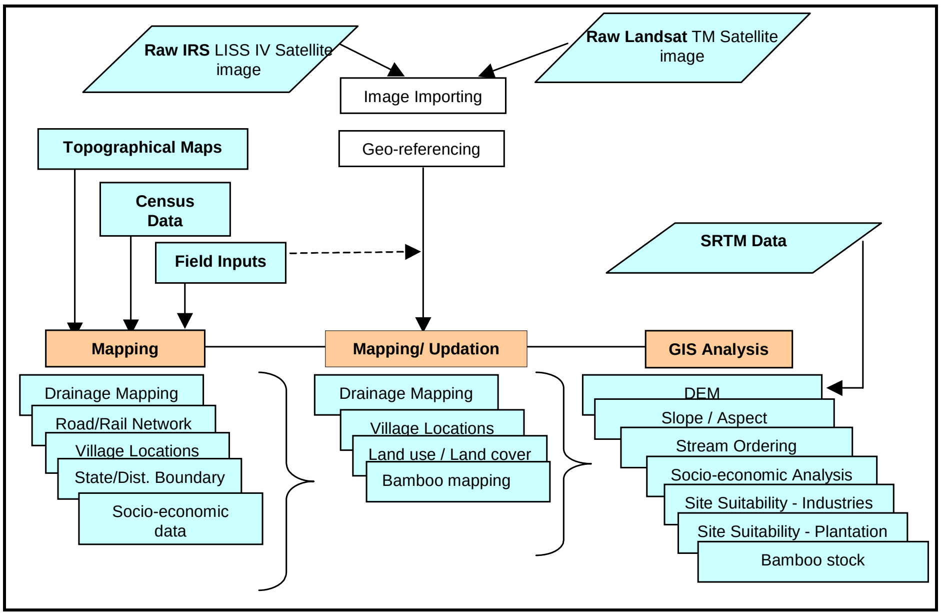


Fig. 4. Overview of Methodology

Satellite images are the most effective tool for mapping and monitoring Land use / Land cover. It is a cost and time effective solution due to its inherent advantages. Throughout the world satellite remote sensing technology is being used for forest inventory and other forestry applications.

In this project, Landsat TM images of year 2000 were utilized to prepare various thematic layers. The spatial resolution of Landsat TM is 30 meters. A detailed schematic workflow diagram showing the activities involved in forest mapping in general and bamboo in particular is given in fig 5.

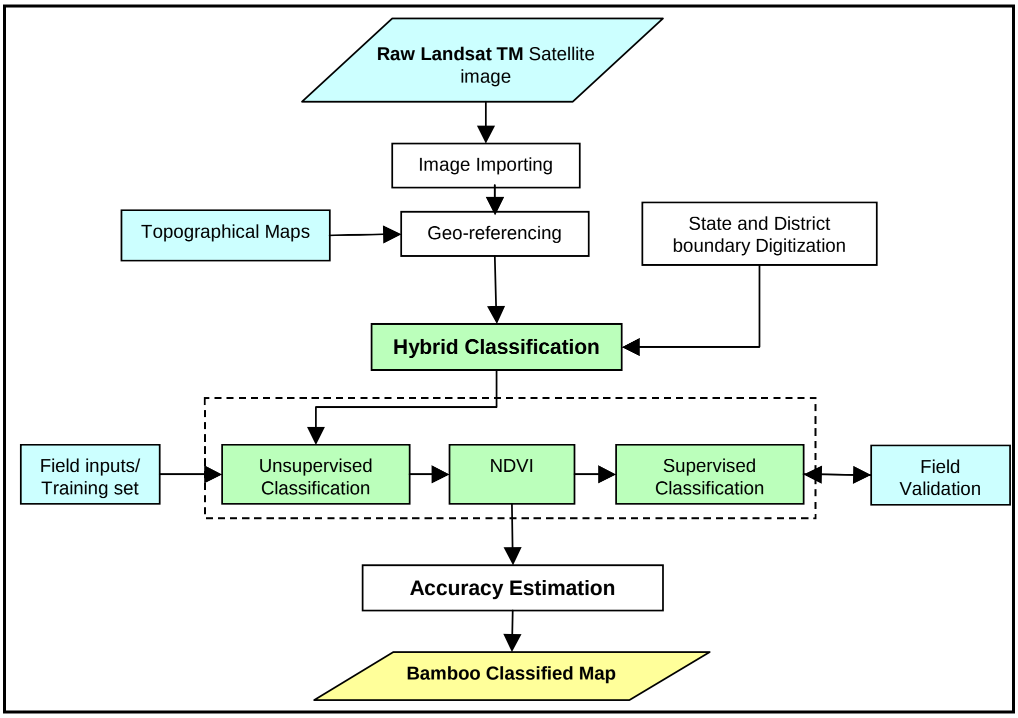


Fig. 5. Methodology for Bamboo Mapping

Signature based hybrid classification technique was used for classifying Forest Species/ Timber Species. Field inputs in the form of GPS points were incorporated as training set for signature based supervised classification and accuracy estimation.

2.5. Fieldwork Preparation

For the purpose of fieldwork expert from RMSI visited Mozambique for field data collection. Satellite imageries were plotted on A3 size sheets at 1: 50 000 scale for the purpose of land use land cover class interpretation. Officials at CEF and DNFB were consulted for logistic, administrative and field support.

2.5.1. Instruments used

(Hardware, Software, other facilities) During the fieldwork handheld Garmin 12 make GPS along with Dell Laptop was used for plotting the waypoints and transferring the information on ground control points. Logistic support in terms of lodging, boarding and flied staff was provided by CEF and Forest Department of Mozambique.

2.5.2. Fieldwork team

Image interpretation expert from RMSI conducted the field survey after pre-field classification of satellite images. CEF and DNFFB inventory officials were consulted for identifying tree species during field survey. Field team consisted of six members. Each team member had a well-planned role and contribution as follows:

Shalabh P. Bharadwaj, RMSI India:

- Collection of parameters related to knowledge based classification such as elevation, slope, soil moisture content etc.
- Collection of GPS location of various land use land cover classes.
- Developing an understanding about the occurrence, distribution and present scenario of natural and human resources.

Castelo Banzee; MOA, Maputo:

- Identification of dominant species
- Information on concentration of bamboo and other dominant species
- Field Photography

Jeremias; Forest Department Beira:

- Identification of dominant species
- Information on concentration of bamboo and other dominant species
- Field Photography
- Measurements (height, diameter) of tree species

Montero, J.C.; Forest Department:

- Recording of information from field staff on a record sheet

Anjos; Catholic University:

- Issues related to administrative and logistic support
- DGPS location measurements along with tree height information

2.5.3. Duration of field work

Fieldwork was carried out for the duration of twelve days. Details of the field plan is given in table below:

Date	Day	Plan	Stay At
29-6-05	Day 1	From Maputo to Beira – Arrangement of Logistics and meeting/discussion at UCM or other organisations	Beira
30-6-05	Day 2	Beira to North of Dondo and adjoining areas	Beira
1-7-05	Day 3	Beira to South-West of Dondo	Beira
2-7-05	Day 4	Beira to North of Nhamthanda – Mehka region	Nhamathanda
3-7-05	Day 5	Nhamatanda to Charira and Emportzam	Nhamathanda
4-7-05	Day 6	Nhamathanda and adjoining areas	Nhamathanda
5-7-05	Day 7	Nhamatanda to South of Nhamatanda	Mucumbezi
6-7-05	Day 8	Mucumbezi to North of Community Construction	Mucumbezi
7-7-05	Day 9	Mucumbezi to South-East of Mucumbezi	Mucumbezi
8-7-05	Day 10	Areas in the vicinity of Mucumbezi	Beira
9-7-05	Day 11	Areas nearby Beira	Beira
10-7-05	Day 12	Discussion at UCM	Beira

2.6. Field Inputs

During fieldwork observations were recorded for different land use land cover and forest types particularly bamboo. Sincere attempts were made to collect GPS locations as close as possible to the target class type (Plate 1). As the study area comprises of a hilly terrain and most of the bamboo dominant areas were difficult to reach, therefore, only major bamboo growing areas were selected and visited for field verification and data collection. During field work location based information was collected for more than 400 locations using handheld Garmin-12 GPS based on random sampling. Information was also recorded at some locations using differential GPS device to validate the accuracy of handheld GPS.

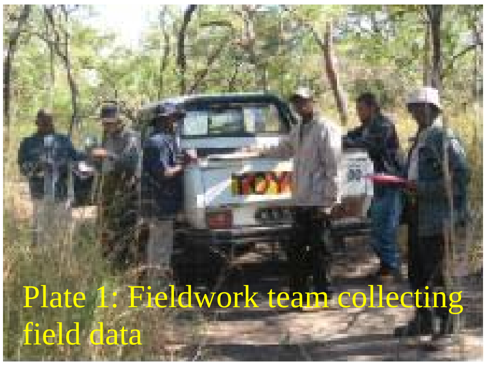


Plate 1: Fieldwork team collecting field data

Following observations were recorded during the fieldwork:

- Co-ordinates at the base of the bamboo clumps, wherever reachable, with the help of GPS System.
- Variety of bamboo.
- Area of bamboo canopy cover.
- Direction from the Road.
- Distance from the GPS point in cases where the co-ordinates are taken at a distance from the bamboo clumps.

2.7. Quality Procedure

Quality process is a very important activity for any GIS based project. The correct spatial location is one of the prerequisite for authentic and correct analysis. All the maps should be correctly geo-referenced using proper reference such as topographical maps and GPS locations. Thorough quality checks (QC) were performed to check the accuracy of geo-referenced maps and satellite imageries. While digitizing the data from the geo-referenced maps, geographical features were captured at the center of the lines drawn on the maps. After digitization of each map QC was done for identifying missing features as well as inaccuracy in digitization. Data was corrected for all the identified errors and cleaned further to maintain intersections of geographical entities.

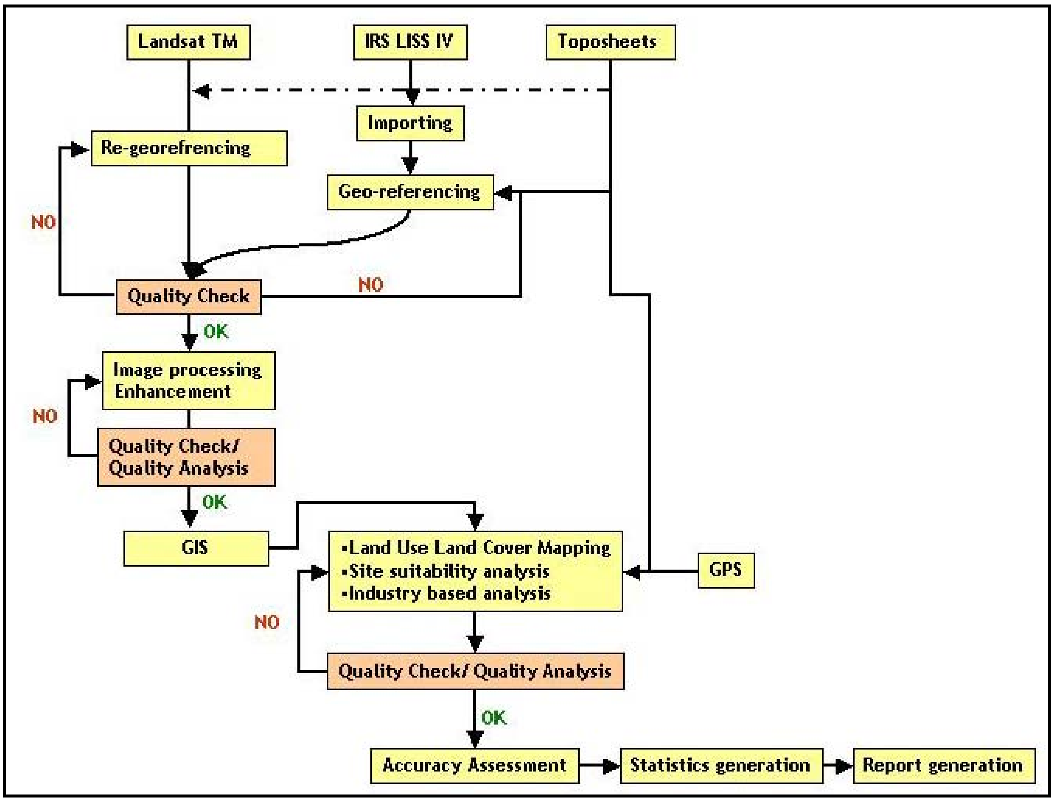


Fig. 6. Work Flow diagram along with Quality Procedure

3.0. GIS Data Layers

All required thematic maps/layers were converted/generated from various sources to digital GIS compatible format. Each thematic layer contains details about one specific feature, which were mapped based on their actual geographical coordinates. All non-spatial databases were either generated automatically or incorporated from maps and field based information.

Due to non-availability of sufficient/ appropriate socio-economic data it was used at a limited scale in the current project. Lack of multi-temporal data was also a constraint while deriving information on trend and magnitude of change in the various human impact areas.

Natural Resources

3.1. DEM – Digital Elevation Model

Digital Elevation Model (DEM) data files are digital representations of cartographic information in raster form. DEM consist of a sampled array of elevations for a number of ground positions at regularly spaced intervals. Elevation details in the form of contours were digitized and interpolated based on the height information to generate DEM from

SRTM (90m) and 50k topographical maps provided by CEF. For Mucombezi area in northwestern part of the study area RMSI took additional efforts in capturing contours from 50k topographical maps for detailed DEM creation. The derived DEM was used for GIS analysis and knowledge based classification of bamboo. For rest of the area DEM was derived from SRTM data.

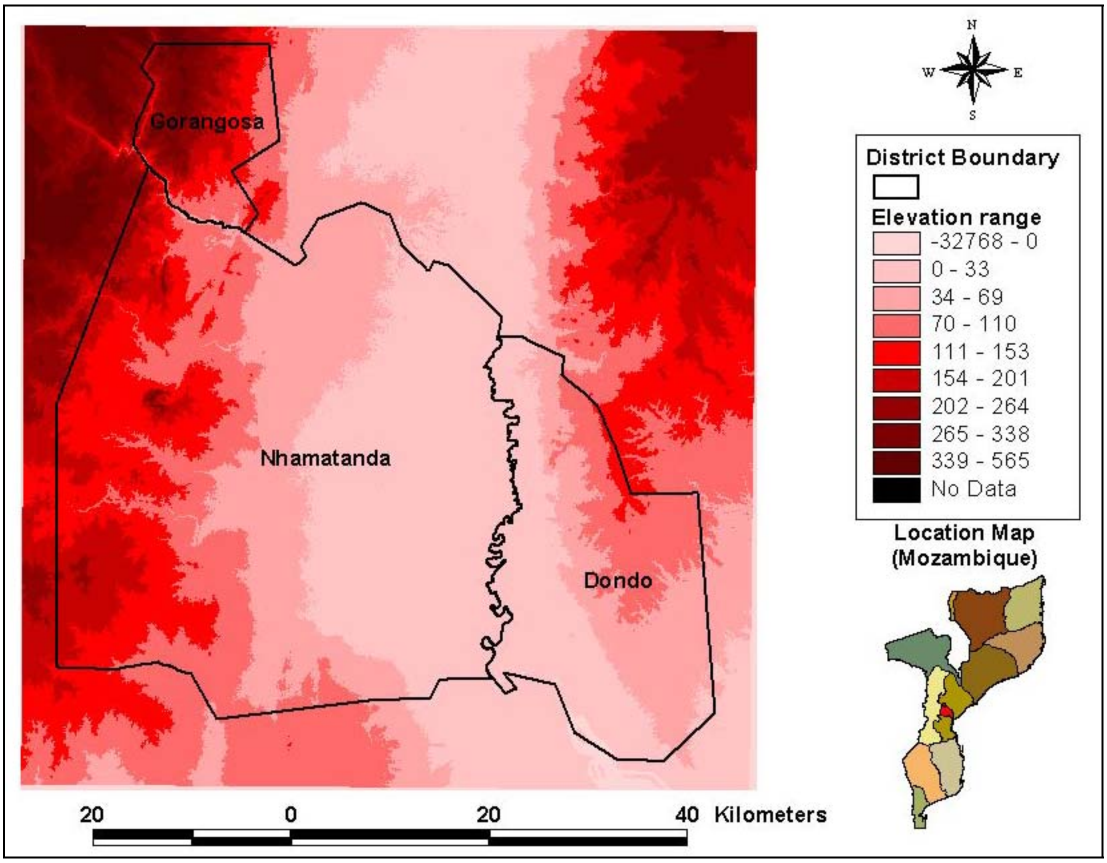


Fig. 7. Digital Elevation Model

Inputs:

- 50 K Topographical maps (20m)
- SRTM (90m)

Methodology:

Contours were digitized from the topographical maps and attributed with the associated elevation values. Captured contour values were first extrapolated by creating TIN (Triangulated) data model, and then converted into a grid layer.

Output:

- The DEM layer, consisting of the extrapolated elevation values in the form of grid.

Significance for Analysis:

DEM is one of the most important parameter responsible for the distribution of vegetation type. In present study DEM in conjunction with slope and aspect was utilized for bamboo classification. Height is also one of the prime factors controlling the establishment of an industry in a specific location. Specifically, in mountainous regions height is one of the determining factors in selecting the suitable location. As for minimizing cost, a suitable location for a resource-based industry should be placed at a height below the source of resource and at a height above the market. DEM is the layer providing the height factor in an analysis process.

3.2. Slope Data

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. An output slope grid showing slope values in degrees is given in Fig. 3.2.

Input:

- DEM Grid

Methodology:

The height values of the DEM are processed under the algorithm of the Slope function. By the slope function slopes in degrees was computed and saved as grid file.

Output:

- The Slope layer, consisting of the extrapolated slope value in the form of a grid.

Significance for Analysis:

Slope is one the factor which controls the location of an industry, neither a industry can be placed in a piece of land of high slope nor the resources growing on the high slope regions are cost effective for production. Again Slope plays the most important role in evaluating the soil erosion zones and identifying the areas suitable for bamboo nursery and plantations.

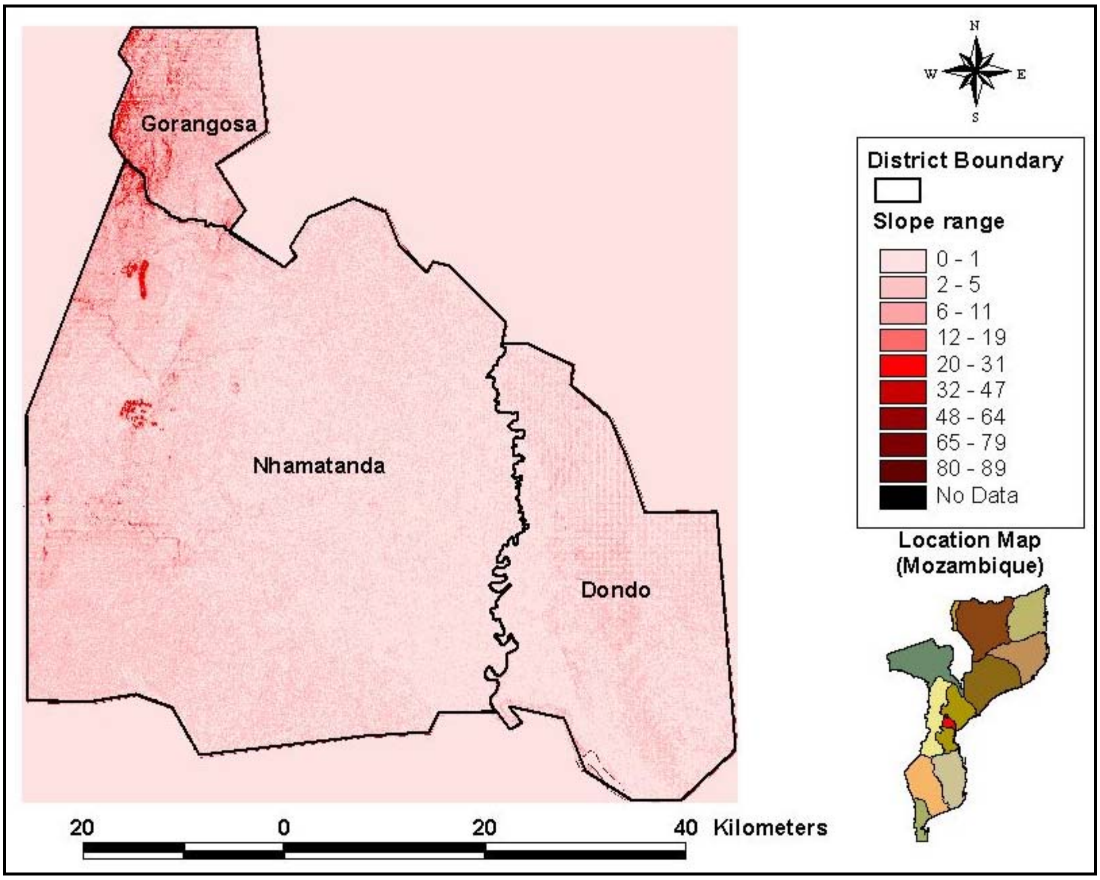


Fig. 8. Slope map

3.3. Drainage Data

Drainage map forms an important input in erosion prone area mapping.

Input:

- Topographical maps
- Satellite Imagery

Methodology:

The drainage (river) network was captured (digitized) from the topographical maps. The digitized river network was updated and rectified from the recent available satellite imageries (landsat-TM). Certain processes were run to calculate the stream order. This information was added to the attribute table of the shape files.

Output:

- Drainage Network Shape file, with the supporting attributes like Stream Order.

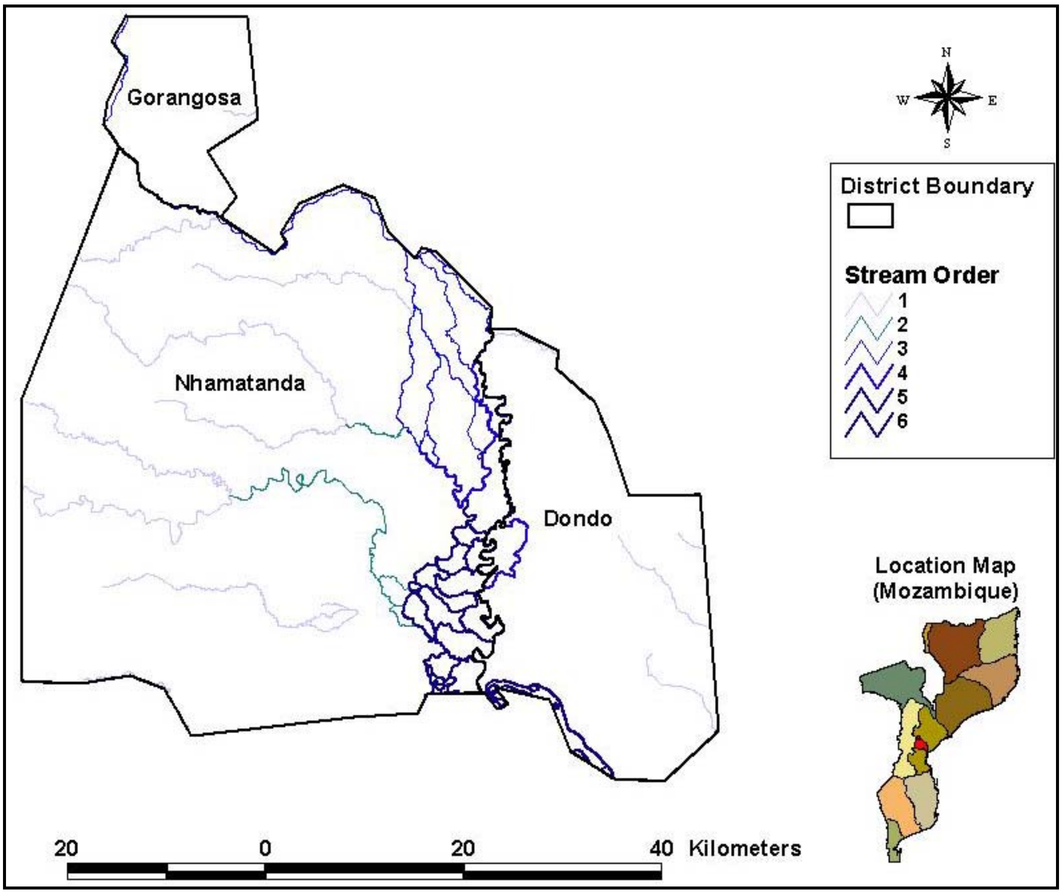


Fig. 9. Drainage map with stream ordering

Significance for Analysis:

The order of drainage is very essential for mapping erosion prone areas and finding suitable site for setting up erosion protection measures in multiple ways. Watershed delineation is also done with multiple sets of data on climate data, DEM, Slope and the topography to calculate run off and the suitable site for construction of check dams in combination with erosion protection measures.

3.4. Soil Map:

Soil map was provided by CEF. It has various attributes such as texture, drainage class etc. For the purpose of analysis soil drainage class was used. (Fig. 10)

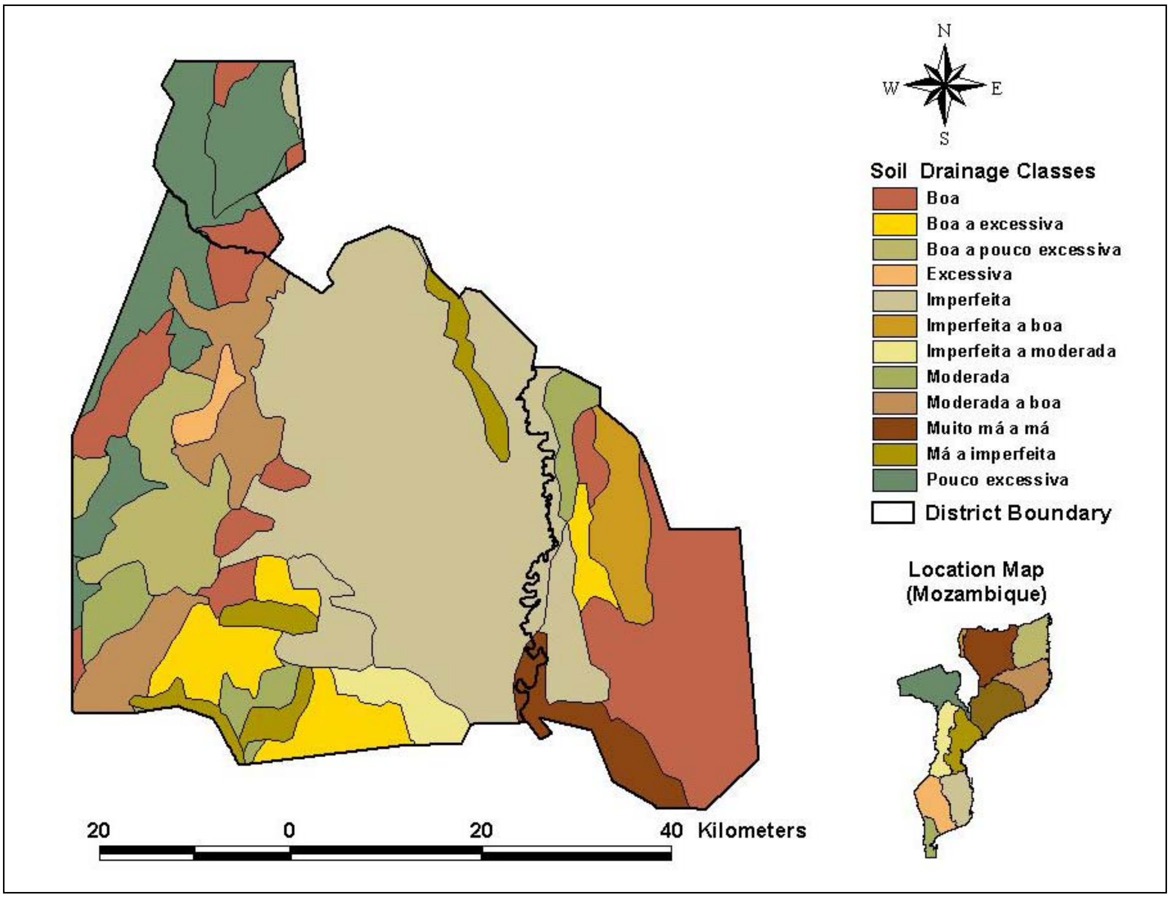


Fig.10. Soil Drainage map

3.5. LULC – Land-Use/Land-Cover Data

Land use/ Land cover (LULC) map shows distribution of natural as well as man-made features on earth surface. Based on the requirement of the project the classification scheme was prepared. Field inputs in the form of training sites were used for identification of land features that also includes bamboo species (Fig. 11).

Inputs:

- Satellite Imagery (Landsat TM)
- Topographical maps
- GPS points

Methodology:

- Raw satellite imageries were geo-positioned with reference to the topographical maps. The accuracy of geo-referencing was validated using GPS location points of road intersection, railway crossing and main power lines (fire lines visible on satellite image).

- Geo-referenced images were processed further using Normalized Difference Vegetation Index (NDVI) to extract the vegetation areas from the image.
- The vegetation layer resulting from NDVI was used for masking the geo-referenced parent image.
- The signatures, associated with the vegetation classes, were identified with the help of GPS points collected from the field. Wherever, the GPS points coincide with the image pixels the signature class was created using supervised classification option. The same process was carried out for non–vegetation areas also and a non-vegetation layer was created. Finally vegetation & non-vegetation layers were mosaiced to prepare the final LULC layer.

Output:

- A LULC map, showing the distribution of the land-use / land-cover classes in the area of study.

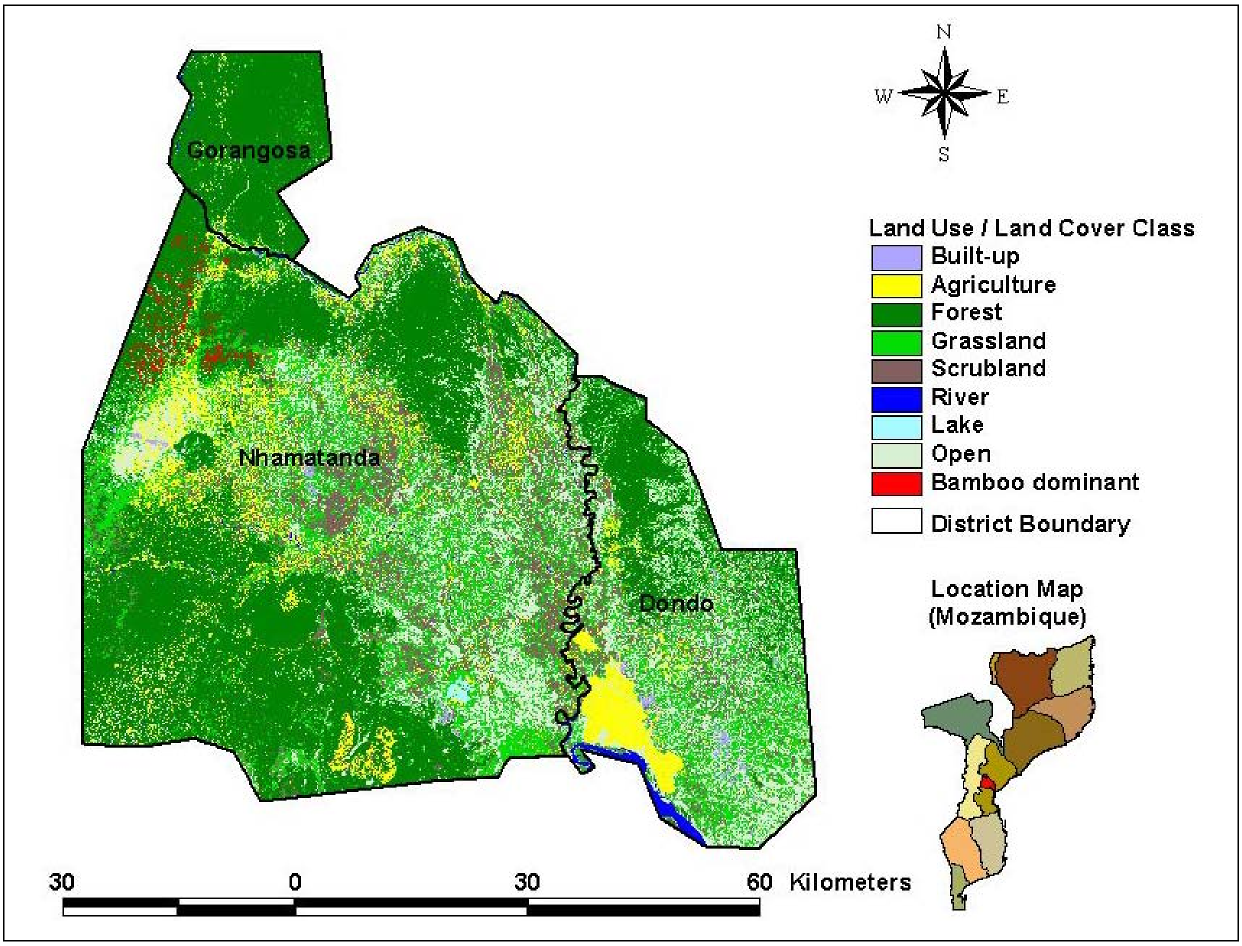


Fig. 11. Land use / land cover map

Significance for Analysis

The LULC layer is the basic input for all bamboo industry based studies. It provides resource distribution information for various analysis. It also provides the exact area under bamboo, which could be exploited for the proposed industry. When overlaid with the road network map it forms a significant input for identifying the location of proposed bamboo based industries.

IRS Resourcesat LISS IV based classification:

In order to have detailed information the LULC classification was also done in five sample sites (fig 12.) using high-resolution IRS RESOURCESAT LISS IV satellite images. With the spatial resolution of 5.8 meter and multi-spectral capabilities IRS RESOURCESAT LISS IV data gives highly accurate information on the type and extent of various land use land cover classes. Also limitation faced due to intermixing of signatures and sub pixel effect in the coarse and moderate resolution images are overcome (fig 13a & 13b).

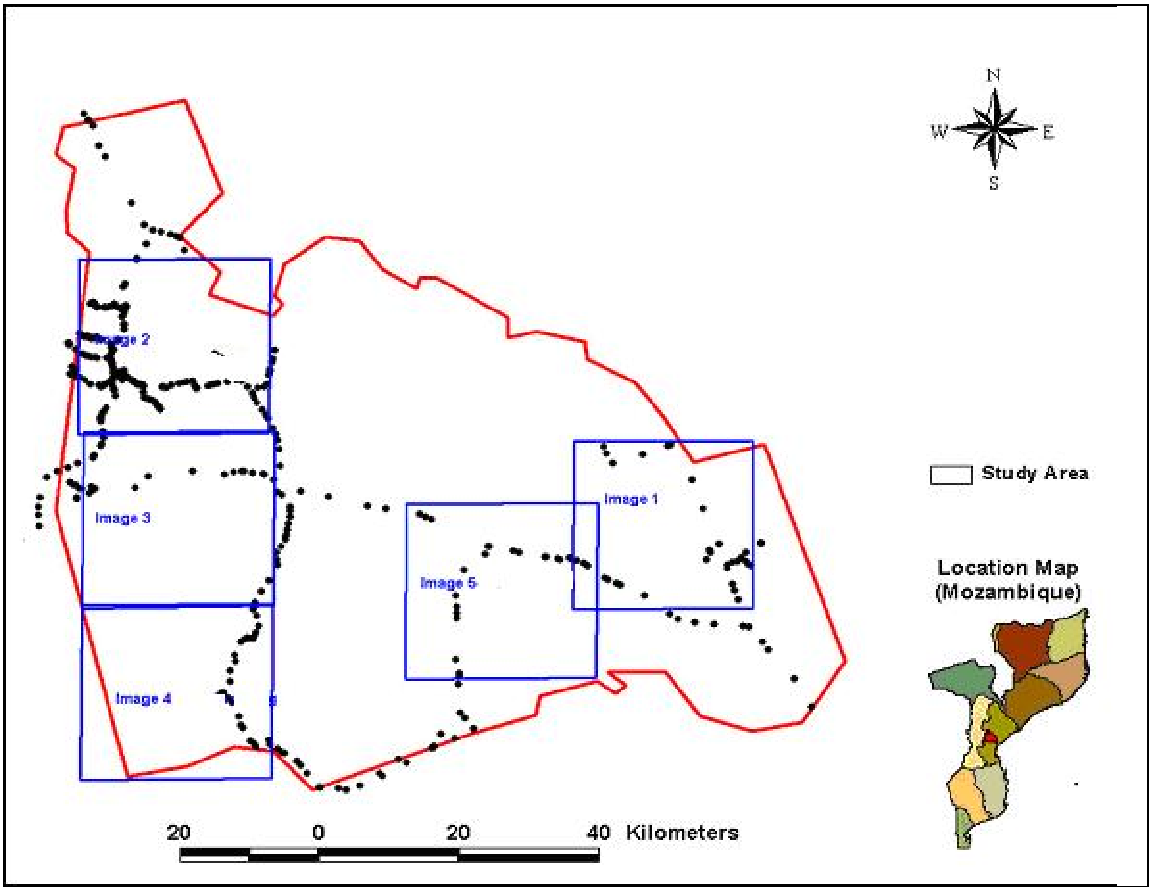


Fig. 12. Graphical representation of IRS Resourcesat LISS-IV sample sites location in the study area

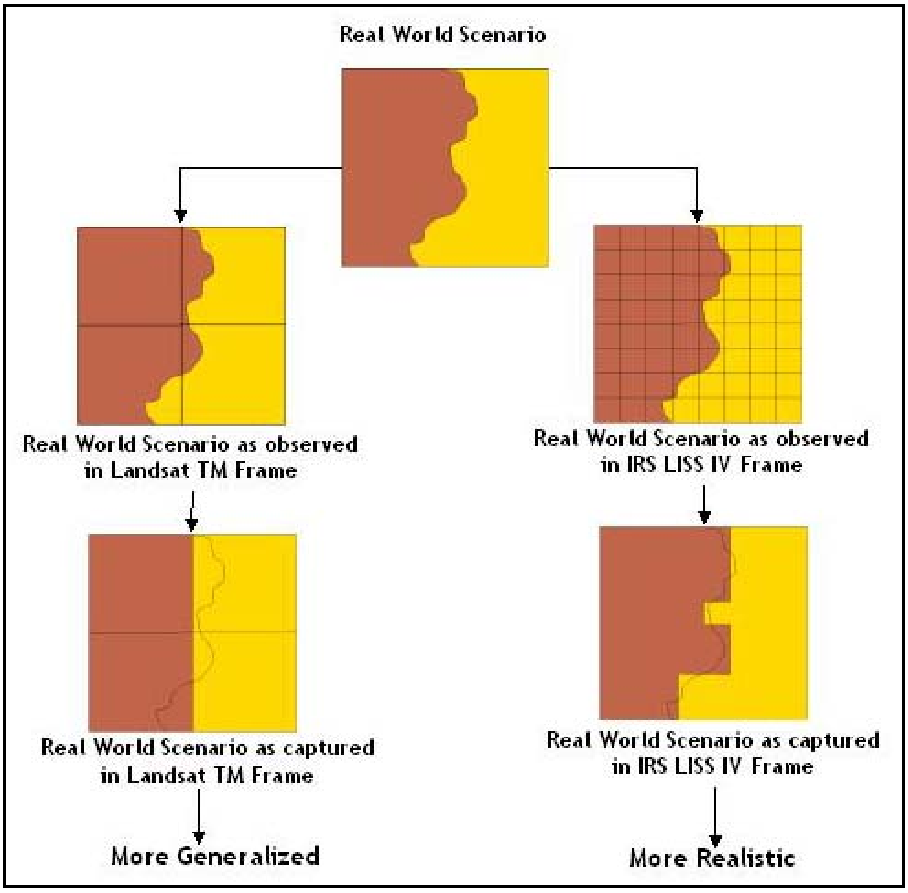


Fig. 13a. Comparative account of interpretation on Coarse and High-resolution images

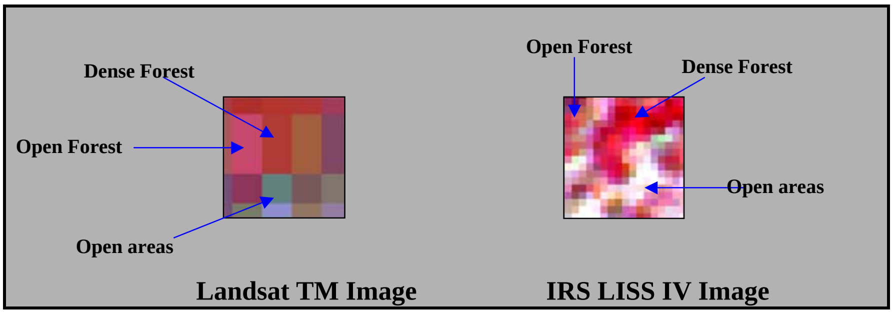


Fig 13b. Landsat TM and IRS RESOURCESAT LISS IV images showing difference in land use land cover class discrimination 1 ha sample in the study area

Given below is the table showing district wise distribution of land use land cover classes as interpreted from Landsat TM image.

Table – Landsat – TM based district-wise distribution of Land use Land cover classes (Area in Ha)

Class Name	Gorongosa	Dondo	Nhamatanda	Total area (ha)
Forest	37794.44	26525.31	160355.44	224675.19
Bamboo	0.00	0.00	2853.75	2853.75
Grassland	1314.19	34661.75	88211.56	124187.50
Scrubland	271.06	13123.19	50192.94	63587.19
Agriculture	716.25	10666.69	30430.69	41813.63
River	107.44	2595.88	1521.19	4224.50
Lakes	0.00	20.50	840.25	860.75
Open	695.81	39097.06	68956.63	108749.50
Builtup	37.88	1523.31	1214.69	2775.88
Total Area (ha)				573727.88

Area estimates for each of the five-sample site location, classified using IRS RESOURCESAT LISS IV images, is also given below.

Table – Land use land cover class distribution extracted from LISS-IV satellite scenes

Sl.No.	LULC Class	Satellite image based Distribution of Area (in ha)				
		Image-1	Image-2	Image-3	Image-4	Image-5
1	Dense Forest	13926.10	27337.17	23343.33	39298.06	2782.05
2	Open Forest	24544.58	17430.60	23530.84	14684.27	327.71
3	Shrubland	8219.46	2454.85	2765.94	3850.75	5465.44
4	Bamboo	0.00	12129.46	5924.48	0.00	0.00
5	Grassland (Dry)	12928.54	18112.74	17821.76	18385.94	51679.69
6	Grassland (Moist)	0.00	0.00	0.00	0.00	2356.57
7	Agriculture	4654.55	0.00	0.00	0.00	10102.24
8	Open/ Builtup/ Barren	5531.37	5137.78	6255.12	4058.92	3485.87
9	River	163.39	214.24	0.00	0.00	479.72
10	Burnt Areas	0.00	0.00	2630.90	1933.45	0.00
11	Orchards	0.00	0.00	0.00	0.00	254.91
12	Homestead	0.00	0.00	0.00	0.00	77.83
Total Area		69967.99	82816.84	82272.37	82211.41	77012.02

It is important to mention here that as depicted in fig 13, information generated from high resolution images are more realistic and close to real world features whereas as we move towards the moderate and coarser resolution the information becomes more and more generalized due to improved spatial resolution of IRS LISS-IV. Due to this reason, there is variation in area of Land use / Land cover classes between Landsat and IRS LISS-IV image derived output. As seen in the table, area under bamboo in one of the sample sites (image 2) is almost three times higher as against the area mapped from Landsat TM. Therefore it can be inferred that in high-resolution LISS-IV satellite images are more suited for mapping of sparse and scattered resources.

Given below is the account of area distribution of land use land cover classes classified from IRS RESOURCESAT LISS IV and its comparative account with respect to Landsat TM

Table: Districtwise comparison of land use land cover distribution as classified on Landsat TM and IRS Resourcesat LISS 4 images

			Dondo		Nhamatanda	
			L4	TM	L4	TM
Sl.No.	**Class**	**Subclass**	**Area (in ha)**			
1	Forest	Open	22305.91		40790.80	
2		Dense	9465.77	15352.81	68353.35	98372.44
4	Bamboo		0.00	0.00	9867.62	2852.43
5	Grass Lands	Dry	10546.67		90455.21	
6		Moist (Echhornia)	0.00	15544.74	2229.67	56547.41
8	Scrublands		7188.88	8190.65	13866.60	24309.99
9	Agriculture		6214.78	3663.84	5522.37	21024.16
10	Orchards		0.00	0.00	77.83	0.00
11	Homestead		0.00	0.00	254.91	0.00
12	Rivers		336.83	457.19	501.31	1061.97
13	Lakes[8]		0.00	8.88	0.00	722.94
14	Open/ Builtup		5288.09	18120.18	14238.42	45138.39
15	Burnt areas		0.00	0.00	3883.31	0.00
	Total area		61346.93	61338.29	250041.40	250029.72

* Lakes are not marked in LISS IV images although they are marked in Landsat images the reason is Landsat Images are of December 2000, which is quite old and month also represent the rainfall period. As observed in LISS IV images Water Hycinth has heavily invaded some of the lakes and some tall aquatic grasses therefore signature of water is not seen in those areas

Table: Comparative account of land use land cover distribution as classified on Landsat tTM and IRS Resourcesat LISS 4 images for five sample locations

			Image-1		Image-2		Image-3		Image-4		Image-5	
Sl.No.	**Class**	**Subclass**	**TM**	**L-4**	**TM**	**L-4**	**TM**	**L-4**	**TM**	**L-4**	**TM**	**L-4**
			Area (in ha)									
1	Forest	Total	15340.06		34351.75		25469.16		46497.12		2827.63	
2		Open	0.00	9487.76	0.00	13180.41	0.00	22463.34	0.00	9089.86	0.00	327.71
3		Dense	0.00	22333.59	0.00	20945.04	0.00	22707.65	0.00	28220.76	0.00	2782.05
4	Bamboo		0.00	0.00	2846.07	9116.36	86.70	2488.69	0.00	0.00	0.00	0.00
5	Grass Lands	Total	16372.01		11382.29		18994.73		3300.47		27557.30	
6		Dry	0.00	12779.02	0.00	14876.19	0.00	16725.72	0.00	13185.79	0.00	51679.69
7		Moist (Echhornia)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2356.57
8	Scrublands		9547.82	8097.32	2931.33	2398.79	6861.11	5386.14	946.56	2039.34	16432.66	5465.44
9	Agriculture		2900.60	4654.55	6133.28	0.00	12259.29	0.00	2533.26	0.00	3892.44	10102.24
10	Orchards		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	254.91
11	Homestead		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	77.83
12	Rivers		197.84	163.39	429.35	204.47	209.97	0.00	19.04	0.00	843.39	479.72
13	Lakes		8.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	723.74	0.00
14	Open/ Builtup		18578.57	5430.16	7518.81	4871.60	13906.04	5461.88	2705.45	2020.36	24718.96	3485.87
15	Burnt areas		0.00	0.00	0.00	0.00	0.00	2553.60	0.00	1445.79	0.00	0.00
	Total area		62945.78	62945.78	65592.87	65592.87	77787.01	77787.01	56001.90	56001.90	76996.13	77012.02

3.6. Bamboo Distribution

Mapping of Bamboo distribution is relatively a difficult task if it occurs as clumps in second or third storey in a forest due to partial reflectance from bamboo canopy and further mixing of spectral signatures with other classes. In the study area bamboo occurs in gregarious as well as co-dominant species (plate 2). Therefore a hybrid approach of classification system was followed which means using different approaches at a time to distinguish land features present on the satellite imagery. All though there were some spatial and spectral limitations while using medium resolution imagery like Landsat-7, knowledge based classification techniques were used to classify bamboo areas with sufficient accuracy.


Plate 2: Bamboo mixed with other tree species

Inputs:

- Satellite data
- Reference documents from CEF
- GCPs / Field tabular data: The Ground Control Points (Ground Truth) collected during field investigation were given different attributes likes species name, occurrence of features on either side of the GCPs etc. Ground Control Points having bamboo on either or both sides were made a separate file and was properly utilized on satellite imagery to extract spectral signature of bamboo classes.

Methodology:

- DEM was sliced into two elevation zone *viz* up to 200 meters and more than 200 meters (200 to 350m)
- PCA analysis of Landsat TM satellite image for masked forest classes was done.
- NDVI image of forest was generated using Landsat TM satellite data.
- To avoid spectral mixing. PCA and NDVI layers were recoded in two ranges i.e. upto 200 and > 200 based on DEM.
- Knowledge based conditional statements were written for each elevation zone to extract the bamboo area.
- The resulting image was cleaned using satellite imagery and single pixels were removed using **clump** and **eliminate** analysis.

Output:

- Bamboo distribution map (fig. 14)

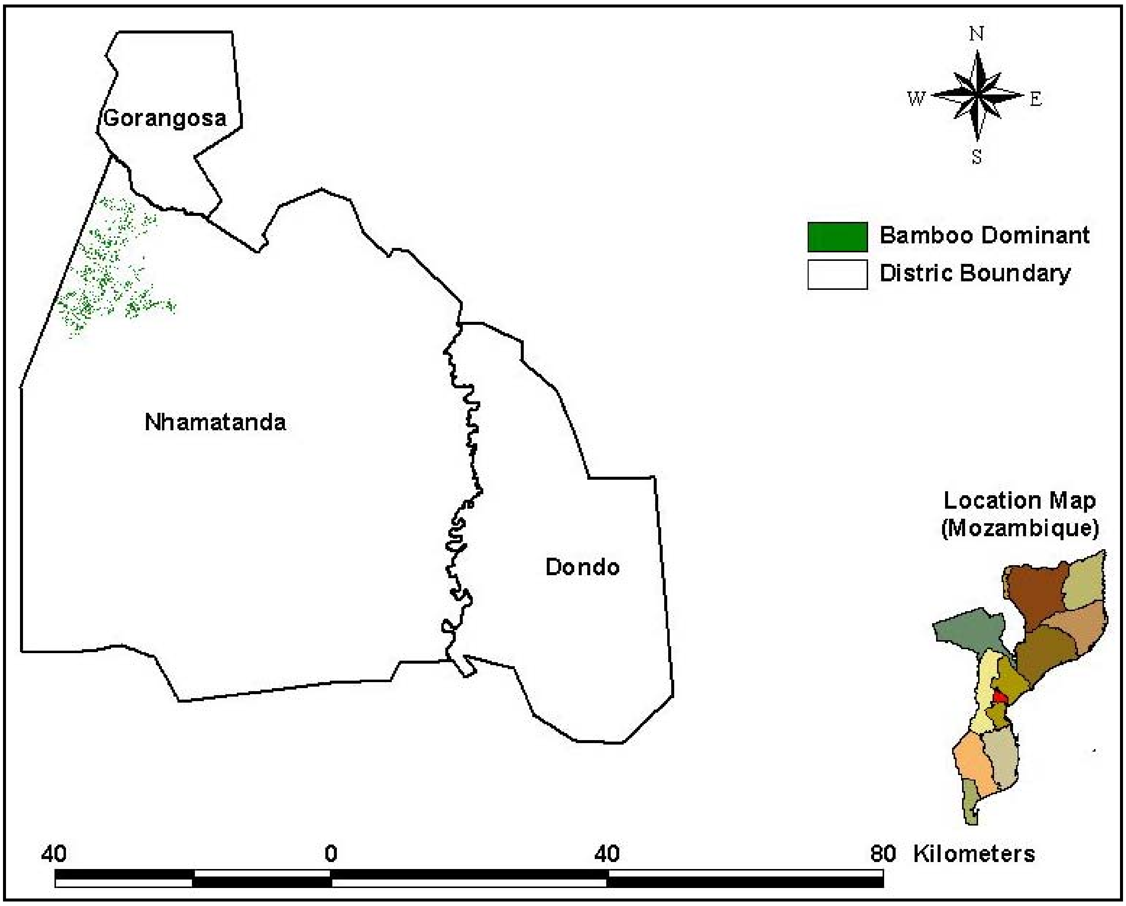


Fig. 14. Bamboo distribution map

As shown in the map above large-scale distribution of bamboo remains only in the north-western part of the study area. In the shifting cultivation dominant areas quite possible that bamboo must have been present in past in plenty but due to continuous human exploitation of land in the form of shifting cultivation has resulted in confined spread of bamboo in some pockets.

Limitation of analysis

Since Landsat- TM has got moderate spatial resolution and most of the bamboo clumps are either scattered or mixed with other tree species as second storey, satellite based signatures cannot be solely used in such cases. In some cases the distribution in the study area limits to few clumps in very small area, thus for separation of such signatures with other land use land cover classes adjacent to bamboo, knowledge based classification technique was utilized in conjunction with satellite based signatures. Through knowledge based classification most probable areas where bamboo is present was delineated.

3.7. Bamboo Stock map

Bamboo stock calculation is very important from the livelihood generation point of view and it helps in planning and organizing the local life for a sustainable living. In this context bamboo stock classes were generated using Satellite imagery. There were some hypotheses to consider. During field investigation sample sites were selected keeping in mind the minimum delineation unit (2 X 2 pixels) wherever possible in order to get the pure and continuous signatures from satellite images. The average number of bamboo in each clumps were also noted during field investigation along with the average number of clumps in the sampling unit. The bamboo map generated was used for calculating the average number of bamboo poles in the bamboo dominant areas based on information collected during the fieldwork. With the help of GCPs, areas were marked for different number of clumps present. Seven classes were made to segregate different patches of different number of cluster present.

Methodology:

The methodology involved in this study is based on the hypothesis of sample size and average number of bamboo clumps present in a single measurement unit. The measurement unit was considered as 2 pixels by 2 pixels and average number of bamboo poles (sticks) per clumps is taken as 30. The stepwise methodology is given below:

Steps Involved:

1. Bamboo map was generated and with the help of ground control points, bamboo areas were marked to know the average number of clumps present. It was classified into seven different classes starting from 50 clumps to 300 clumps.
2. According to field investigation it was concluded that the sample size could be of two pixels by two pixels, hence
3. It was also concluded that within this sample size one clump may have 30 number of bamboo poles (sticks). These hypotheses were built, based on the actual ground survey.
4. Hence the stock (total no of bamboo) was calculated by multiplying number of bamboo poles/culms per clump and number of clump. The total stock was calculated by multiplying total area and stock value.
5. Formula used to calculate number of bamboo per pixel is equal to (number of bamboo per clump*no of clump)/4

Table: Satellite based estimation of class wise number of bamboo clumps

S.no	Classes	No. of pixels	Area (ha)	No of bamboo per clump	Average clumps per pixel	Total no of bamboo culms per pixel	Total number of bamboo culms per class
1	Average 15 clumps	27208	1700.50	25	15	375	10203000
2	Average 20 clumps	3290	205.63	25	20	500	1645000
3	Average 30 clumps	3632	227.00	25	30	750	2724000
4	Average 40 clumps	3010	188.13	25	40	1000	3010000
5	Average 50 clumps	2627	164.19	25	50	1250	3283750
6	Average 60 clumps	1387	86.69	25	60	1500	2080500
7	Average 70 clumps	4688	293.00	25	70	1750	8204000
			2865.13				31150250

Output:

- Bamboo stock distribution map (fig. 15)

Fig. 15. Bamboo stock distribution map

3.8. Forest distribution map

Forest distribution map was prepared from land use land cover map (fig. 16). Since the Landsat TM images data used in the study are of November and May month, it is best suited to represent the overall distribution of forests since most of the forest canopies remain green during November to April as the monsoon starts in the month of November and ends till April. For mapping the specific forest types (evergreen and deciduous) use of two season images is necessary.

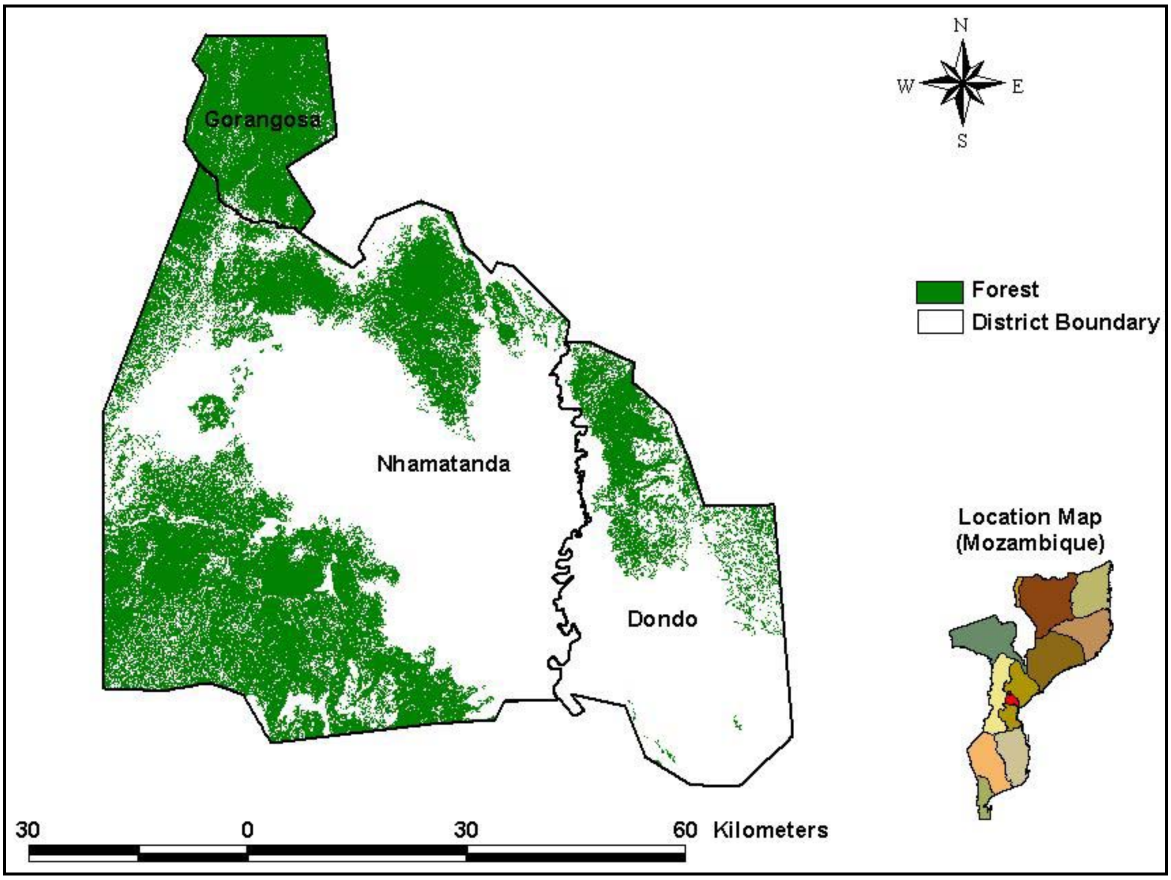


Fig .16. Forest distribution map

3.9. Timber species map

Till date species identification from moderate resolution satellite data is a debated issue due to limitations of the satellite data. However the communities occurring gregariously can be effectively mapped using sufficient ground truth. Timber species distribution map was generated using satellite based classification and ground information collected during fieldwork.

Inputs:

- LULC Map
- NDVI image derived from Landsat TM data
- Ground Control Points

Methodology:

- The NDVI map was generated from Landsat TM image.
- NDVI was used to generate vegetation map.
- From vegetation map Landsat TM image was masked out and new image of forest area was created.

- GPS points were overlaid on the masked Landsat forest image. 10-15 communities were recorded during the ground truth, however based on the dominant species they were grouped into 7 classes and signatures were collected from the image for a association of the observed tree species (plate 3-6).
- Supervised classification was run for the given signature sets
- The final map was generated in 7 classes.

Output: Area statistics and timber species map (fig. 17.)

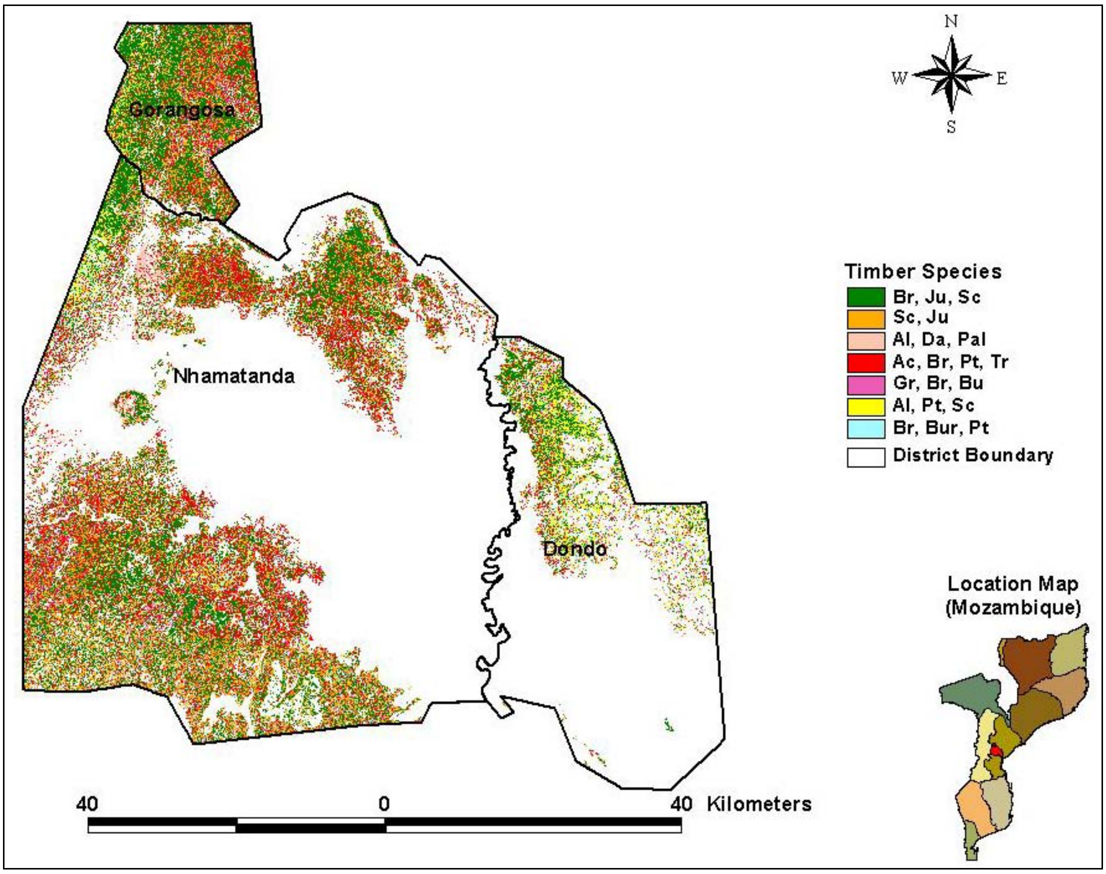


Fig. 17. Timber species map

Table: Area estimates of major association of timber species in forest

Sl. No.	Timber Species	Abbreviation used	Area (Ha)
1	Brachystegia, Julbarnadia, Sclerocarya	Br_Ju_Sc	76258.00
2	Sclerocarya, Julbarnadia	Scl_Ju	46200.56
3	Albizia, Dalbergia, Paleostigma	Al_Da_Pal	6987.19
4	Acacia, Brachystegia, Pterocarpus, Terminalia	Ac_Br_Pt_Tr	51431.25
5	Brachystegia, Burkea Africana	Gr_Br_Bu	13592.13
6	Albizia, Pterocarpus, Sclerocarya	Al_Pt_Sc	16582.13
7	Brachystegia, Burkea africana, Pterocarpus	Br_Bur_Pt	13812.25

Significance for Analysis: The timber species map forms an important input for number for forestry operations. It gives the distribution of important tree/timber species that may serve as a resource for charcoal extraction and thereby identifying the site suitability for setting up charcoal industry. In the study area several species such as *Pterocarpus angolensis*, *Millettia stuhlmannii*, *Burkea africana*, *Dalbergia melanoxylon*, etc. are highly threatened due to frequent fires and selective logging. The timber species map helps locate zones where these species may occur so that timely and effective measures can be taken up to ensure their protection and conservation.

Plate3:*Comberetum* and *Acacia* dominated forest

Plate 4: *Acacia* and *Bracstegia* dominated forest

Plate5: *Paleostigma* dominated forest

Plate 6: *Strychnos* and *Bracstegia* dominated forest

3.10. Wasteland Delineation

Wasteland map was prepared as per the classification given below:

1. Ravinous / Gully Erosion
2. Land with or without scrub
3. Water logged and Marshy land
4. Shifting cultivation area
5. Degraded forest
6. Degraded pasture / grazing land

Inputs:

- LULC map
- Satellite data

Methodology:

This was a semi-automatic process. Using unsupervised classification and visual interpretation of satellite imagery. Steps followed are given below:

- Forest was mask in the satellite data using LULC map generated in the previous exercise
- Unsupervised classification was run further on the masked image
- Results were refined using clump/eliminate and final polygons were demarcated using on-screen visual interpretation f the unsupervised map.

Output: Wasteland map having six classes was obtained in the output (fig. 18)

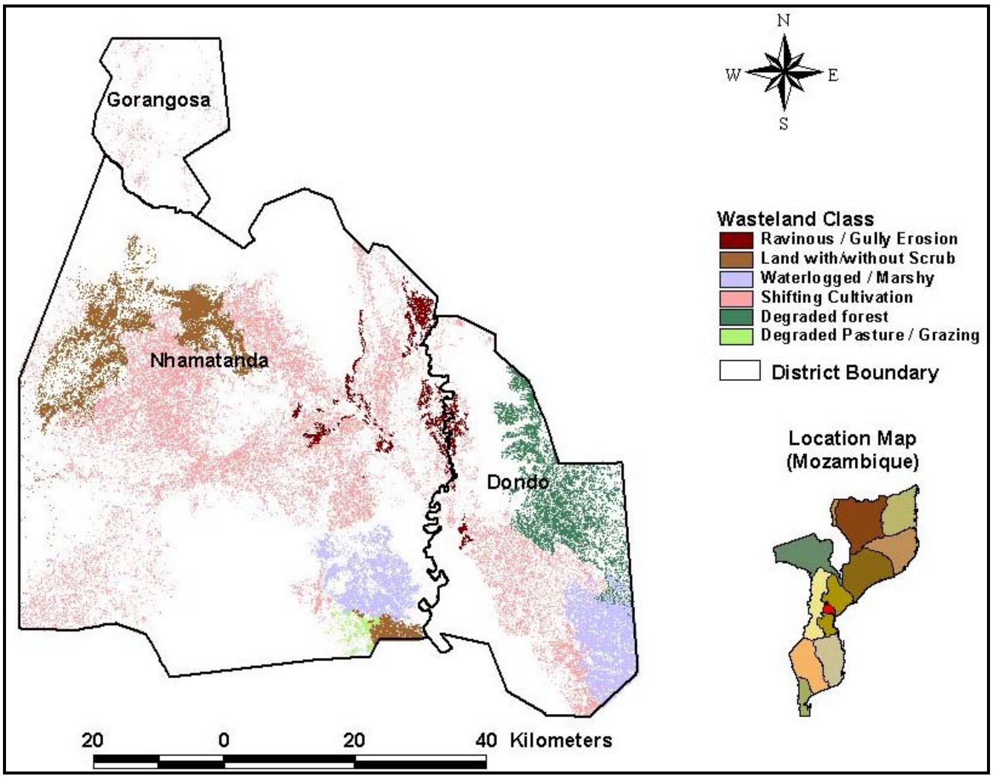


Fig. 18. Wasteland map

Table: District wise distribution of wasteland classes in the study area

Sl. No.	Wasteland Class	Gorongosa	Dondo	Nhamatanda	Total Area
		Area (ha)			
1	Ravinous / Gully Erosion	0.00	1269.39	5256.13	6525.53
2	Land with or without scrub	0.00	0.00	20738.27	20738.27
3	Water logged and Marshy land	0.00	11545.56	9449.69	20995.25

4	Shifting cultivation area	1408.38	11274.98	51004.47	63687.83
5	Degraded forest	0.00	15732.49	0.00	15732.49
6	Degraded pasture / grazing land	0.00	0.00	1250.19	1250.19
Total area		1408.38	39822.42	87698.75	128929.54

3.11. Shifting cultivation area


Plate 7: Clearing of land for shifting cultivation

Slash and Burn agriculture i.e. shifting cultivation system with a rotation cycle of 10 -12 years is commonly practiced by peasant communities in Mozambique (plate 7). Shifting cultivation is a form of subsistence farming in communal areas and affects hundreds of square kilometers. Current shifting cultivation areas were mapped from the satellite image using ground based information and interpretation skills. This class was mapped along with the wasteland map as one of the classes. Figure below shows the distribution of shifting cultivation areas in the study area (fig. 19)

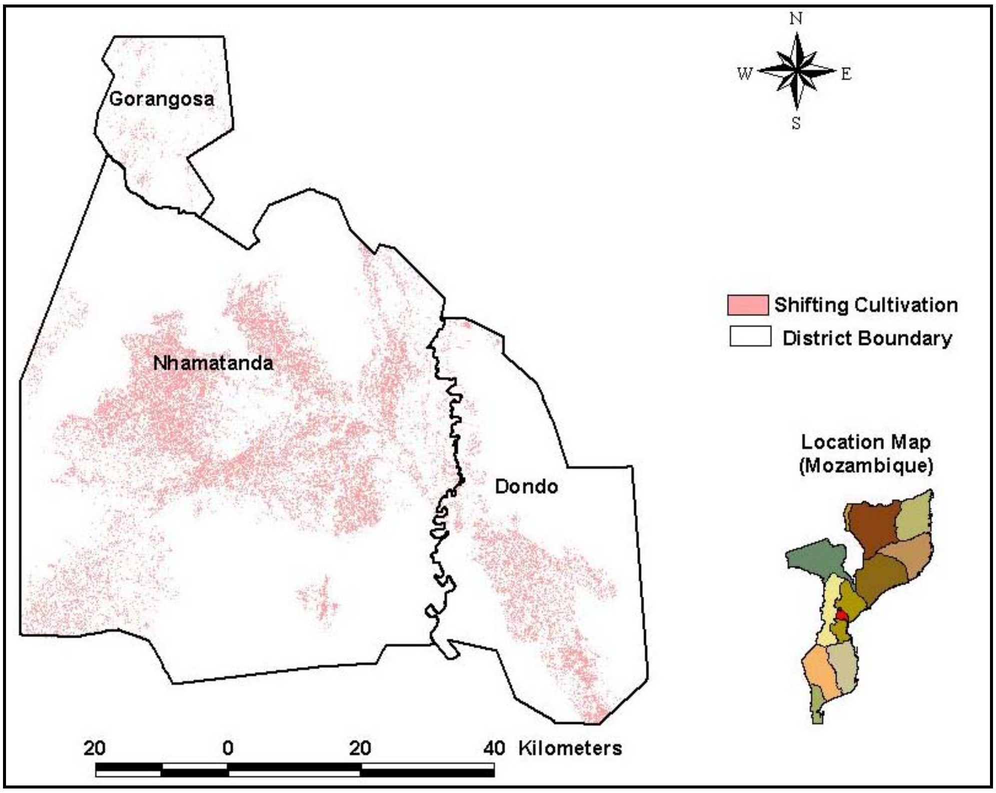


Fig. 19. Map showing district wise distribution of shifting cultivation in study area

3.12. Climatic data

Rainfall and temperature maps were acquired from CEF. Temperature maps were available in grid form.

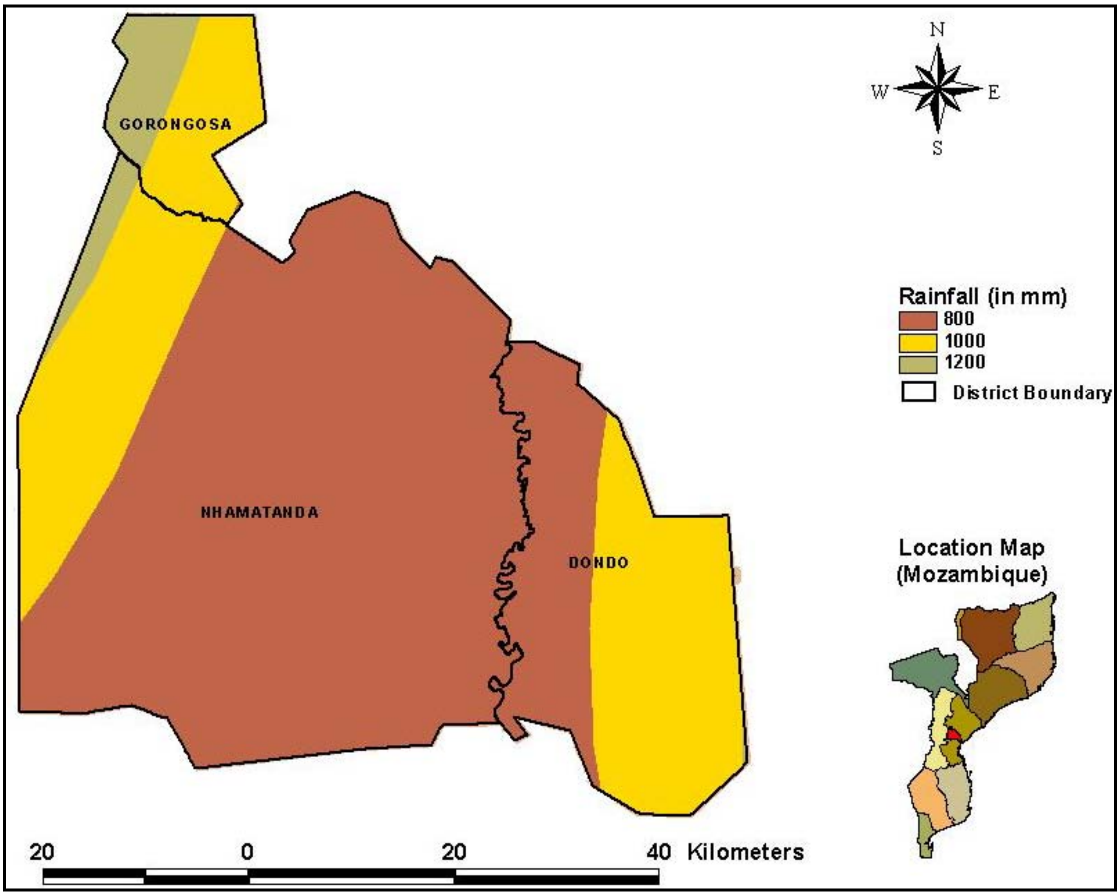


Fig. 20. Rainfall map of study area

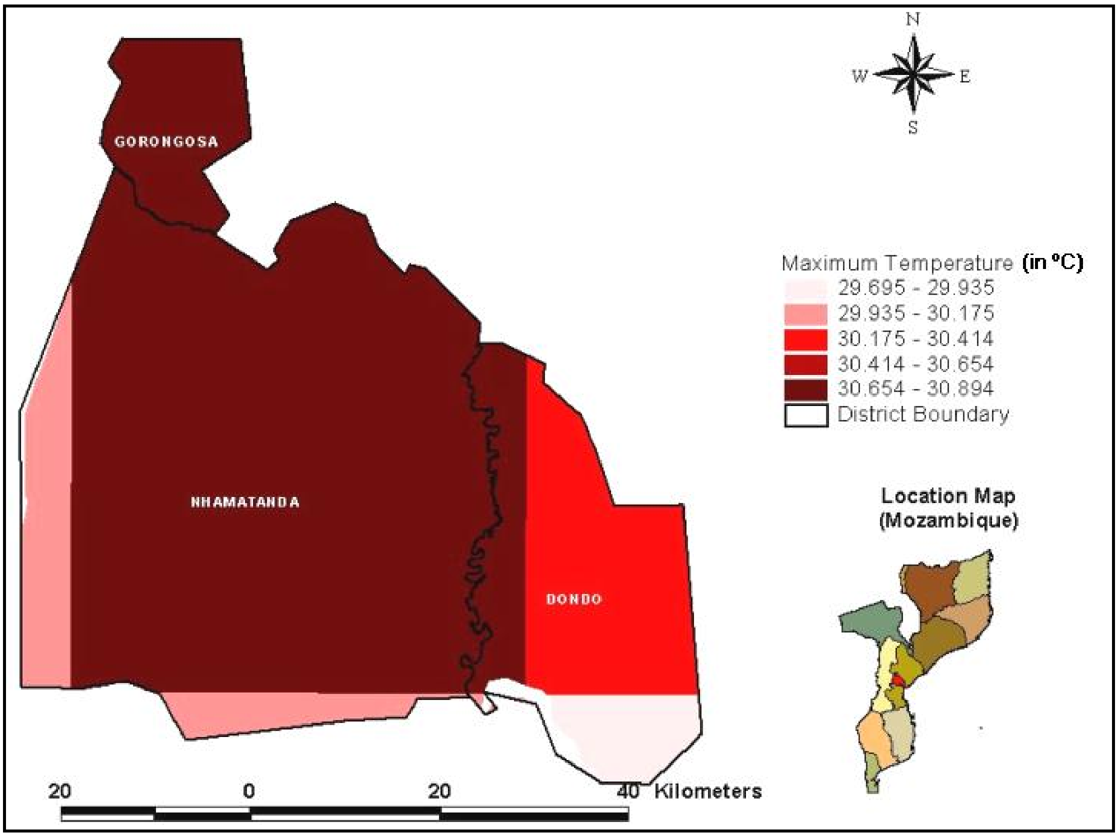


Fig. 21. Map showing maximum temperature in the study area

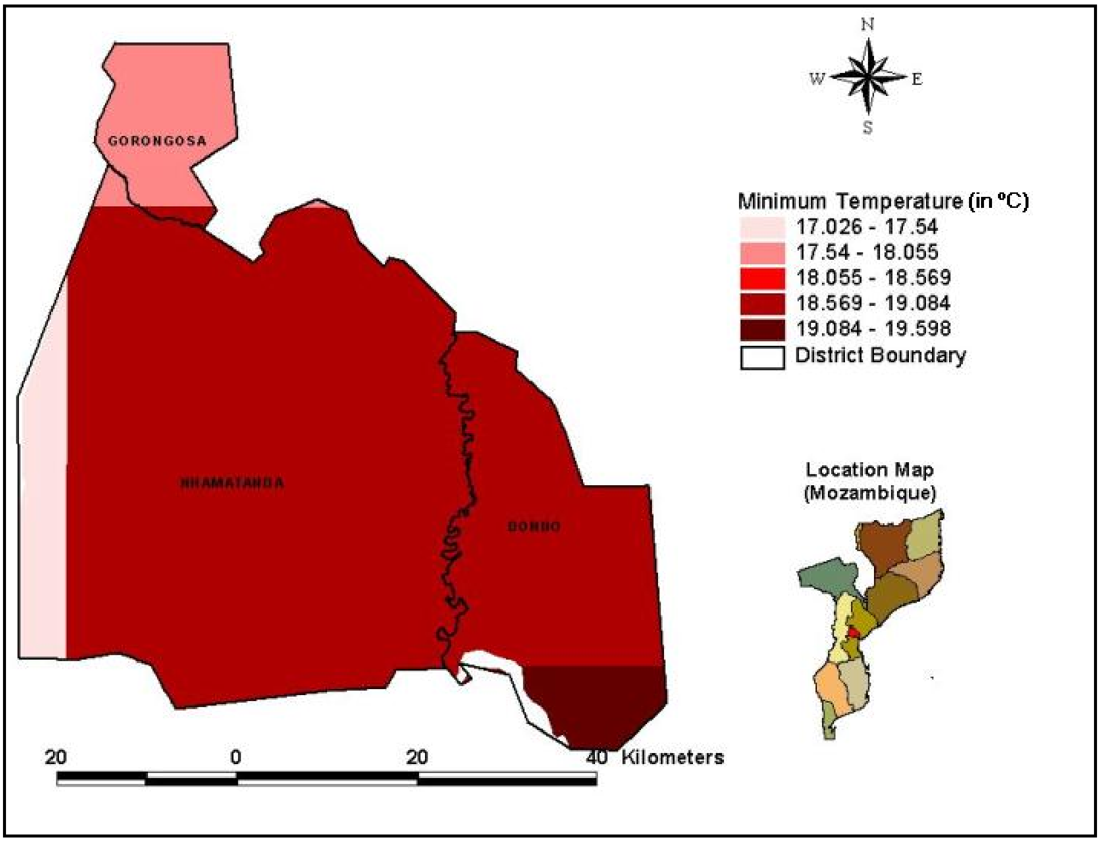


Fig. 22. Map showing minimum temperature in the study area

3.13. Wood stock map

Wood stock classification was performed to know the total volume of wood present in the forest. This was done with the help of simple mathematical formula (volume of a cone) to calculate the wood volume.

Inputs: There were mainly three input maps generated like diameter map, height map and number of tree map. The steps involved in generation of these maps are discussed in methodology below.

Methodology

1. NDVI image was generated from Landsat TM images
2. Supervised classification using GPS based height and diameter attribute was performed. Height was in meter and diameter was in cm.
3. Five classes out put were generated, where each class represents height and diameter in two different files.
4. For number of trees again GPS based information was used which was collected during fieldwork.
5. Minimum and maximum number of trees per pixel were calculated and it was applied to the NDVI image for rescaling where minimum value of NDVI was assigned the minimum value of trees and maximum value of NDVI was assigned to the maximum number of trees per pixel. For example

NDVI	No of Trees
0.35	1
0.75	15

6. In this way three input files i.e. Tree radius map, Height map and No of tree map were generated.
7. The formula used to calculate Wood Stock = $(1/3) * \pi R^2 H$
8. The above formula was divided by 1000000 to convert cm to hectare and again divided by 16 to get per pixel value in **tons per year per pixel.**

Output: Woodstock map and table showing district-wise woodstock distribution

Table: District wise Woodstock distribution

Sl No.	Wood Stock	Gorongosa	Dondo	Nhamatanda
		Area (ha)	Area (ha)	Area (ha)
1	0 to 1 cubic meter	1298.19	3529.06	13896.00
2	1 to 3 cubic meter	713.94	828.00	19615.56
3	3 to 5 cubic meter	10649.31	4646.31	59047.50
4	5 to 8 cubic meter	23469.38	16928.19	67934.69

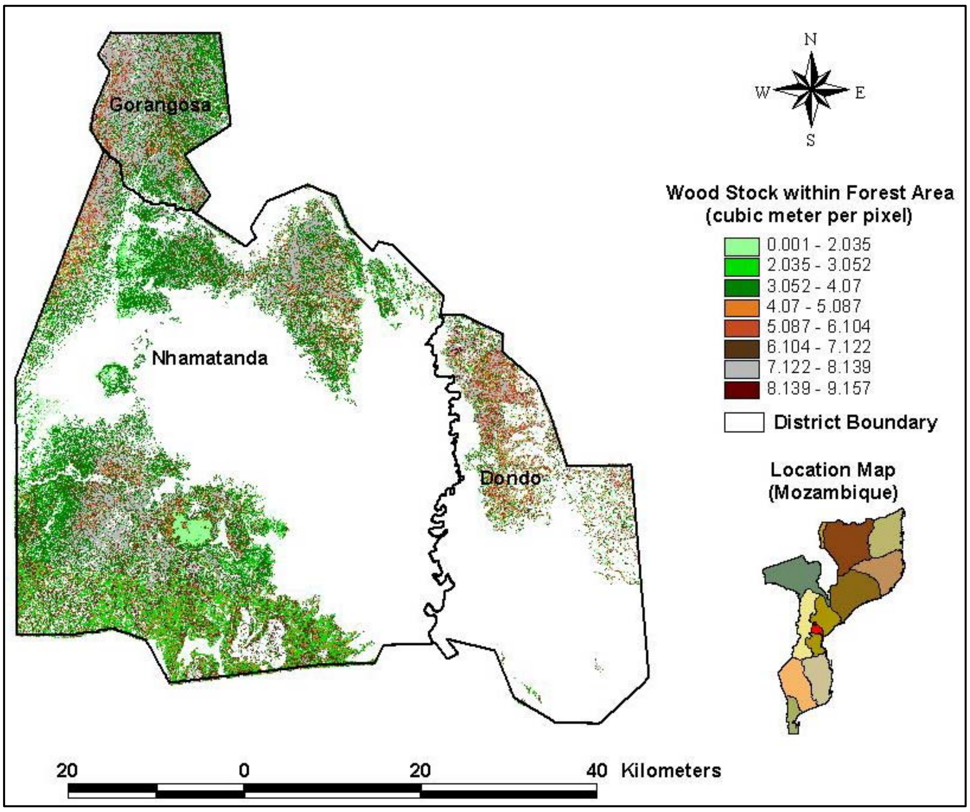


Fig. 23. Map showing Woodstock distribution

3.14. Carbon emissions

Fires are the main source of carbon emissions. In Mozambique fires generally occur during the clearing of forest for shifting cultivation, hunting or clearing grassland for facilitating grass growth for cattle ranching, which creeps uncontrolled into the forest as well. Natural fires in forest are also a common feature. The carbon emission map was prepared using MODIS satellite images.

Inputs:

- MODIS Image of year 2003
- Woodstock Map

Methodology:

- MODIS active fire product was downloaded and the actual extent of fire area were mapped on the MODIS imagery of year 2003.
- Using the actual fire extent a wood stock map was masked out to know wood stock burnt by fire.
- The subset of the final wood stock map gives the total carbon present in the forest area.
- The total carbon emitted was estimated by the following formula

C = M*B (Trozzi and Vaccaro 2002)

Where M is the biomass (Stock map) and b is carbon's quantity contained in the biomass, which can be set equal to 0.45

- Using the above said formula the carbon emission map was generated

Output:

Carbon emission map and table showing per pixel and per class carbon emission values

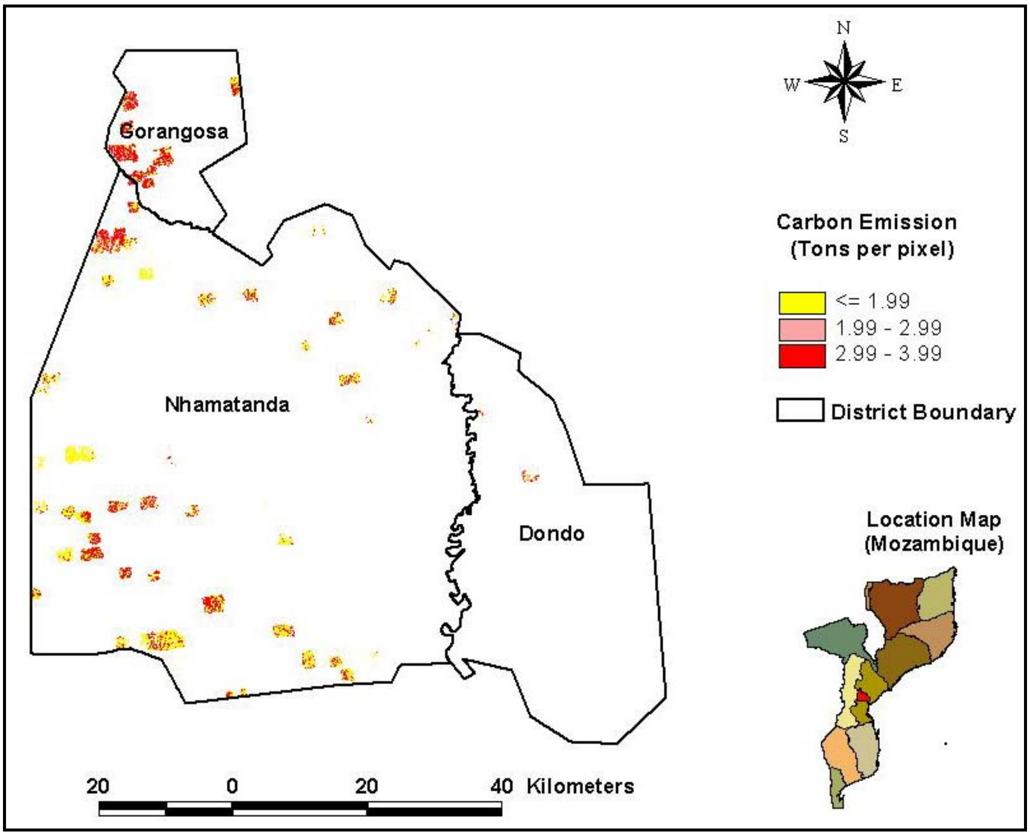


Fig. 24. Carbon Emission map

Table: Per Pixel carbon emission values

Class	Carbon Emission Per Pixel	Total Carbon Emission per Class (tons)
1	< 1.99	184043
2	2.0 – 2.99	77885
3	3.0 – 3.99	410653

3.15. Carbon Sequestration of Forest

Carbon emission is supposedly the strongest causal factor for global warming. So, increasing carbon emission is one of today's major concerns. Trees are amongst the most significant elements of any landscape, both due to biomass and diversity. However, it is paradoxical that the vegetation has undergone destruction and degradation in the modern times due to industrial and technological advancement achieved by human society. Therefore, there is need to address environmental issues related to them. Trees are important sinks for atmospheric carbon i.e. carbon dioxide, since 50% of their standing biomass is carbon itself. Importance of forested areas in carbon sequestration is already accepted. Satellite based forest inventory was utilized for generating layer of carbon sequestration for agriculture, bamboo and forest.

Inputs:

- Land Use/Land Cover Map
- Carbon Sequestration factor (in tones per hectare per year)

Source:

1. Roadel *et al*. 2000; Carbon Dioxide (Co2) Storage And Sequestration In The Leyte Geothermal Reservation, Philippines; Proceedings World Geothermal Congress 2000, Kyushu - Tohoku, Japan, May 28 - June 10, 2000
2. http://bamboocentral.org/whybamboo.html

Methodology:

- The carbon sequestration factor was converted from per hectare to per pixel for Landsat TM data
- Per Pixel carbon sequestration factor was multiplied with number of pixels of respective land use/ land cover class to obtain carbon sequestration map showing values in tones per year.
- The detailed result is given below in a table showing total carbon sequestration in tones per year for respective land use / land cover class:

Output:

Carbon sequestration map and a table showing carbon sequestration value for various land use land cover classes.

Table: Total carbon sequestration in tones per year for respective land use / land cover class

Land use / Land cover	Carbon Sequestration factor (tons per hectare per year)	No. of pixels in each class	Carbon Sequestration (tons per year)
Builtup	0	44426	0
Agriculture	4.29	669171	179421
Forest	0.28	3599418	62989
Grass Lands	1.5	1988419	186414
Scrublands	0	1017865	0
Rivers	0	67992	0
Lakes	0	13772	0
Open	0	1741240	0
Bamboo	14	45696	39984

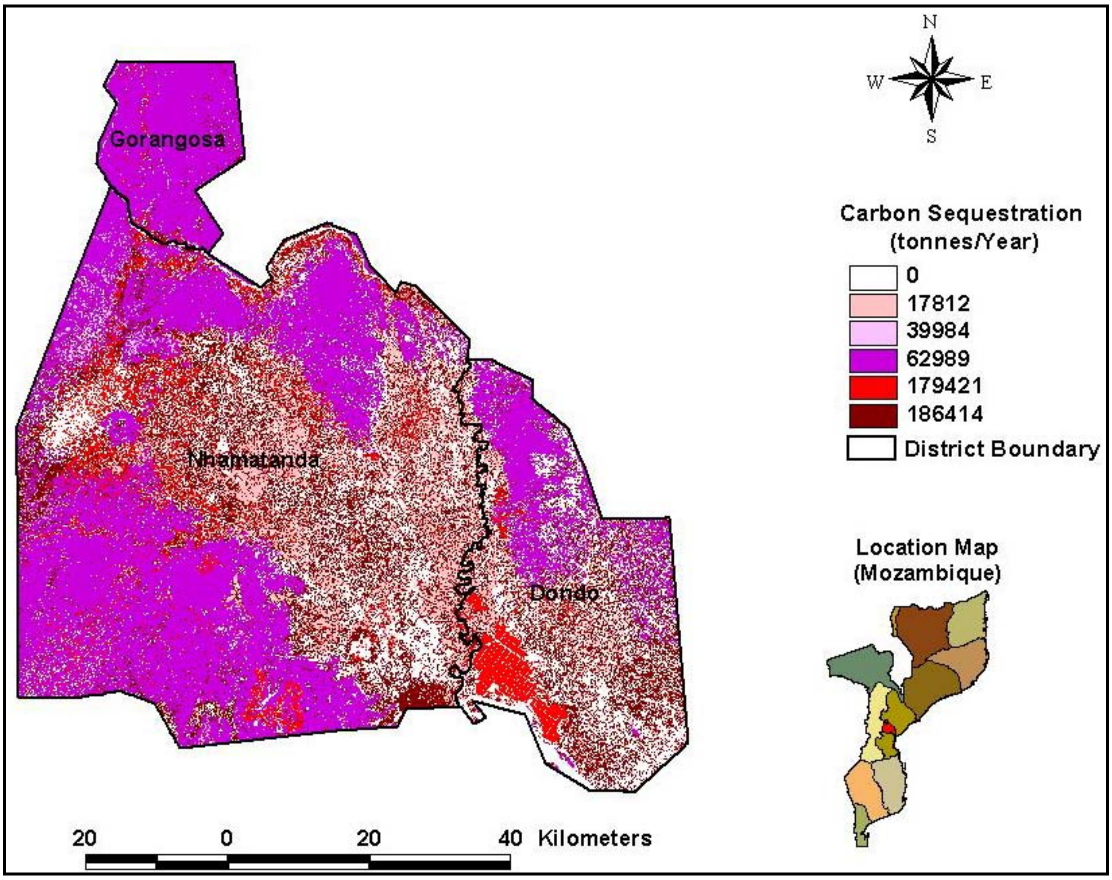


Fig. 25. Carbon sequestration map

3.16. Potential Agriculture Zone Map

Inputs:

- LULC Map
- Drainage Map
- Soil Map
- Digital Elevation Model

Methodology:

1. LULC map was rearranged into eight classes with highest priority given to agriculture.
2. Soil drainage classes were generated with the existing soil type map and finally reclassified into five classes.
3. To find out the availability of water for irrigation was proximity from the river was calculated using drainage buffer map
4. DEM was sliced into four classes of different elevation zone.
5. Final weightage were assigned to each of the input layers to derive output map

Table: Weightages used for potential Agriculture Zone Mapping

Layer name	Layer weightage	Class	Class weightage	Final Weightage
LULC	35	Open + Forest	1	0.35
		Scrublands	2	0.7
		Grass Lands	3	1.05
		Agriculture	4	1.4
Soil Drainage	30	Imperfect	1	0.3
		Excessive	2	0.6
		Little Excessive	3	0.9
		Moderate	4	1.2
		Good	5	1.5
Drainage	25	1 Km	1	0.25
		2 Km	2	0.50
		3 Km	3	0.75
		4 Km	4	1.00
		5 Km	5	1.25
DEM	10	GT 300	1	0.10
		200 TO 300	2	0.20
		100 TO 200	3	0.30
		0 TO 100	4	0.40

Output:

- Potential agriculture development map.

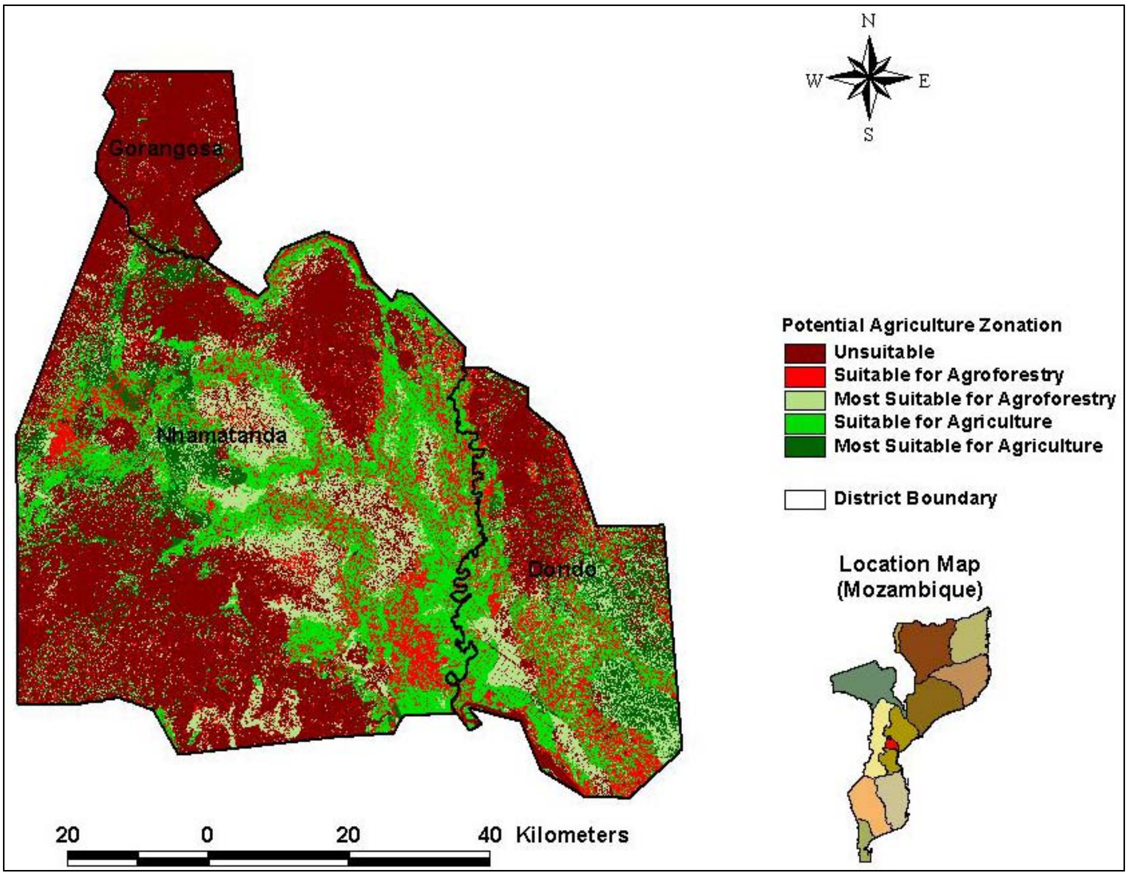


Fig. 26. Potential Agriculture zones map

Significance for analysis

The potential agriculture zonation map generated in the present analysis can be used as an input for assessing crop species wise suitability map for sugar cane, wet rice, maize, tapioca, or fruit trees etc. However it further requires information on market and supply chain channels. Another important consideration in such analysis would be that most of the time the communities like to go for mixed crop. Therefore any planning should be made with the active participation of the community members so that effective action plan with sustainable pattern may be developed based on existing TKS (*Traditional Knowledge Systems*) and it will be more appropriate to identify the suitable locations at broader level and the crop selection should de done after a proper rural appraisal of resources and existing *Best Practices.*

3.17. Area Vulnerable to Soil Erosion

Soil erosion is one of the major concerns in the study area (plate 8). The main drivers of erosion are human induced changes in land cover and land use practices such as mining, forest fires, deforestation, overgrazing etc. However in nature also erosion is always taking place. Physical factors such as topography (slope in particular), soil properties and underlying rock, vegetation, and climate characteristics (rainfall in particular) are important factors in the acceleration of human induced erosion The vulnerable sites need to be mapped through overlay analysis. The sites were identified and classified in four categories based on the weightage value through overlay analysis (Fig. 3.6).

Plate 8. Soil erosion in Mozambique

Inputs:

- Stream Network
- Land-use/ Land-cover Grid
- DEM
- Slope Grid

Methodology:

1. The aim was to identify the vulnerable areas along the drainage network for soil erosion.
2. DEM was sliced into six elevation zones; details are given in the table below.
3. Land use map having six classes was generated and based on susceptibility each class was assigned a weightage.
4. Slope map was grouped in to six classes and weightage were given
5. River vicinity map (buffer map) was generated to delineate areas affected by bank erosion.
6. Each input layer was further given weightage as given in the table below.
7. Final map showing erosion prone area was generated based on the Overlay analysis of the above-motioned input layers.

Table: Weightage used for Soil Vulnerability mapping

Layer name	Layer weightage	Class	Class weightage	Final Weightage
LULC	40	Open	6	2.4
		Agriculture	5	2
		Scrublands	4	1.6
		Grass Lands	3	1.2
		Forest	2	0.8
		Bamboo	1	0.4
DEM	10	> 300	6	0.6
		241-300	5	0.5
		181-240	4	0.4
		121-180	3	0.3
		60-120	2	0.2
		< 60	1	0.1
Slope	20	> 60	6	1.2
		40-60	5	1

Layer name	Layer weightage	Class	Class weightage	Final Weightage
		25 to 40	4	0.8
		15 to 25	3	0.6
		5 to 15	2	0.4
		< 5	1	0.2
River	30		3	0.9
			2	0.6
			1	0.3

Output:

- Soil Vulnerability Zone grid with highest value representing erosion prone areas whereas values on lower side represent low erosion.

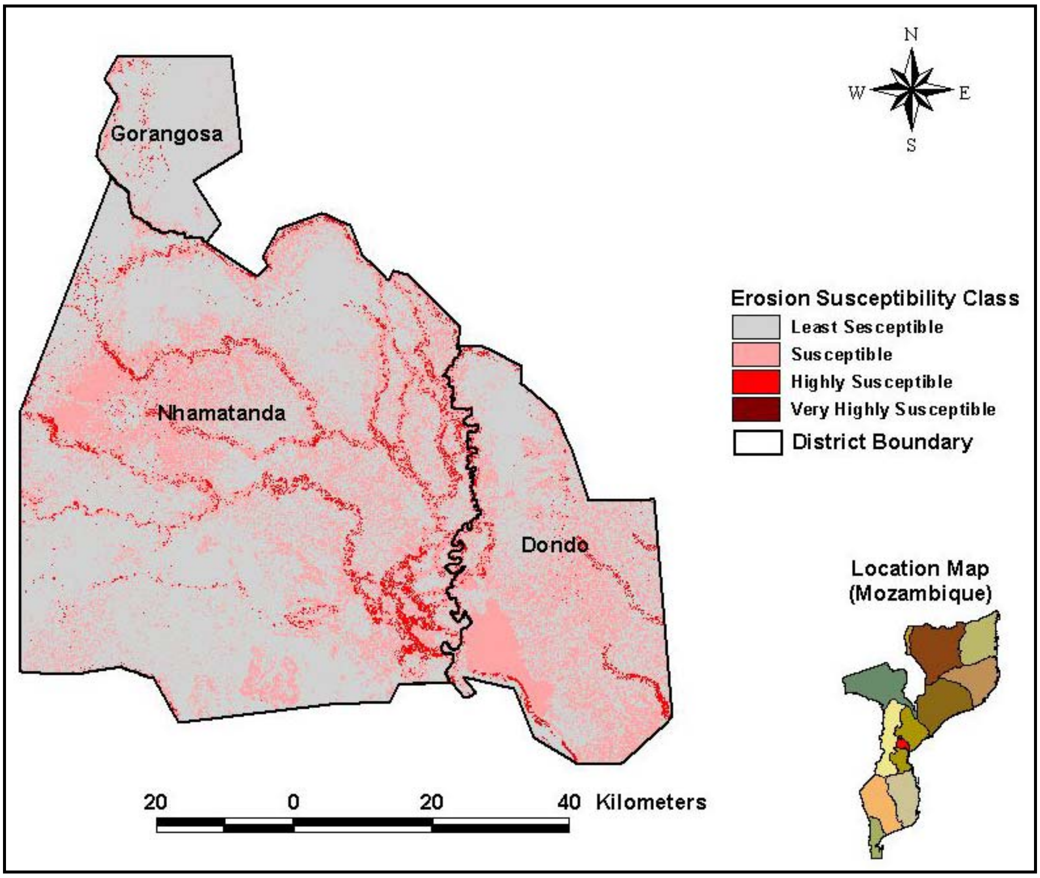


Fig. 27. Soil Erosion vulnerability map

Significance for Analysis:

The soil erosions zones have considerable importance while identifying the suitable locations for Bamboo nurseries and Plantations. Community nursery for Bamboo & other sites are always preferred near the stream network due the high water requirements. Also planting bamboo/other trees can check the lateral cutting by the speedy waters along the banks of the rivers. Bamboo is considered as the most suitable tree/grass species for protecting fragile slopes as it holds the soil particles together and can still grow even after cutting down the bamboo culms. The slope failures can be avoided as bamboo is very light in weight and does not put additional weight on the fragile slope. So, in order to protect the highly vulnerable slopes and riverbanks, pure bamboo plantation can be taken up as the remedial measure or they could also be mixed with some deep-rooted tree species.

3.18. Erosion Protection Measures

Inputs:

- Landuse map
- DEM
- Slope
- River map

Methodology:

- DEM was sliced into six elevation zone
- Land use map was also reclassified into six class
- Slope map was also generated
- River vicinity map (buffer map) was generated to find out the bank erosion
- The conditional statement used in the model is given below

```
($n1_dem_6cls  * 0.10) + ($n4_slope_6cls * 0.20) +
($n5_landuse_for_erosion * 0.40) + ($n6_rivbuf * 0.30)
```

Table: Weightage used for Erosion Protection area mapping

Layer name	Layer weightage	Class	Class Weightage	Final Weightage
LULC	40	Open	6	2.4
		Agriculture	5	2
		ScrubLands	4	1.6
		Grass Lands	3	1.2
		Forest	2	0.8
		Bamboo	1	0.4
DEM	10	> 300	6	0.6
		241-300	5	0.5
		181-240	4	0.4
		121-180	3	0.3
		60-120	2	0.2
		< 60	1	0.1
Slope	20	> 60	6	1.2
		40-60	5	1

Layer name	Layer weightage	Class	Class Weightage	Final Weightage
		25 to 40	4	0.8
		15 to 25	3	0.6
		5 to 15	2	0.4
		< 5	1	0.2
River	30		3	0.9
			2	0.6
			1	0.3

Output:

Based on the analysis suitable sites have been proposed for taking up erosion protection measure (fig.28)

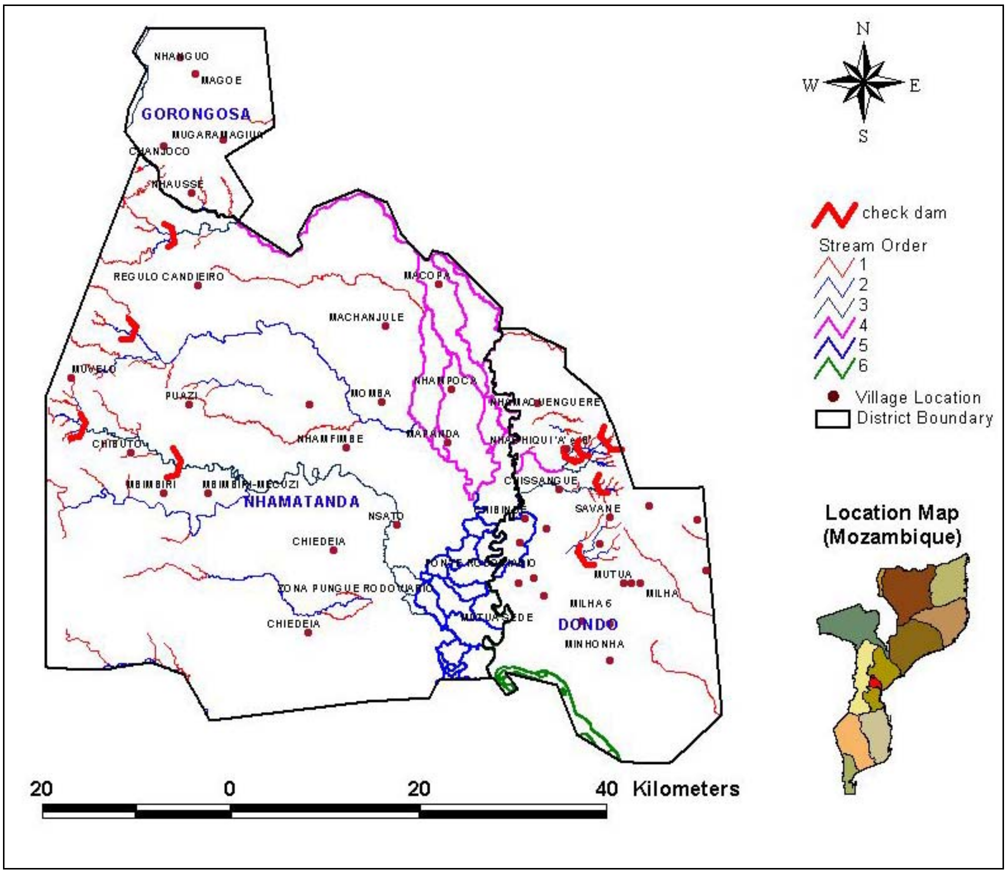


Fig. 28. Map showing erosion protection measures

Recommendations:

1. In higher elevation areas wherever erosion is high, check dams were suggested.
2. Along the riverbanks bamboo can be planted as shelterbelt. Due to agriculture activity the topsoil continues to be more prone to topsoil erosion. Through bamboo plantation these fertile areas can be protected from topsoil erosion.

Further it is important to mention that in Mozambique the productive land is limited only on the banks of the river so the purpose to create shelterbelt is not to convert the potential agriculture area into bamboo plantation but planting bamboo along the bunds could be suggested.

3. Besides bamboo other species can also be planted as agro-forestry measures however due to its multipurpose usage and fast growth, bamboo is considered better in comparison to any other species.
4. In the areas where there is naturally regenerating forests area, no activity / measures are required unless natural growth is very poor. Also in that case some measures can be taken up for ANR otherwise bamboo remains the best option, as it does not have any negative impact on the soil quality also unlike eucalyptus, which have high water requirement.
5. Pine can be promoted in higher elevation areas, which are not suitable for growing bamboo, based on field knowledge.

3.19. Watershed Delineation

Watershed delineation is generally done based on the contours and drainage pattern. It is also done on the basis of terrain relief. In this study due to insufficient presence of contours on the topomaps provided, the watershed and sub-watershed were delineated based on the river networks and drainage pattern, which was mapped from the LANDSAT TM satellite data. However, the coarse and moderate resolution satellite data have their own limitations in drainage mapping as higher order streams could not be digitized unless their width is higher or at least equal to the minimum mapping unit of the satellite data or some perennial water flowing in it. In the present study this limitation was overcome at some locations where high resolution IRS LISS IV RESOURCE SAT data was available. Final drainage map was updated with the RESOURCESAT data where available and the final drainage map was prepared based on it three watersheds were delineated in the study area (Fig.28b)

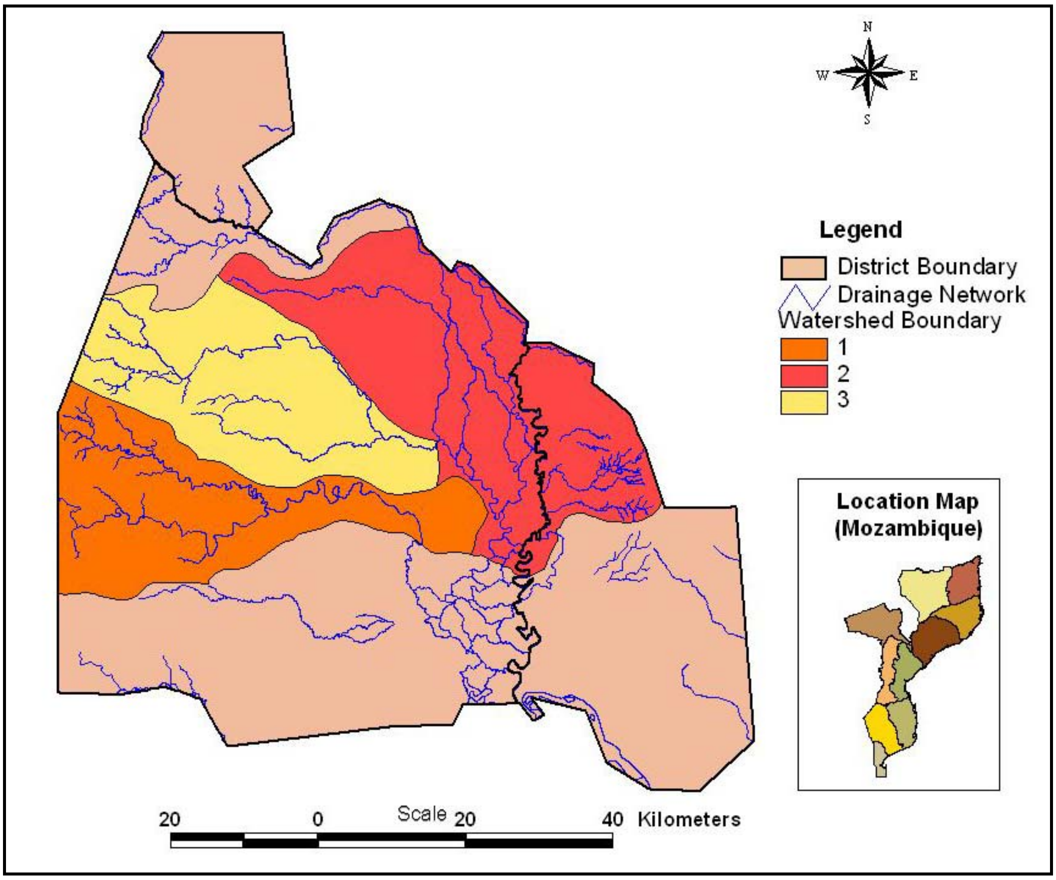


Fig. 28b. Map showing erosion protection measures

Infrastructure

3.20.Transport Network/ Road Network/Power Line

Road and rail network plays an important role in economic development of any region. It serves as a linkage between the source (resource base) and the sink (market). For analyzing the existing surface transportation network, road and rail network map was created in GIS using existing maps and recent satellite imageries. The condition of the roads was validated through the fieldwork (plate 9) and attributes were attached to each segment in GIS environment (Fig. 29). In addition to road and rail, power line was also digitized from the satellite imagery. Understanding of the complete setup of transportation network, which includes distance, type, condition of the roads etc. helps in planning setting up of bamboo based industries and other developmental activities. As a part of infrastructure map power lines were also digitized from

Plate 9: View of Roadside

toposheets provided by CEF since availability of electricity forms an important criteria for setting up industrial plant. For planimetric accuracy in terms of x, y coordinates satellite images were used. This was utilized only in identifying power lines crossing forest area and can be inferred from fire lines visible on satellite image.

Inputs:

- Topographical maps
- Satellite Imagery

Methodology:

Different types of road were captured (digitized) from the topographical maps. They were then updated and rectified from the recent satellite imageries.

Output:

- Infrastructure Network map (shape file)

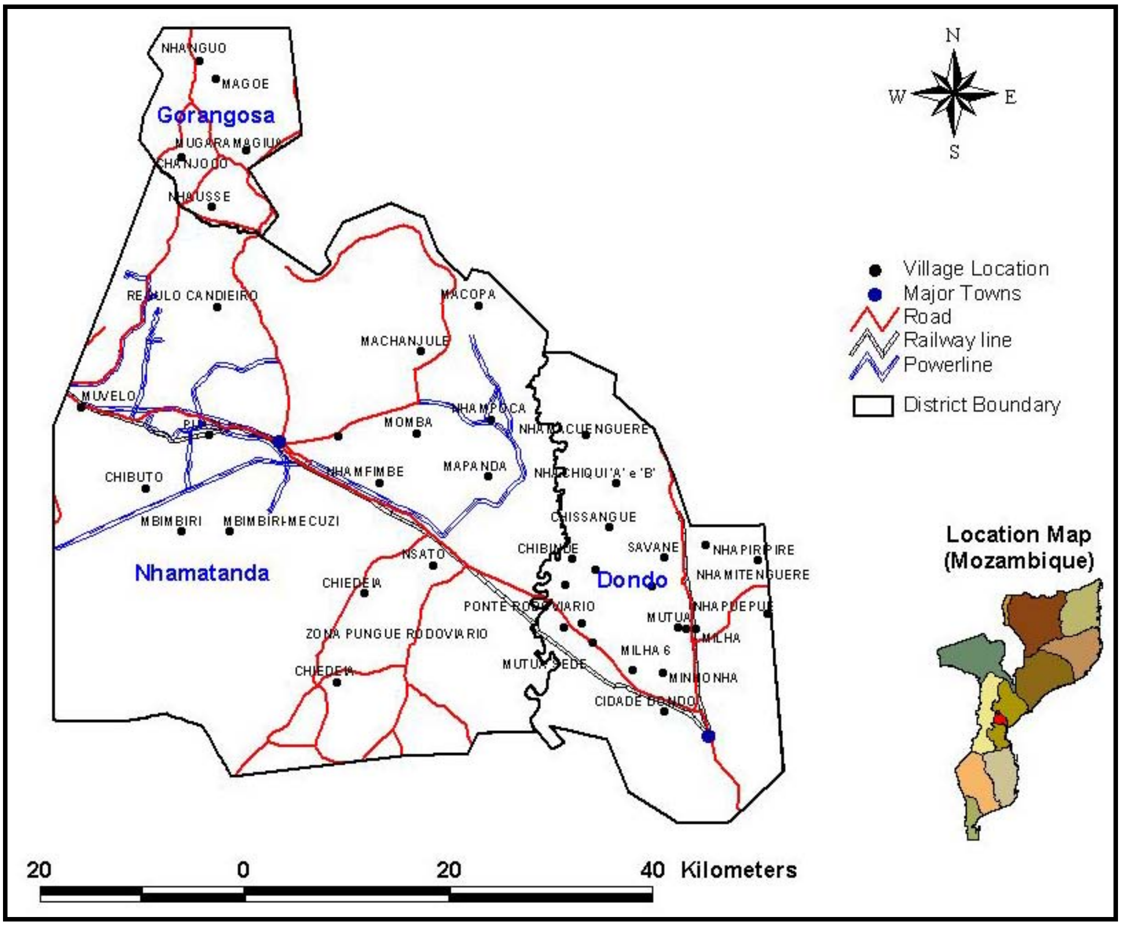


Fig. 29a. Infrastructure map showing road, rail, power line and village locations

Significance for Analysis:

Road map generated in the project is updated from the satellite imagery. New roads may be proposed in the areas having low road density and high population. Also in areas having frequent fires in continuous forest patches a new road can be laid where it may serve a purpose of fire line. Proximity of a proposed industry location to road network is also important in bamboo based industrial location analysis in many ways. The manufactured products or the produced goods will be easily transported through the road network, specially for the locations with proximity to metalled road network will be the best suitable ones for setting up bamboo based industry provided resource is also available in the nearby areas.

3.21. Village / Hospital Map

Villages come at the bottom most levels in the hierarchy of the process of development. In micro-level planning, villages are considered as the most important unit of development from where the developmental activities should start. A detailed village location map was prepared using topographical maps and the field based information (Fig.29). Hospital location map was provided by CEF.

Inputs:

- Village location map supplied by CEF
- Hospital Location Map supplied by CEF

Output:

Village data point file along with the name of the villages in the attribute table.

Significance for Analysis:

Most of the analysis was done keeping villages as the center of focus. The main objective of most of the analysis was to identify suitable locations based on the village locations with a buffer of few kilometers. For any developmental work vicinity to a habitation is the most important factor as it provides labour force and market. All the socio-economic data, that includes old Census data and the new field survey data, was attached to respective village points. The final output with village level action plan was also proposed.

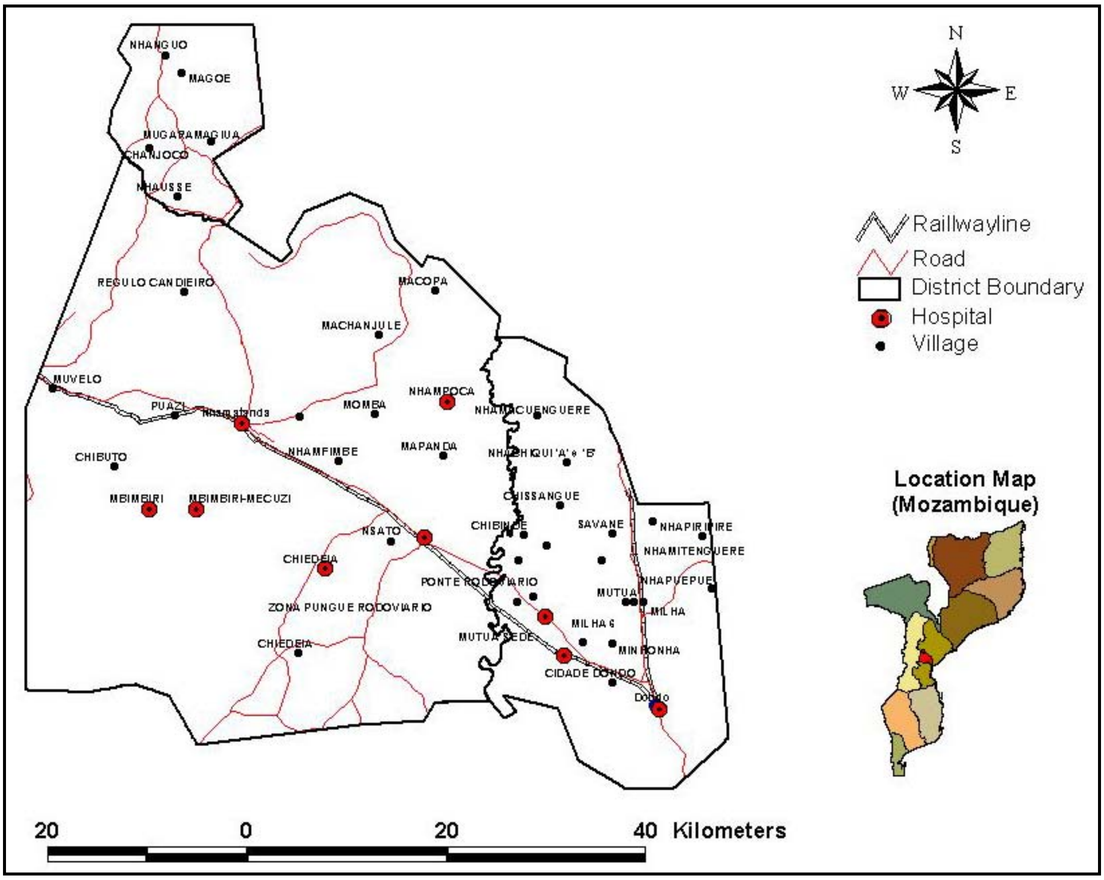


Fig. 29b. Location of hospitals in study area

4.0. Industrial locations and other analysis

Suitable Villages for Setting up industries

Industrial setup in a region is very essential for providing employment opportunities to the local population and thus generating income and circulation of money in the local economy. It is very important to understand the need of the local people and to identify the locally available resources in abundance. Based on the pre-conditions decided as per the knowledge gained from the fieldwork, a GIS based analysis was done for site suitability analysis for various bamboo-based industries.

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 GIS analysis based on the guidelines set by expert committee from organization like INBAR/CEF whose inputs would be essential and critical.
For proposing any analysis related to industrial development it is mandatory to consider all segments of supply chain of a particular activity the (a) creation, management and harvesting of resources by the user (b) User strengths and constrains (c) systems to do processing (d) transport to market/consumer (e) marketing and

realizing the value, so that an ideal suitability analysis could be done and a better picture of the overall management and suitability analysis is attained. In the present study resource availability, manpower availability and accessibility to road (transportation) have been taken as am important inputs in the analysis. However due to the unavailability of detailed information on the financial institution, existing livelihood pattern (village wise) and the price value of the particular commodity (pole, handicraft, mats etc.) only primary level analysis has been taken up and the suitable villages have been identified accordingly. Further ranking of information can however be taken up based on detailed local observation and data available with the local departments, NGOs and CBOs.

General Methodologies followed:

Different set of criterion were used to shortlist and prioritize villages suitable for setting up specific bamboo based industrial plant through GIS based site suitability overlay analysis. Weightages were assigned to each input layer based on the relevance/importance of the layer for particular analysis. The scores were further analysed and best suitable village for each type of industry was arrived at. To achieve this two methods were used as follows:

1. Suitability Analysis (Sites for Bamboo based industries and bamboo plantation):

1. Suitability analysis is a process of overlay analysis. In this analysis the complete layers are considered as an input (viz **bamboo stock class map, digital elevation model, slope map, road buffer map and village buffer map**). From each layer suitable areas are extracted out based on suitable range for a specific analysis, i.e., areas falling outside the favorable range of values are eliminated from the respective layer. The selected portion of each layer was further classified into 4 to 5 classes based on their suitability. Later on a buffer of 1 km was created around each village point. The output buffer layer of village points was overlaid & intersected with each filtered layer. This resulted in selection of those areas where portion of each layer was falling within a buffer of the village. The final output layer consists of those areas, which satisfied all the conditions. The major steps followed are:

- Each one of the input grid layers (used for a specific analysis) was reclassified and the acceptable range of value was extracted out (the range suitable for the establishment of the industry).
- Buffers were created around the point and line layers like Villages and Road. Road buffer was made to analyze the proximity of site and starting form 500 meter to 2-kilometer buffer was made

- Village point data was filtered by each processed layer
- Finally only those villages were selected which satisfy all the conditions.

2. Prioritizing through Weighted Analysis:

Weighted analysis is also a process of overlay analysis. In this analysis all the suitable ranges of factors for each village point was short-listed. The short-listed ranges of factors were weighted according to their level of importance in analysis. Bamboo stocks were given 30% weight. DEM and slope were given the weightages of 10% and 15% respectively. Village an important segment of the analysis was given 20% weight. Using the above weight assigned to the layers, the final site for bamboo based charcoal plant was identified. Once the weightages are assigned to all the GIS layers they are further overlaid in GIS domain. The weightage values from each layer are added up with village point locations. The final score is stored in a column of village point table and are grouped in classes. In this study the major activities involved are:

- Buffer was created along all the village points and values for each layer is cumulated in one single table for each analysis. This is done by keeping in consideration the fact that each factor has its independent influence during analysis procedure, some of them exerts more while others exert less influence.
- Under this process the tabulated value of each factor is reclassified into subclasses (with specific weightage according to their influence)
- The influences of all the factors are cumulated and the final percentage of suitability is calculated for each village, even if it is unsuitable for particular analysis.

For this analysis only target villages were used.

4.1. Gasifier Site Suitability Map Generation

In Mozambique wood fuel is the most important source of domestic/industrial energy needs in rural as well as urban areas. The charcoal is the most sought by urban households whereas firewood is the dominant form of fuel in rural areas. The use of charcoal by urban households is affected by the availability. During every rainy season, there is usually a shortage of charcoal in urban markets and invariably prices go up. However with the increasing population the patches of woodland are either shrinking or getting degraded. Considering the scarcity if energy resources and adverse environmental impacts due to population pressure on existing resources it is proposed to set up gasifier plants in the region. Gasifier Plants produces electricity by burning bamboo/ wood fuel with high conversion efficiency and low emissions. Besides meeting the industrial and institutional needs, charcoal produced as a by-product from these gasifier can be used to meet the domestic needs of the local people.

4.1.1. Bamboo Based Gasifier Site Suitability Map Generation

Inputs:

- Bamboo Stock Map
- DEM
- Slope
- Village buffer
- Road buffer

Methodology:

- Bamboo stock map of six class was generated
- DEM was sliced into six classes (elevation zone)
- Slope map was also generated and classified into six classes.
- Village shape files were used to create the buffer map to find out the proximity to village.
- All above-mentioned layers were given weights, as shown in the table below

Table: Weightage used for Bamboo Based Gasifier Site Suitability Mapping

Layer name	Layer Weightage	Class Name	Class Weight	Final
Bamboo	30	0 to 500	1	0.3
		500 to 750	2	0.6
		750 to 1000	3	0.9
		1000 to 1250	4	1.2
		1250 to 1500	5	1.5
		1500 and above	6	1.8
Dem	10	> 300	1	0.1
		241-300	2	0.2
		181-240	3	0.3
		121-180	4	0.4
		60-120	5	0.5
		< 60	6	0.6
Slope	15	> 60	1	0.15
		40-60	2	0.3
		25 to 40	3	0.45
		15 to 25	4	0.6
		5 to 15	5	0.75
		< 5	6	0.9
Road buff	20	2000m	1	0.2

		1500m	2	0.4
		1000m	3	0.6
		500m	4	0.8
Village Buffer	25	6000m	1	0.25
		4000m	2	0.5
		2000m	3	0.75

Output: Gassifier Site Suitability Map

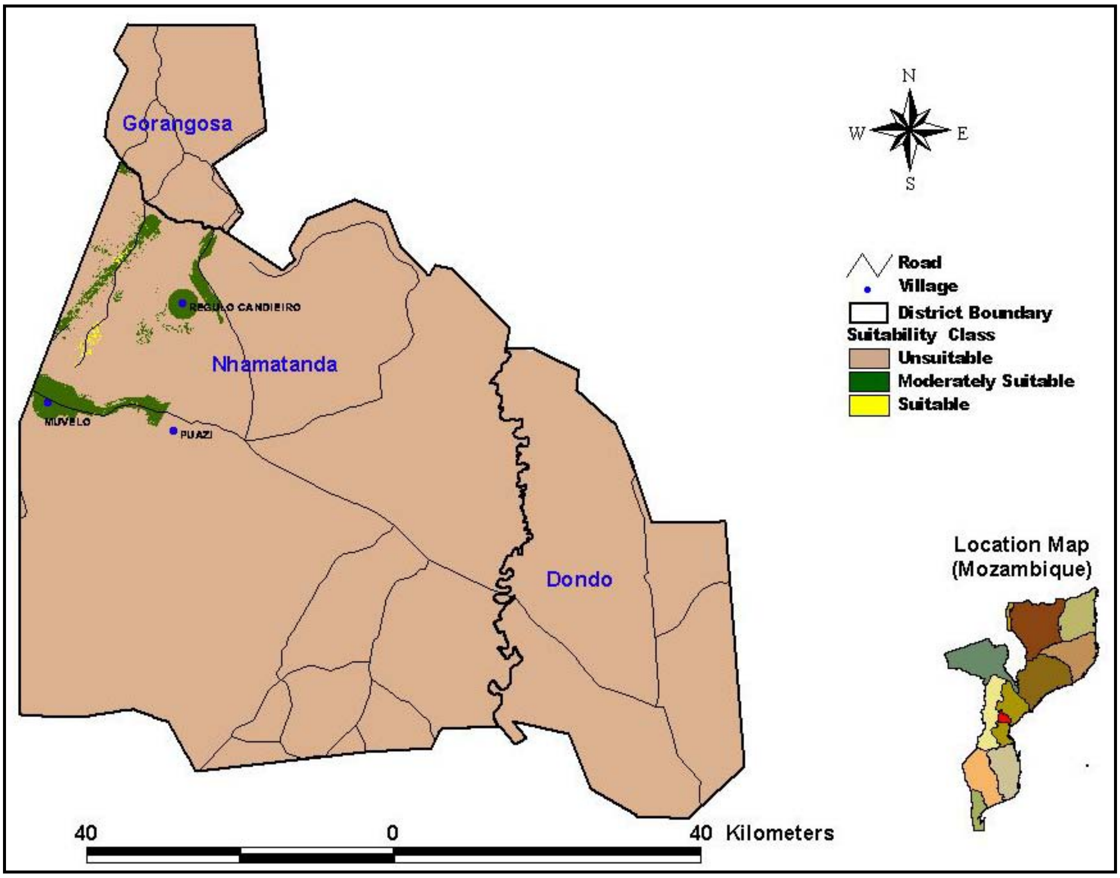


Fig. 30. Bamboo Gasifier Site Suitability Map

Best suitable villages

Based on the conditions above and ground observations only 3 out of 41 target villages are found to be suitable for setting up a gasifier plant. List of suitable villages is as under:

Village Name	Latitude	Longitude	Population		
			Male	Female	Total
REGULO CANDIEIRO	-19.1125	34.1333	17482	18562	36044
PUAZI	-19.2625	34.1236	1289	1421	2710
MUVELO	-19.2306	33.9667	676	641	1317

4.1.2 Timber Based Gasifier Site Suitability Map Generation

Inputs:

- Forest species map
- Woodstock map
- DEM
- Slope
- Village buffer
- Road buffer

Methodology

- Forest species map and woodstock map were sliced into four classes
- DEM was sliced into six classes (elevation zone)
- Slope map was also generated and classified into six classes.
- Village shape files were used to create the buffer map to find out the proximity to village.
- All above-mentioned layers were given weights, as shown in the table below

Table: Weightage used for Timber Based Gasifier Site Suitability Mapping

Layer Name	Layer Weightage	Class	Class Weightage	Final Weightage
Forest Species Map	**20**	Others	1	0.2
		Al_Pt_Sc	2	0.4
		Al_Da_Pal	3	0.6
		Ac_Br_Pt_Tr	4	0.8
		0 to 1 cubic meter	1	0.25
Wood Stock Class	**25**	1 to 3 cubic meter	2	0.5
		3 to 5 cubic meter	3	0.75
		5 to 8 cubic meter	4	1
DEM	**10**	> 300	1	0.1
		241-300	2	0.2
		181-240	3	0.3
		121-180	4	0.4
		60-120	5	0.5
		< 60	6	0.6
Slope	**10**	> 60	1	0.1
		40-60	2	0.2
		25 to 40	3	0.3
		15 to 25	4	0.4
		5 to 15	5	0.5
		< 5	6	0.6
Road	**15**	2000m	1	0.15
		1500m	2	0.3
		1000m	3	0.45

		500m	4	0.6
Village	**20**	6000m	1	0.2
		4000m	2	0.4
		2000m	3	0.6

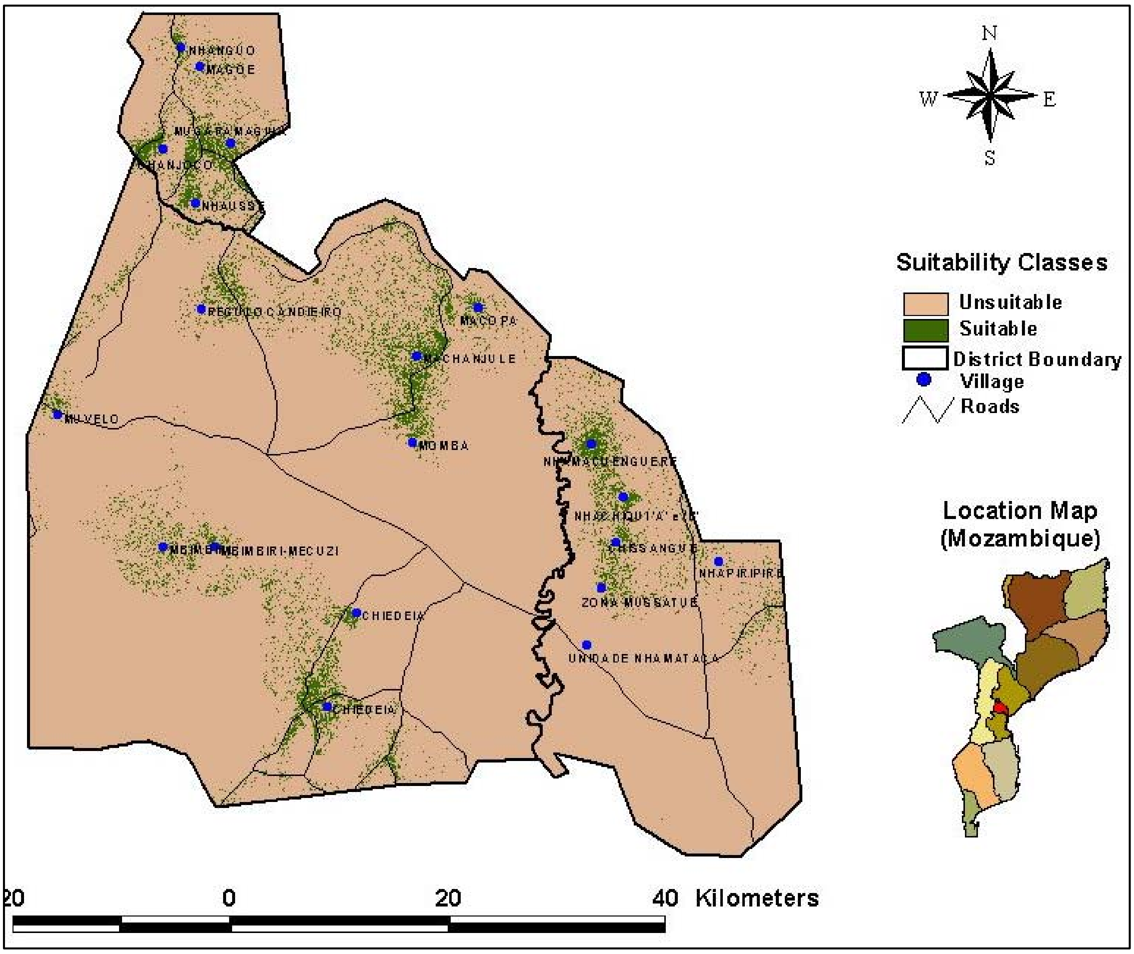


Fig. 31. Timber based Gasifier site suitability map

List of selected villages is given below:

Village Name	Latitude	Longitude	Population		
			Male	Female	Total
NHAPIRIPIRE	-19.39	34.74	439	442	881
NHAMACUENGUERE	-19.26	34.59	192	215	407
NHACHIQUI 'A' e 'B'	-19.32	34.62	423	434	857
CHISSANGUE	-19.37	34.62	694	751	1445
ZONA MUSSATUE	-19.42	34.60	1196	1214	2410
UNIDADE NHAMATACA	-19.48	34.58	212	191	403
NHANGUO	-18.83	34.11	245	265	510
MAGOE	-18.85	34.13	175	238	413
MUGARAMAGIUA	-18.93	34.17	235	246	481
CHANJOCO	-18.94	34.09	962	1012	1974
NHAUSSE	-19.00	34.13	116	129	245
REGULO CANDIEIRO	-19.11	34.13	17482	18562	36044
MBIMBIRI-MECUZI	-19.38	34.15	4353	4805	9158
CHIEDEIA	-19.55	34.28	1050	1057	2107

MBIMBIRI	-19.38	34.09	2438	2763	5201
CHIEDEIA	-19.45	34.32	1858	1943	3801
MACHANJULE	-19.16	34.38	3207	3332	6539
MACOPA	-19.11	34.45	691	729	1420
MOMBA	-19.26	34.38	841	887	1728
MUVELO	-19.23	33.97	676	641	1317

4.2. Suitable Locations for timber based charcoal plant setup

Inputs:

- Forest species map
- Woodstock map
- Digital elevation model
- Slope map
- Road buffer map
- Village buffer map

Table: Weightage used for Timber Based charcoal plant suitability analysis

For the purpose of analysis better results are expected if we use woodstock and forest density map also in the model. Since density map was not prepared due to limitations of Landsat TM data, woodstock map was used in the analysis (table…)

Layer name	Layer weightage	Class	Class weightage	Final Weightage	Remarks
Forest Species map	35	Others	1	0.35	High weightage is given to the timber species providing fuelwood/charcoal e.g. *acacia* followed by *albezia.* Rest of the species are given lower weightage
		Al_Pt_Sc	2	0.7	
		Al_Da_Pal	3	1.05	
		Ac_Br_Pt_Tr	4	1.4	
DEM	25	> 300	1	0.25	The areas having elevation less than 60 m is considered to be most suitable and is provided with the highest weightage.
		241-300	2	0.5	
		181-240	3	0.75	
		121-180	4	1	
		60-120	5	1.25	
		< 60	6	1.5	
Slope	25	> 60	1	0.25	Areas with minimum slope are preferred for industry. High slope areas make the transportation difficult. Maximum weightage is given to villages with lowest maximum slope and lowest mean slope in its 1 km buffer.
		40-60	2	0.5	
		25 to 40	3	0.75	
		15 to 25	4	1	
		5 to 15	5	1.25	
		< 5	6	1.5	
Road Buffer	5	2000m	1	0.05	Areas with proximity to road are given higher weightage as compared to the far off areas
		1500m	2	0.1	
		1000m	3	0.15	
		500m	4	0.2	
Village Buffer	10	6000m	1	0.1	Villages with distance <= 2000m is given the highest weightage as vicinity to villages will provide sufficient labour force & consumers for the produced electricity.
		4000m	2	0.2	
		2000m	3	0.3	

Table: Criteria used for timber Based charcoal plant suitability analysis using woodstock map

Sl. No.	A	B	(A+B)/2
	Wood Stock Classes	**Charcoal Plant Site Map**	**Final Charcoal site Map**
	Class Name	**Class Name**	
1	0 to 1 cubic meter	Unsuitable	Unsuitable
2	1 to 3 cubic meter	Suitable	Suitable
3	3 to 5 cubic meter	Moderate Suitable	Moderate Suitable
4	5 to 8 cubic meter	Most Suitable	Most Suitable

Methodology:

1. Forest species map were sliced into 4 classes and Acacia dominant class was kept at higher class since acacias are the legally permitted species for charcoal production followed by Al_Da_Pal and Al_Pt_Sc and rest species were kept in single class “others”. 35% weight was given to this layer.
2. DEM was sliced into 6 classes and 25% weight was given.
3. Slope had six classes and 25% weight was given.
4. Road buffer was made to analyze the proximity of site and starting form 500 meter to 2-kilometer buffer was made and 0.05% weight was given.
5. Village an important segment of the analysis was given 10% weight.
6. Using the above weight assigned to the layers, the final site for Timber based charcoal plant was identified.

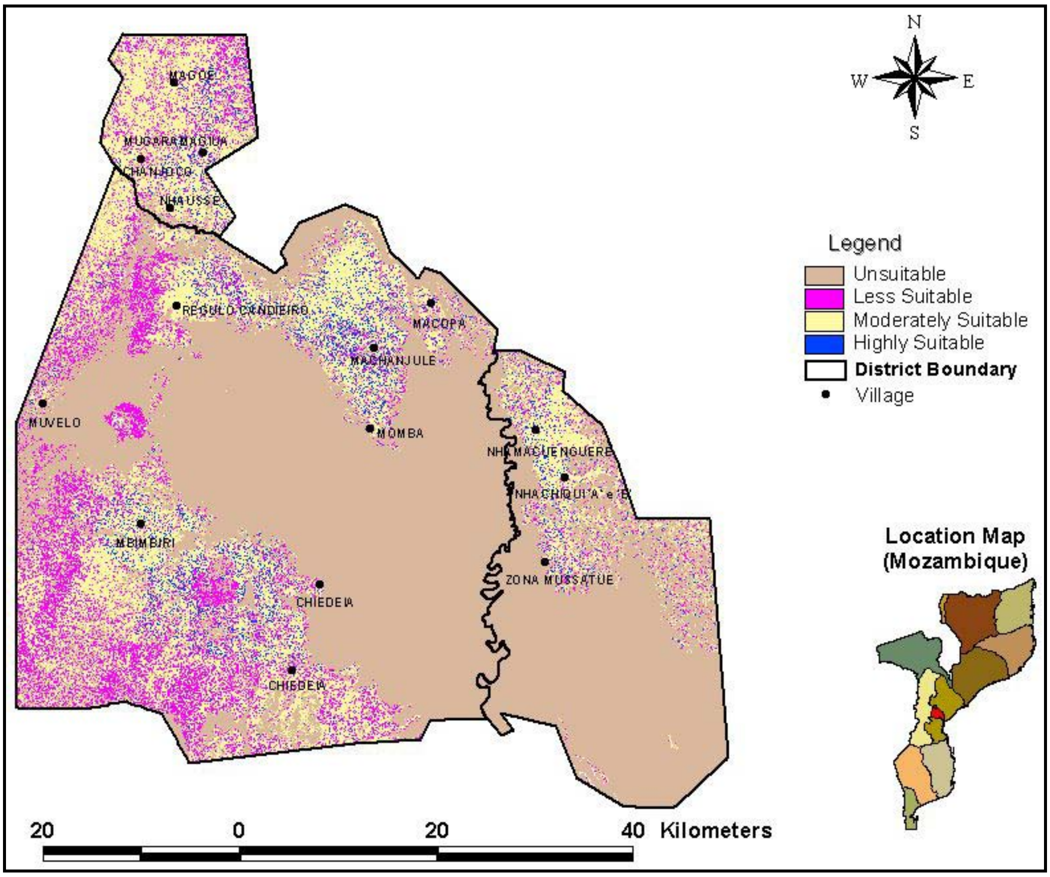


Fig. 32. Proposed sites for timber based charcoal plant setup

Best Suitable Villages

Eighteen villages were selected from 41 target villages on the basis of the conditions mentioned above. These eighteen villages are best suited for setting up timber based charcoal plant among all the target villages. None of the other industry has higher weightage in these villages. Details of the proposed suitable villages for timber based charcoal plant setup are as follows:

Village Name	Total Population	Male	Female	Latitude	Longitude	District
NHAMACUENGUERE	407	192	215	-19.2583	34.5867	Dondo
NHACHIQUI 'A' e 'B'	857	423	434	-19.3153	34.6247	Dondo
ZONA MUSSATUE	2410	1196	1214	-19.4167	34.6	Dondo
MAGOE	413	175	238	-18.8458	34.1292	Grongosa
MUGARAMAGIUA	481	235	246	-18.9292	34.1667	Grongosa
CHANJOCO	1974	962	1012	-18.9375	34.0875	Grongosa
NHAUSSE	245	116	129	-18.9958	34.125	Grongosa
REGULO CANDIEIRO	36044	17482	18562	-19.1125	34.1333	Nhamatanda
CHIEDEIA	2107	1050	1057	-19.55	34.2833	Nhamatanda
MBIMBIRI	5201	2438	2763	-19.375	34.0903	Nhamatanda
CHIEDEIA	3801	1858	1943	-19.4458	34.3161	Nhamatanda
MACHANJULE	6539	3207	3332	-19.1625	34.3833	Nhamatanda
MACOPA	1420	691	729	-19.1083	34.4542	Nhamatanda
MOMBA	1728	841	887	-19.2583	34.3792	Nhamatanda
MUVELO	1317	676	641	-19.2306	33.9667	Nhamatanda

4.3. Suitable Location for Bamboo based charcoal plant setup

Bamboo based charcoal is a good energy resource. It can be consumed in the local market as well as regional market.

Inputs:

- DEM
- Slope
- Village Data
- Field Survey Tabular Data
- Transport Data
- Drainage Data
- Bamboo Data

Weightage Used: Table below shows the weightage used for bamboo based charcoal plant set suitability analysis

Table: Weightage used for bamboo based charcoal plant set suitability analysis

Layer name	Layer weightage	Class	Class weightage	Final weightage	Remarks
Bamboo stock classes	35	0 to 500	1	0.35	Areas having higher bamboo stock have are more suitable source of bamboo, hence higher weightage is given to high bamboo stock and vice versa
		500 to 750	2	0.7	
		750 to 1000	3	1.05	
		1000 to 1250	4	1.4	
DEM	25	> 300	1	0.25	The areas with an elevation of less than 60 mts is considered to be most suitable and is provided with the highest weightage.
		241-300	2	0.5	
		181-240	3	0.75	
		121-180	4	1	
		60-120	5	1.25	
		< 60	6	1.5	

Layer name	Layer weightage	Class	Class weightage	Final weightage	Remarks
Slope	25	> 60	1	0.25	Areas with minimum slope are preferred for industry. High slop areas make the transportation difficult. Maximum weightage is given to villages with lowest maximum slope and lowest mean slope in its 1 km buffer.
		40-60	2	0.5	
		25 to 40	3	0.75	
		15 to 25	4	1	
		5 to 15	5	1.25	
		< 5	6	1.5	
Road Buffer	5	2000m	1	0.05	Areas with proximity to road are given higher weightage as compared to the far off areas
		1500m	2	0.1	
		1000m	3	0.15	
		500m	4	0.2	
Village Buffer	10	6000m	1	0.1	Villages with distance less than or equal to 2000m is given the highest weightage as closer the village, it will provide sufficient labours & consumers for the produced electricity.
		4000m	2	0.2	
		2000m	3	0.3	

Output : Bamboo based charcoal plant setup map (Fig. 33)

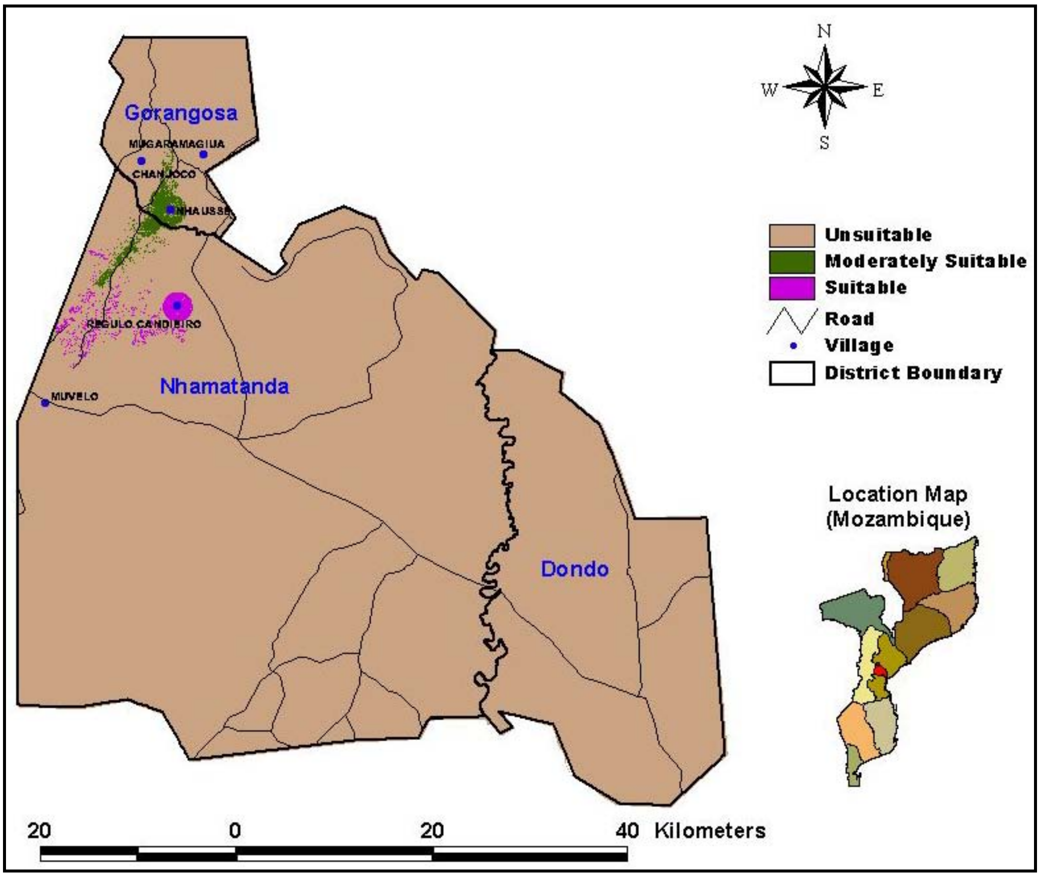


Fig. 33. Proposed sites for bamboo based charcoal plant set up

Best suitable Villages

Based on the ground observations and conditions mentioned above five villages out of 41 are proposed for setting up bamboo based charcoal plant. Details of these villages are as follows:

Village Name	Latitude	Longitude	Population		
			Male	Female	Total
MUGARAMAGIUA	-18.9292	34.1667	235	246	481
CHANJOCO	-18.9375	34.0875	962	1012	1974
NHAUSSE	-18.9958	34.1250	116	129	245
REGULO CANDIEIRO	-19.1125	34.1333	17482	18562	36044
MUVELO	-19.2306	33.9667	676	641	1317

Although as seen in the map below two villages are fully suitable for bamboo based charcoal plant setup. Remaining three have been proposed taking into consideration resource flow due to availability of road network

4.4. Suitable location for Bamboo Based Active Carbon Plant setup

Activated carbons are the low cost carbon produced from both plant waste and animal manures. Activated carbon is used as adsorbents due to their excellent metal ion binding properties as compared to available commercial carbons. Thus they are used to produce ion-exchange resins, which make them very attractive products for commercialization. Activated carbon has several other uses such as solution purification and industrial and domestic water treatment. It is also used in chemical and pharmaceuticals, vegetable and animal fat and oil production, furniture, construction, etc. Active carbon plants use charcoal and electricity to produce Active carbon. So these plants should be located in areas having electricity and plenty of resources.

Inputs:

- Bamboo distribution
- DEM
- Slope
- Transport network
- Village Data
- Drainage data
- Bamboo based gasifier map
- Field Survey Tabular Data

Weightage Used: Table below shows the weightage used for locating suitable villages for active carbon plant setup

Table: Weightage used for locating suitable villages for bamboo based active carbon plant setup

Layer name	Layer weightage	Class	Class weightage	Final Weightage	Remarks
Bamboo stock	15	Low	1	.15	Areas having higher bamboo stock have are more suitable source of bamboo, hence higher weightage is given to high bamboo stock and vice versa
		Medium	2	.30	
		High	3	.45	
DEM	10	> 300	1	.10	The areas with an elevation of less than 60 m are considered to be most suitable and are provided with the highest weightage.
		241-300	2	.20	
		181-240	3	.30	
		121-180	4	.40	
		60-120	5	.50	
		< 60	6		
Slope	15	> 60	1	0.15	Areas with minimum slope are preferred for industry. High slop areas make the transportation difficult. Maximum weightage is given to villages with lowest maximum slope and lowest mean slope in its 1 km buffer.
		40-60	2	0.3	
		25 to 40	3	0.45	
		15 to 25	4	0.6	
		5 to 15	5	0.75	
		< 5	6	0.9	
Road Buffer	10	2000m	1	0.1	The best suitable villages are those at a distance of 500 m or less from the resource
		1500m	2	0.2	
		1000m	3	0.3	
		500m	4	0.4	
Village Population	15		1	0.15	Villages with population more than 750 are given the highest weightage as high population villages will provide sufficient labour force.
			2	0.3	
			3	0.45	
			4	0.6	
			5	0.75	
			6	0.9	
Drainage Network	10	6000m	1	0.1	Proximity of the village to higher order streams (streams of order > 5[th]) is given the
		4000m	2	0.2	

		2000m	3	0.3	highest weightage and the stream is preferred to be within a distance of 20000 m As higher order streams as more effective in transporting the raw materials and the finished products due to their depth and water bearing capacity.
Bamboo based Gassifier Plant Site	25	Suitable		0.25	The villages suggested or probable or having Gasifier plant will be given higher weightage, as they will be a source of locally produced uninterrupted industry.
		More Suitable		0.5	
		Most Suitable		0.75	

Output: Potential areas for bamboo active carbon plant setup

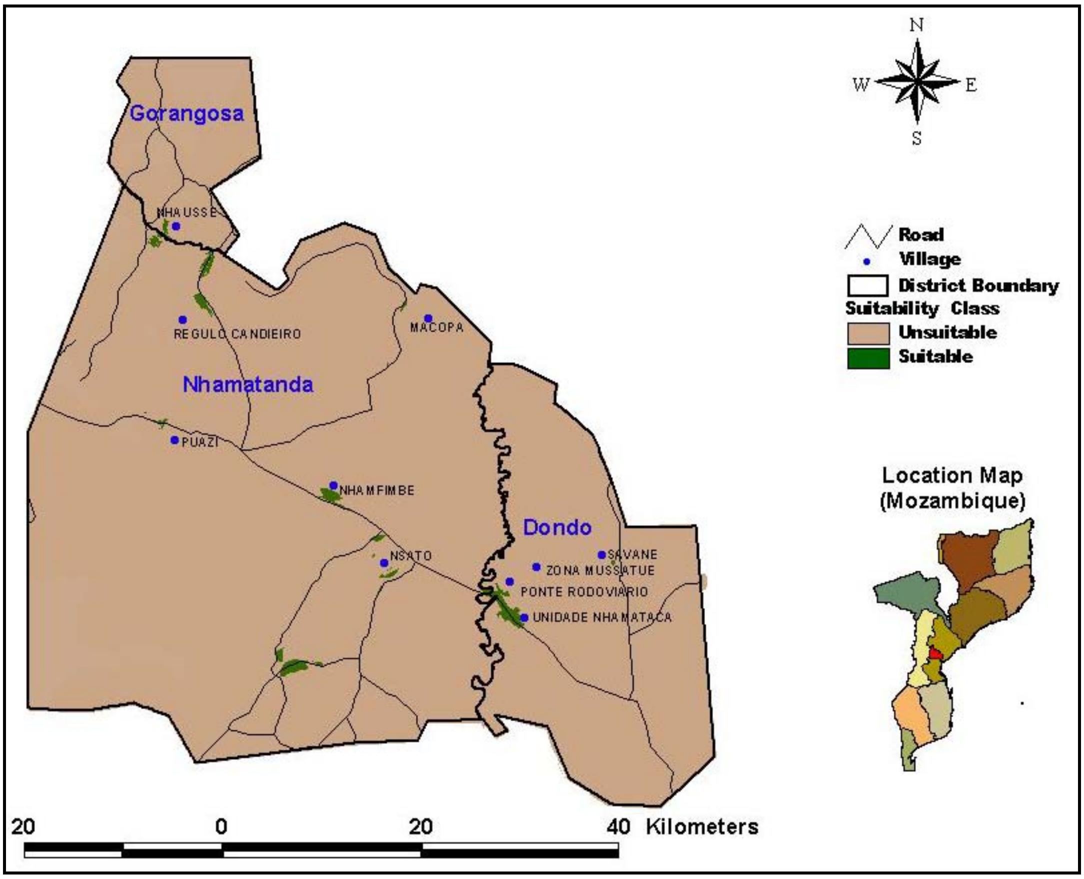


Fig. 34. Potential areas for bamboo based active carbon plant setup

Best Suitable Villages

Ten villages are selected as best suitable for setting up Active Carbon Plant. At general look all these villages have sufficient bamboo resources in their vicinities. Lastly in all these villages transportation network (both surface and water) is developed due its nearness to prominent streams and metalled roads. The list of villages includes:

Village Name	Latitude	Longitude	Population		
			Male	Female	Total
Savane	-19.4008	34.6842	1050	947	1997
Zona Mussatue	-19.4167	34.6000	1196	1214	2410
Unidade Nhamataca	-19.4792	34.5836	212	191	403
Ponte Rodoviario	-19.4342	34.5639	246	246	492
Nhausse	-18.9958	34.1250	116	129	245
Regulo Candieiro	-19.1125	34.1333	17482	18562	36044
Puazi	-19.2625	34.1236	1289	1421	2710
Nhamfimbe	-19.3167	34.3333	9060	9432	18492
Nsato	-19.4125	34.4000	9055	9554	18609
Macopa	-19.1083	34.4542	691	729	1420

4.5. Suitable location for Timber Based Active Carbon Plant setup

Inputs:

- Woodstock Map
- DEM
- Slope
- Transport network
- Village Data
- Drainage data
- Timber based gasifier map
- Field Survey Tabular Data

Weightage Used: Table below shows the weightage used for locating suitable villages for active carbon plant setup

Table: Weightage used for locating suitable villages for timber based active carbon plant setup

Layer name	Layer weightage	Class	Class weightage	Final Weightage	Remarks
Woodstock Map	15	Low	1	.15	Areas having higher woodstock stock have are more suitable source of timber,
		Medium	2	.30	

		High	3	.45	hence higher weightage is given to high woodstock and vice versa
DEM	10	> 300	1	.10	The areas with an elevation of less than 60 mts are considered to be most suitable and are provided with the highest weightage.
		241-300	2	.20	
		181-240	3	.30	
		121-180	4	.40	
		60-120	5	.50	
		< 60	6		
Slope	15	> 60	1	0.15	Areas with minimum slope are preferred for industry. High slop areas make the transportation difficult. Maximum weightage is given to villages with lowest maximum slope and lowest mean slope in its 1 km buffer.
		40-60	2	0.3	
		25 to 40	3	0.45	
		15 to 25	4	0.6	
		5 to 15	5	0.75	
		< 5	6	0.9	
Road Buffer	10	2000m	1	0.1	The best suitable villages are those at a distance of 500 mts or less from the resource
		1500m	2	0.2	
		1000m	3	0.3	
		500m	4	0.4	
Village Population	15		1	0.15	Villages with population more than 750 are given the highest weightage as high population villages will provide sufficient labour force.
			2	0.3	
			3	0.45	
			4	0.6	
			5	0.75	
			6	0.9	
Drainage Network	10	6000	1	0.1	Proximity of the village to higher order streams (streams of order > 5th) is given the highest weightage and the stream is preferred to be within a distance of 20000 mts. As higher order streams as more effective in transporting the raw materials and the finished products due to their depth and water bearing capacity.
		4000	2	0.2	
		2000	3	0.3	
Timber Based Gasifier Plant	25			0.25	The villages suggested or probable or having timber based
				0.5	

Site				0.75	gasifier plant will be given higher weightage, as they will be a source of locally produced uninterrupted industry.

Output: Potential areas for timber based active carbon plant setup

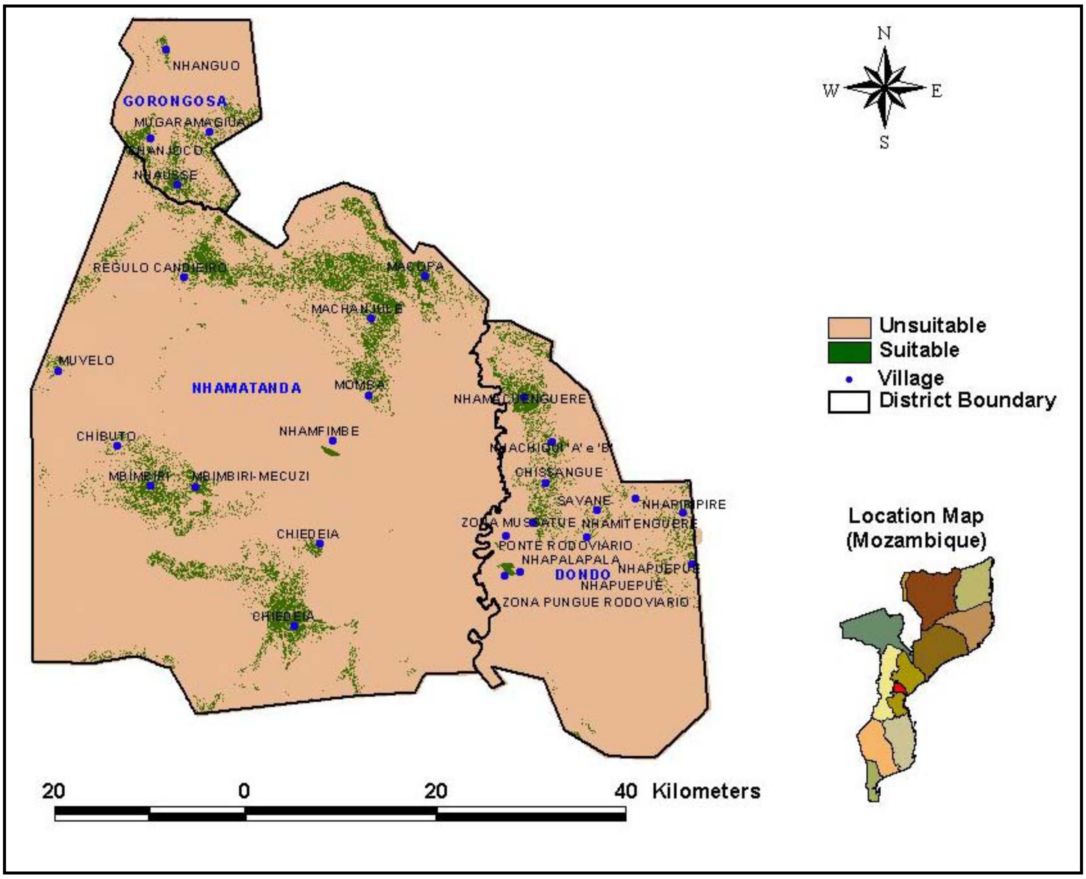


Fig. 35. Potential areas for timber based active carbon plant setup

Best Suitable Village

Based on analysis 27 villages have been selected as suitable for developing timber based active carbon plant set up.

Village Name	Latitude	Longitude	Population		
			Male	Female	Total
CHANJOCO	-18.9375	34.0875	962	1012	1974
CHIBUTO	-19.3250	34.0458	1500	1664	3164
CHIEDEIA	-19.5500	34.2833	1050	1057	2107
CHIEDEIA	-19.4458	34.3161	1858	1943	3801
CHISSANGUE	-19.3669	34.6167	694	751	1445
MACHANJULE	-19.1625	34.3833	3207	3332	6539
MACOPA	-19.1083	34.4542	691	729	1420
MBIMBIRI	-19.3750	34.0903	2438	2763	5201
MBIMBIRI-MECUZI	-19.3750	34.1500	4353	4805	9158
MOMBA	-19.2583	34.3792	841	887	1728
MUGARAMAGIUA	-18.9292	34.1667	235	246	481
MUVELO	-19.2306	33.9667	676	641	1317

NHACHIQUI 'A' e 'B'	-19.3153	34.6247	423	434	857
NHAMACUENGUERE	-19.2583	34.5867	192	215	407
NHAMFIMBE	-19.3167	34.3333	9060	9432	18492
NHAMITENGUERE	-19.4031	34.7997	206	183	389
NHANGUO	-18.8250	34.1083	245	265	510
NHAPALAPALA	-19.4342	34.6708	179	176	355
NHAPIRIPIRE	-19.3858	34.7361	439	442	881
NHAPUEPUE	-19.4664	34.8125	627	572	1199
NHAUSSE	-18.9958	34.1250	116	129	245
PONTE RODOVIARIO	-19.4342	34.5639	246	246	492
REGULO CANDIEIRO	-19.1125	34.1333	17482	18562	36044
SAVANE	-19.4008	34.6842	1050	947	1997
UNIDADE NHAMATACA	-19.4792	34.5836	212	191	403
ZONA MUSSATUE	-19.4167	34.6000	1196	1214	2410
ZONA PUNGUE RODOVIARIO	-19.4847	34.5625	275	283	558

4.6. Potential Bamboo poles production and enterprise area with sustainable harvesting patterns

Those villages in which the plantation of bamboo can be developed as potential bamboo pole production and enterprise areas. To ensure the sustainable harvesting only few clumps can be felled at the time of harvesting leaving the few and at a gap of five years the other crop can be harvested.

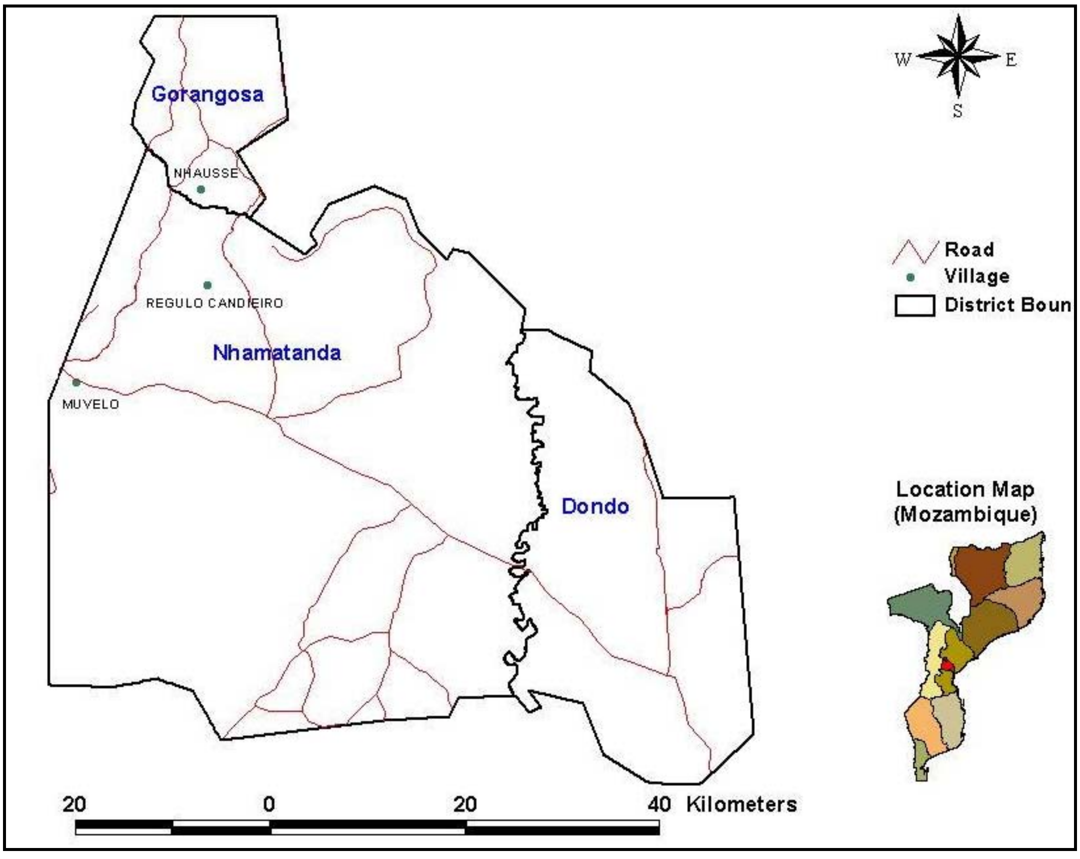


Fig. 36. Potential Bamboo poles production and enterprise area with sustainable harvesting patterns

Out of 41 target villages two villages in Nhamatanda and one village in Gorangosa district are selected for developing bamboo poles production unit. Details of these villages is given below:

Village Name	Latitude	Longitude	Population		
			Male	Female	Total
NHAUSSE	-18.9958	34.1250	116	129	245
REGULO CANDIEIRO	-19.1125	34.1333	17482	18562	36044
MUVELO	-19.2306	33.9667	676	641	1317

4.7. Potential Bamboo Mat production and enterprises area with sustainable harvesting patterns

Areas where resource availability of bamboo is sufficient and the bamboo occurs in natural form can be exploited for livelihood generation through Mat Production.

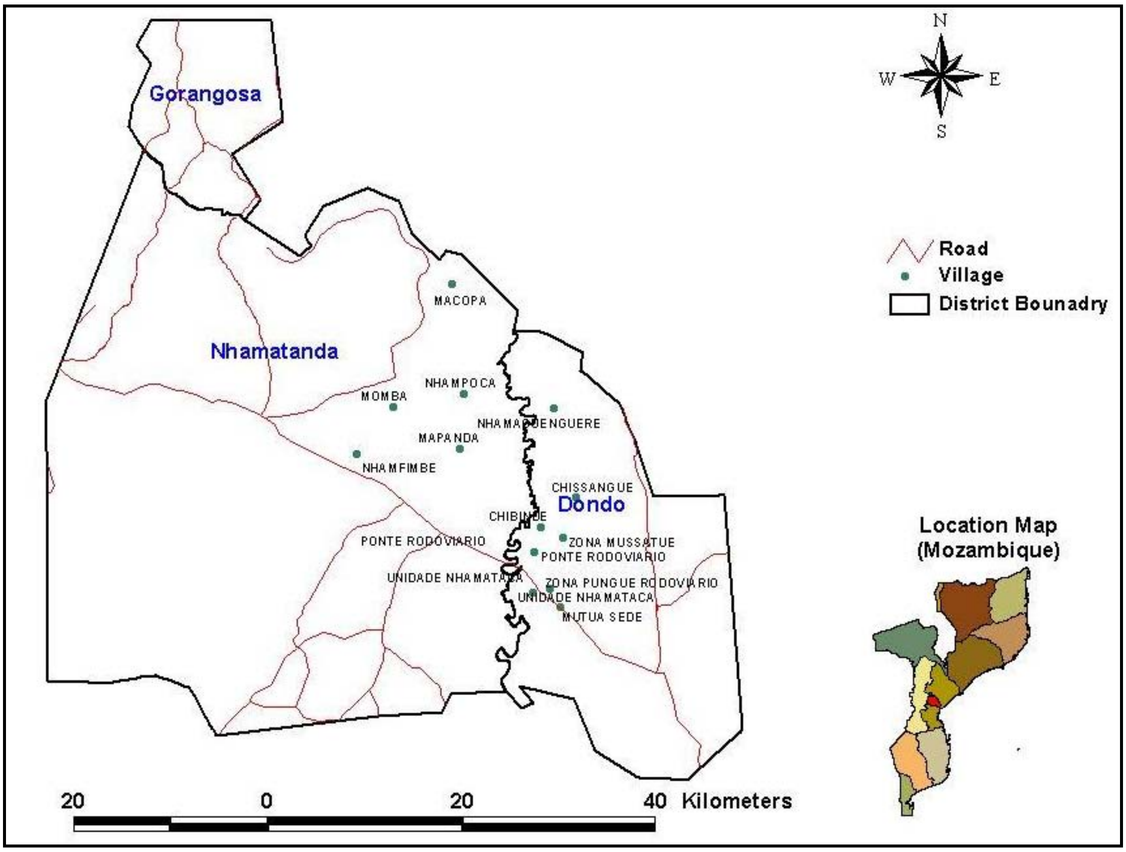


Fig. 37. Potential Bamboo Mat production and enterprises area with sustainable harvesting patterns

As shown in the map above 13 villages are selected for the purpose. Details of the villages are given below:

Village Name	Latitude	Longitude	Population		
			Male	Female	Total
NHAMACUENGUERE	-19.2583	34.5867	192	215	407
CHISSANGUE	-19.3669	34.6167	694	751	1445
CHIBINDE	-19.4033	34.5708	220	255	475
ZONA PUNGUE RODOVIARIO	-19.4847	34.5625	275	283	558
ZONA MUSSATUE	-19.4167	34.6000	1196	1214	2410
UNIDADE NHAMATACA	-19.4792	34.5836	212	191	403
MUTUA SEDE	-19.5014	34.5978	2323	2277	4600
PONTE RODOVIARIO	-19.4342	34.5639	246	246	492
NHAMFIMBE	-19.3167	34.3333	9060	9432	18492
MACOPA	-19.1083	34.4542	691	729	1420
NHAMPOCA	-19.2417	34.4708	954	984	1938
MAPANDA	-19.3083	34.4667	853	909	1762
MOMBA	-19.2583	34.3792	841	887	1728

4.8. Potential Bamboo handicrafts production and enterprise area with sustainable harvesting patterns

Shifting cultivation dominant area and the deep interior areas are given more priority for setting up bamboo based handicraft production unit. The income generated is supposed to provide the livelihood options to the local community at one hand and it will also reduce the frequency of clearing of forests as the abandoned shifting cultivation areas will themselves be protected in the form of secondary forests (bamboo dominant) to serve as a source of raw materials. However for this purpose initial steps are to be taken up for building the capacities of the community and giving them some training in handicraft making.

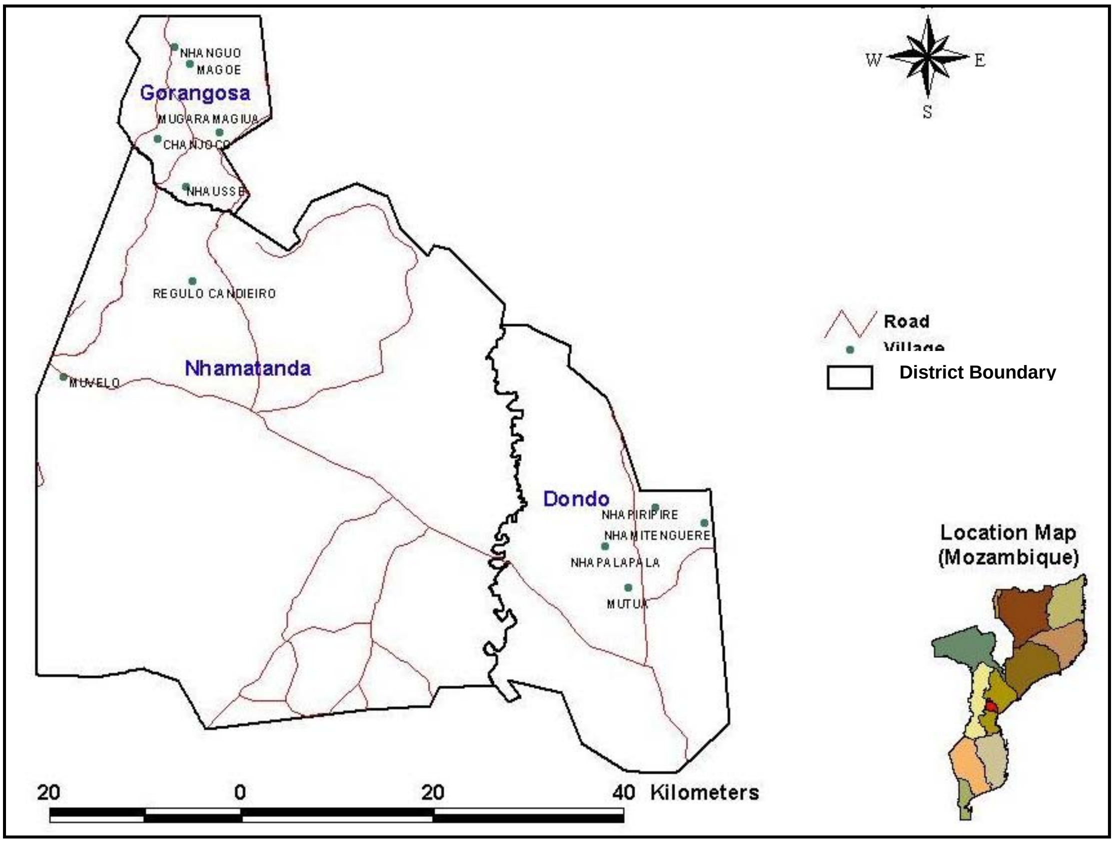


Fig. 38. Potential Bamboo handicrafts production and enterprise area with sustainable harvesting patterns

Out of 41 total 11 villages are selected for setting up bamboo based handicraft enterprise

Village Name	Latitude	Longitude	Population		
			Male	Female	Total
NHAPIRIPIRE	-19.3858	34.7361	439	442	881
NHAMITENGUERE	-19.4031	34.7997	206	183	389
NHAPALAPALA	-19.4342	34.6708	179	176	355
MUTUA	-19.4836	34.7025	471	462	933
NHANGUO	-18.8250	34.1083	245	265	510
MAGOE	-18.8458	34.1292	175	238	413
MUGARAMAGIUA	-18.9292	34.1667	235	246	481
CHANJOCO	-18.9375	34.0875	962	1012	1974
NHAUSSE	-18.9958	34.1250	116	129	245
REGULO CANDIEIRO	-19.1125	34.1333	17482	18562	36044
MUVELO	-19.2306	33.9667	676	641	1317

4.9. Semi degraded areas for ANR

In Mozambique local people depend on forest for various needs e.g. fuel wood, timber and other Non-Timber Forest Products (NTFPs). However, overexploitation due to increased human pressure has resulted into degradation of forests. The situation is further worsened due to increased requirement of land for agriculture and settlement and eventually the forests are becoming fragmented. Degradation and fragmentation of forests cause loss of biodiversity, reduced carbon sequestration and increased emission from the bare soil due to its low carbon absorbing capability/potential. Hence it is very important to check the rate of forest degradation. Assisted natural regeneration can be taken up as a control measure to check forest degradation in high human impact areas within forest such as fragmented forest/openings and shifting cultivation. This will help forests to regenerate in a natural manner at a slow rate and over a period of time high-density forests would be restored. In the present analysis, potential ANR areas have been suggested based on forest and bamboo distribution map and the wasteland map. There were six classes mapped in the wasteland map of which three classes i.e. degraded forest, shifting cultivation areas and open areas were located within and in the vicinity of forest areas. The wasteland classes occurring in and around dense bamboo areas are proposed for bamboo regeneration whereas in the remaining area forest species can be allowed to regenerate. Selection of the species should be done based on their IUCN status, economic importance, ecological role they play (if any) in consultation with the local community. It is also proposed to generate alternative livelihood for the local community in the nearby villages so that the pressure on forests/ bamboo resources due to shifting cultivation is brought under a check.

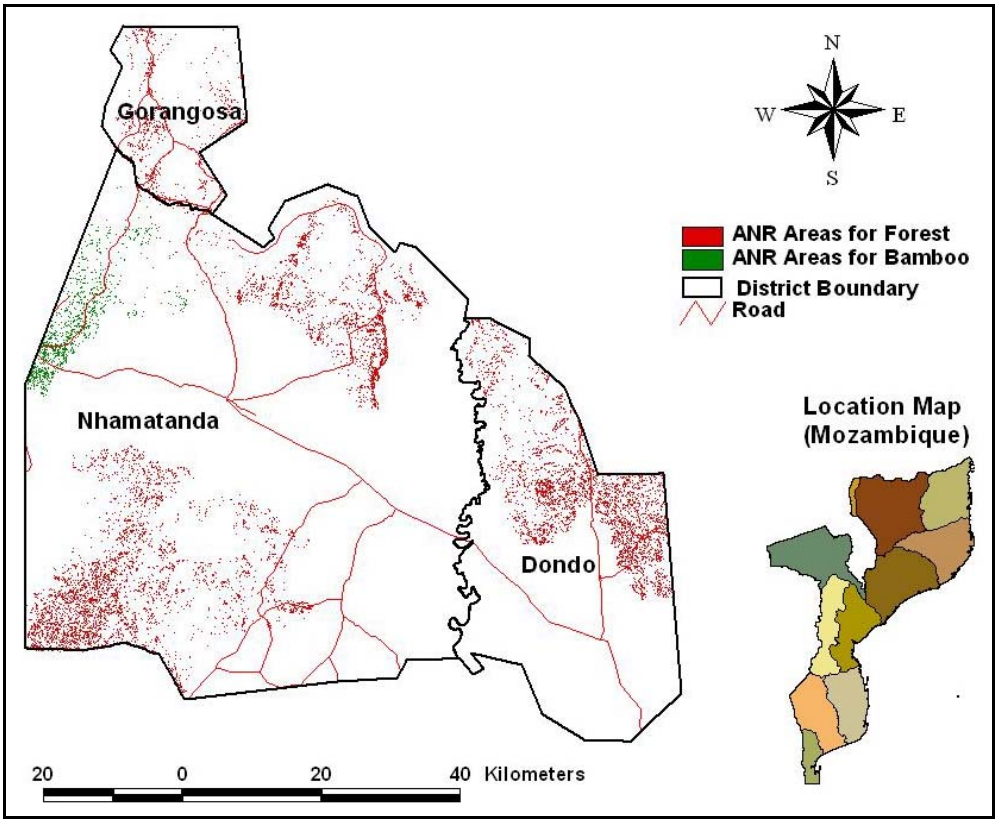


Fig. 39. Suitable sites for ANR activities in forest and bamboo areas

4.10. High value forests for timber species

High value forests for timber species are the areas having dense forest with dominance of timber species of high economic importance in terms of its wood. Also roughly the hard would species can be calculated for 50 – 75 years maturation period. In a full grown mature forest having age 35 years and above the DAB is mostly above 50 cm. Such forests are considered as sustainable source of a particular species. Based on these criteria high value timber forest areas have been identified using forest distribution map and timber species map (fig. 40). These areas correspond to high-density forest and a dominance of species such as Julbernadia, Pterocarpus, Dalbergia, Burkea africana etc.

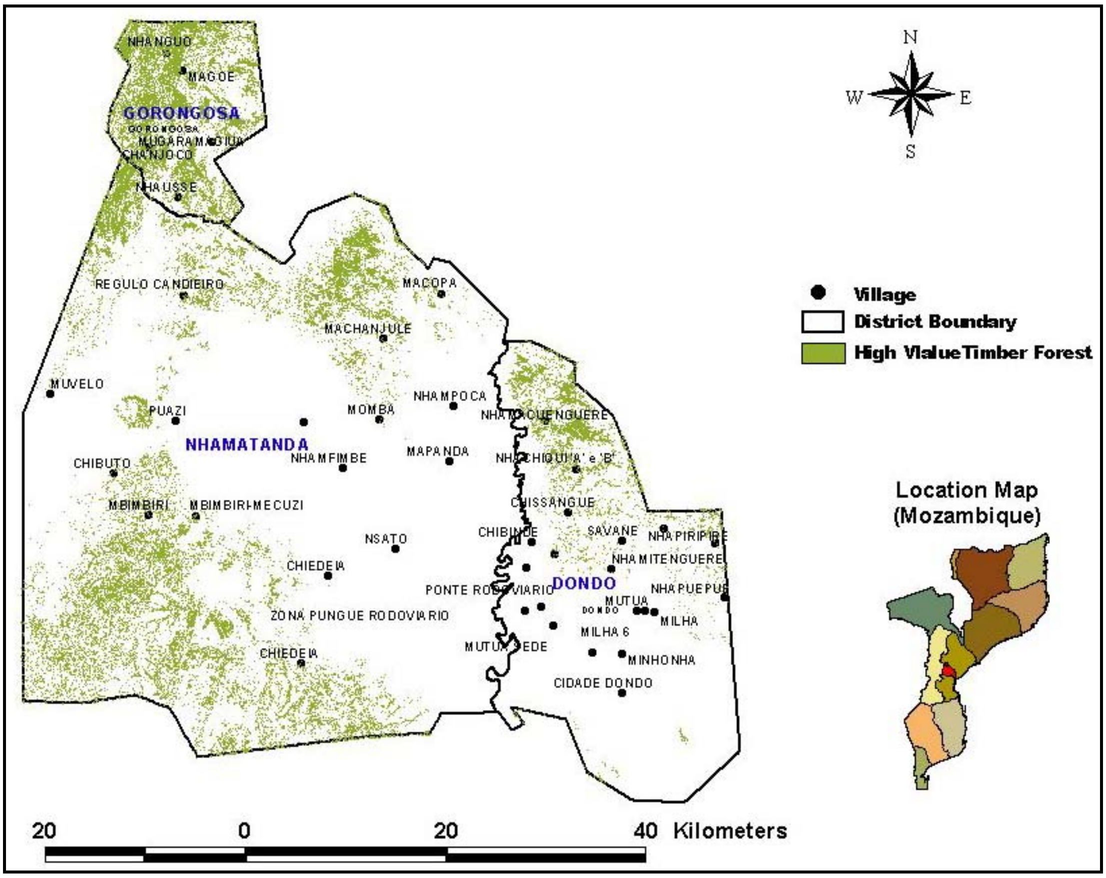


Fig. 40. High value timber forest in study area

4.11. High and medium value forests for bamboo with sustainable harvesting patterns

Assessment for high and medium value forests for bamboo with sustainable harvesting was done using bamboo distribution and bamboo stock map. As shown in fig. 41, areas having bamboo stock distribution of average 30-70 clumps are considered as most suitable high value forest for bamboo with sustainable harvesting. Those areas where the average stock distribution of bamboo is 10-20 can be considered as moderately suitable and strict management aspects should be followed in these areas.

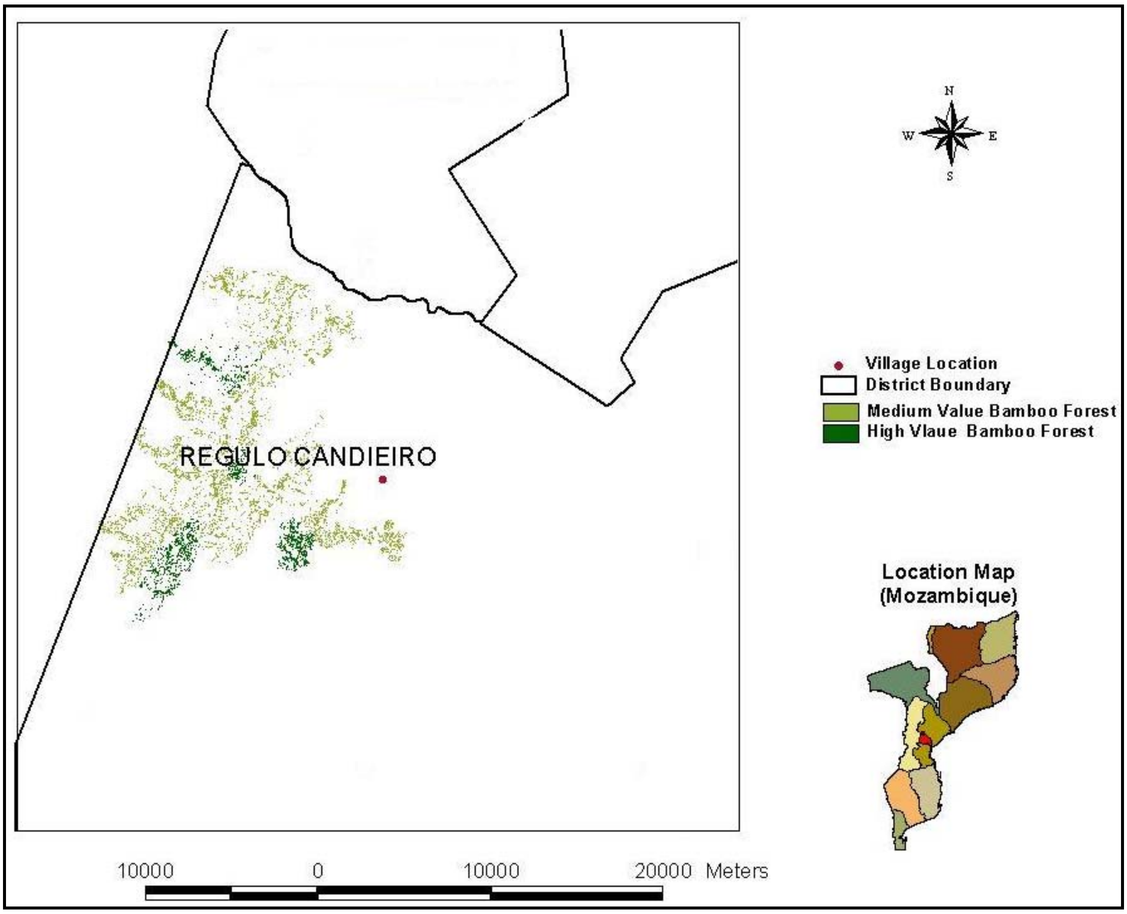


Fig. 42. High and medium value bamboo forest in Nhamatanda District

4.11. Optimal human settlement areas

For finding the optimal human settlement areas elevation map, road network map, wasteland map and the soil erosion area map were used. Those areas are optimal for human settlements that are located at the moderate elevation e.g. southeastern reaches of the study area. Further those areas can be selected which are presently under the wasteland category but where the soil erosion is less. If the settlement were done in erosion area it would lead to negative impact on the environment as well as the people. Yet another aspect is road connectivity, the proposed areas should have the accessibility by road.

4.12. Suitable areas for Bamboo Nursery

Bamboo nurseries are required to develop various species of bamboo. They are also helpful in meeting the requirement for plantation activities. Bamboo nurseries require sufficient amount of water as well as they should be near the transportation network and villages for labour and peoples participation. For environmental conservation and to utilize the open areas sites such as riverbanks and barren areas, bamboo plantation activity will prove to be the best source of land use. Along the rivers bamboo will not only protect the riverbanks from erosion but will also get sufficient amount of water, which is required for the growth of certain bamboo species.

Inputs:

- Stream Network
- Road Network
- Land-use/land-cover grid

Methodology:

In this analysis above mentioned layers were considered as input. From each layer the suitable areas are extracted out based on the suitable range for a specific analysis, i.e., all the areas falling outside the favorable range of values are eliminated from the respective layer. The selected portion of each layer was further classified into 4 to 5 classes based on their suitability. Later on a buffer of 1 km was created around each village point. The output buffer layer of village points was overlaid & intersected with each filtered layer. This resulted in selection of those areas where portion of each layer was falling within a buffer of the village. The final output layer consists of those areas, which satisfied all the conditions. The area selected should be positive to all the conditions used. In this study the following steps were followed:

- Buffer was prepared for each one of the input files according to the conditions mentioned
- The open areas are extracted from the Land-use grid
- The open area grid was filtered by each layer
- Finally only those areas were selected which satisfied all the conditions

Weightage Used:

- ➢ The suggested area should be 500m of the stream network
- ➢ The suggested area should be within 1 km of the road network
- ➢ The suggested area should at present have open areas or scrub lands
- ➢ The suggested area should not be location in Very High Soil Erosion Zone

Table: Weightage used for mapping bamboo nursery locations

Layer Name	Layer Weightage	Class	Class Weightage	Final Weightage
Bamboo Plantation Area	15	Least Suitable	1	0.15
		More Suitable	2	0.3
		Most Suitable	3	0.45
Bamboo Stock	30	0 to 500	1	0.3

		500 to 750	2	0.6
		750 to 1000	3	0.9
		1000 to 1250	4	1.2
		1250 to 1500	5	1.5
		1500 and above	6	1.8
River Buffer	20	5km	1	0.2
		4km	2	0.4
		3km	3	0.6
		2km	4	0.8
		1km	5	1
Road Buffer	15	2000m	1	0.15
		1500m	2	0.3
		1000m	3	0.45
		500m	4	0.6
Village Buffer	20	6000m	1	0.2
		4000m	2	0.4
		2000m	3	0.6

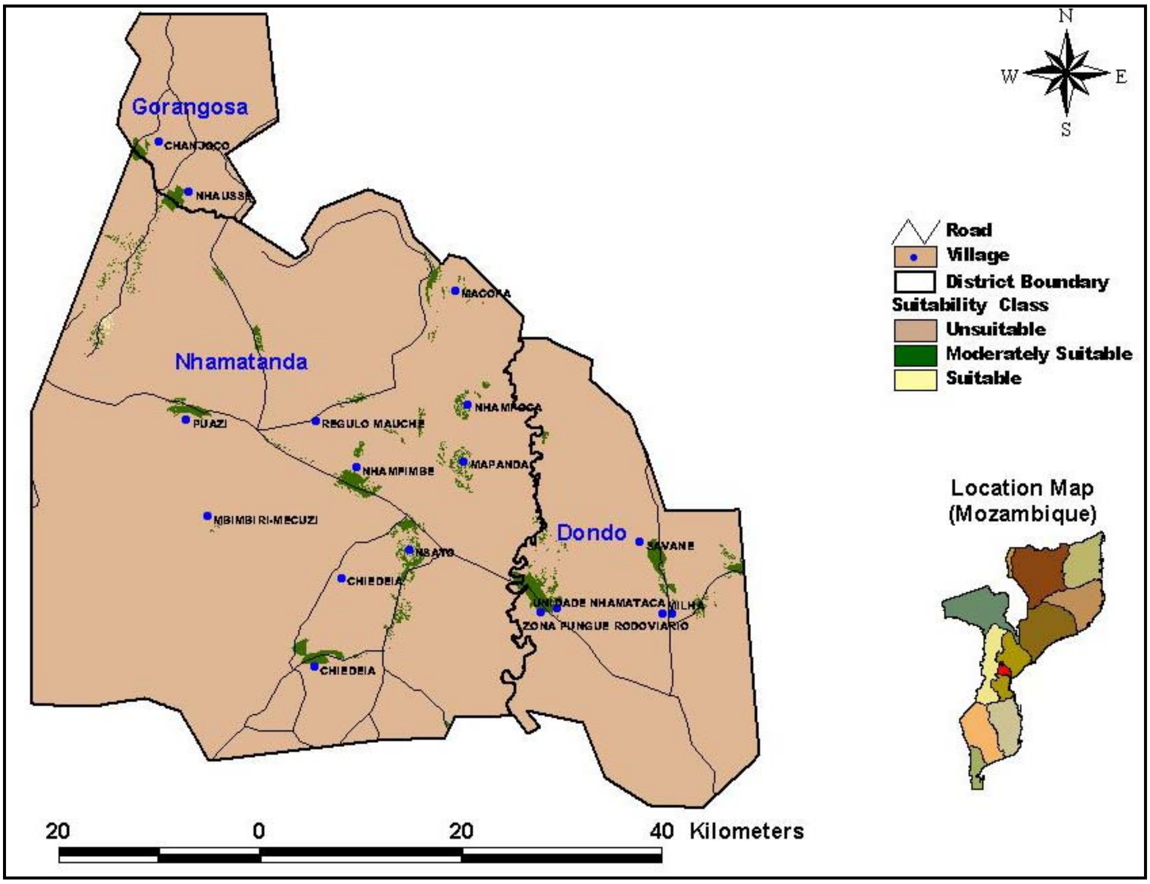


Fig. 43. Proposed Bamboo nursery locations

Best suitable villages:

Based on the conditions mentioned above total 17 villages out of 41 target villages are found to be best suitable for raising bamboo nurseries. Details of proposed villages are as follows:

Village Name	Latitude	Longitude	Population		
			Male	Female	Total
MILHA 6	-19.4839	34.7131	124	141	265
SAVANE	-19.4008	34.6842	1050	947	1997
MILHA	-19.4842	34.7250	150	145	295
ZONA PUNGUE RODOVIARIO	-19.4847	34.5625	275	283	558
UNIDADE NHAMATACA	-19.4792	34.5836	212	191	403
CHANJOCO	-18.9375	34.0875	962	1012	1974
NHAUSSE	-18.9958	34.1250	116	129	245
REGULO MAUCHE	-19.2625	34.2833	4329	4544	8873
MBIMBIRI-MECUZI	-19.3750	34.1500	4353	4805	9158
CHIEDEIA	-19.5500	34.2833	1050	1057	2107
PUAZI	-19.2625	34.1236	1289	1421	2710
NHAMFIMBE	-19.3167	34.3333	9060	9432	18492
NSATO	-19.4125	34.4000	9055	9554	18609
CHIEDEIA	-19.4458	34.3161	1858	1943	3801
MACOPA	-19.1083	34.4542	691	729	1420
NHAMPOCA	-19.2417	34.4708	954	984	1938
MAPANDA	-19.3083	34.4667	853	909	1762

4.13. Suitable areas for Bamboo Plantation

Although native bamboo is found in abundance in north western areas of Nhamatanda district however to ensure sustainable harvesting patterns and livelihood basis for the local community in Gorangosa and Dondo where there is limited bamboo vegetation new plantations should be developed in future.

Inputs:

- Wasteland Map
- Drainage Buffer
- Soil Drainage Map

Weightage used: Table below shows weightage used for finding suitable sites for bamboo plantation

Table: Weightage used for bamboo plantation

Layer name	Layer weightage	Class Name	Class weightage	Final weightage
Wasteland map	50	Land with or without scrub	1	0.5
		Shifting cultivation	2	1
		Degraded pasture	3	1.5
		Degraded forest	4	2
		Waterlogged area	5	2.5
		Ravineous land	6	3
Drainage buffer	20	5km	1	0.4
		4km	2	0.6
		3km	3	0.8
		2km	4	1
		1km	5	1.2
Soil Drainage Map	30	Good	1	0.6
		Moderate	2	0.9
		Little Excessive	3	1.2
		Excessive	4	1.5
		Imperfect	5	1.8

It is important to mention here that areas, which are under wasteland category including shifting cultivation areas, are given more priority for establishing bamboo plantations. Shifting cultivation patches inside the dense forest however are unsuitable for bamboo plantation as it may further increase human activities in the adjacent areas and may further degrade the forests. Therefore periphery of the forests is considered suitable for bamboo plantation along with the areas where already existing bamboo resources are there. For the district of Dondo big exotic species of bamboo can be planted after a thorough appraisal of available local resources.

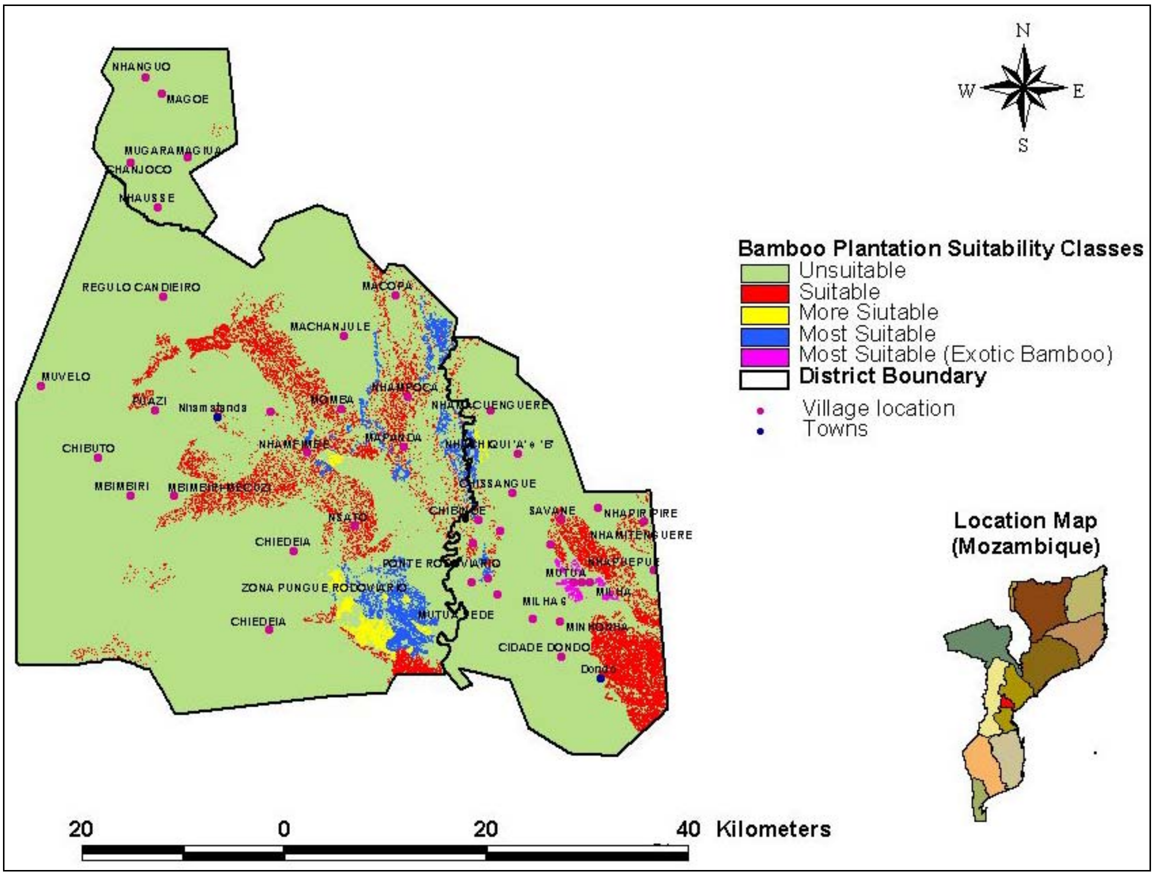


Fig.44. Suitable areas for Bamboo Plantation

4.14. Vulnerability analysis

Vulnerability is defined as degree of loss to a given element or set of elements resulting from the occurrence of a natural disaster such as flood, fire, drought etc. Under vulnerability analysis assessment of extent to which an individual, community, sub-group, structure, service, or geographic area is likely to be damaged or disrupted by the impact of a particular disaster is carried out.

4.14.1 Flood and disaster response priority villages mapping

Flood is the most common and widespread form of natural disaster that leads to loss of lives and property and sometimes-complete villages. Floods that occurred in Southern and Central Mozambique in late 1999 and early 2000 resulted in the displacement of 500,000 people, severely damaging housing, agricultural infrastructure, public buildings, schools, hospitals, water and energy supply systems, roads networks, railways and telecommunications. These losses represented an enormous setback for the Mozambican national economy and for the efforts achieved in the area of poverty reduction (World Bank, 2000). Hence, it becomes essential to create baseline information on the flood prone areas so that timely mitigation measure can be taken up.

Inputs: Following layers were used for GIS analysis

- Slope map
- Soil Drainage Map
- River Buffer Map

Weightage Used: Following weightage were used for mapping flood prone areas (Table)

Table: Weightage used for Flood prone area zonation

Layer name	Layer weightage	Class	Class weightage	Final Weightage
Slope	40	0-1	1	0.40
		1-2	3	1.2
		>2	5	2.0
Soil Drainage	30	Imperfect	4	1.2
		Moderate	3	0.9
		Good	2	0.6
		Little Excessive- Excessive	1	0.3
Drainage Buffer*	30	2km	1	0.3
		2-6km	2	0.6
		> 6km	3	0.9

- For creating drainage buffer stream of the order greater than 3 were considered

Output: Zonation of flood prone areas was obtained as the output (fig.45). It was observed that central region of the study area i.e. northeastern and southeastern portion of Nhamatanda district having flat topography and imperfect soil drainage class is most vulnerable to the floods. The region also have a dense network of high order streams with lot of meandering which makes it more vulnerable to floods. Part of Dondo district bordering Nhamatanda and southwestern part of Dondo also falls under high flood risk area. Mitigation villages were also identified and ranked on the basis of flood risk zone in which they were falling. Twenty-three out of forty-one villages in the study area are threatened by virtue of their close proximity to high and medium flood risk zones.

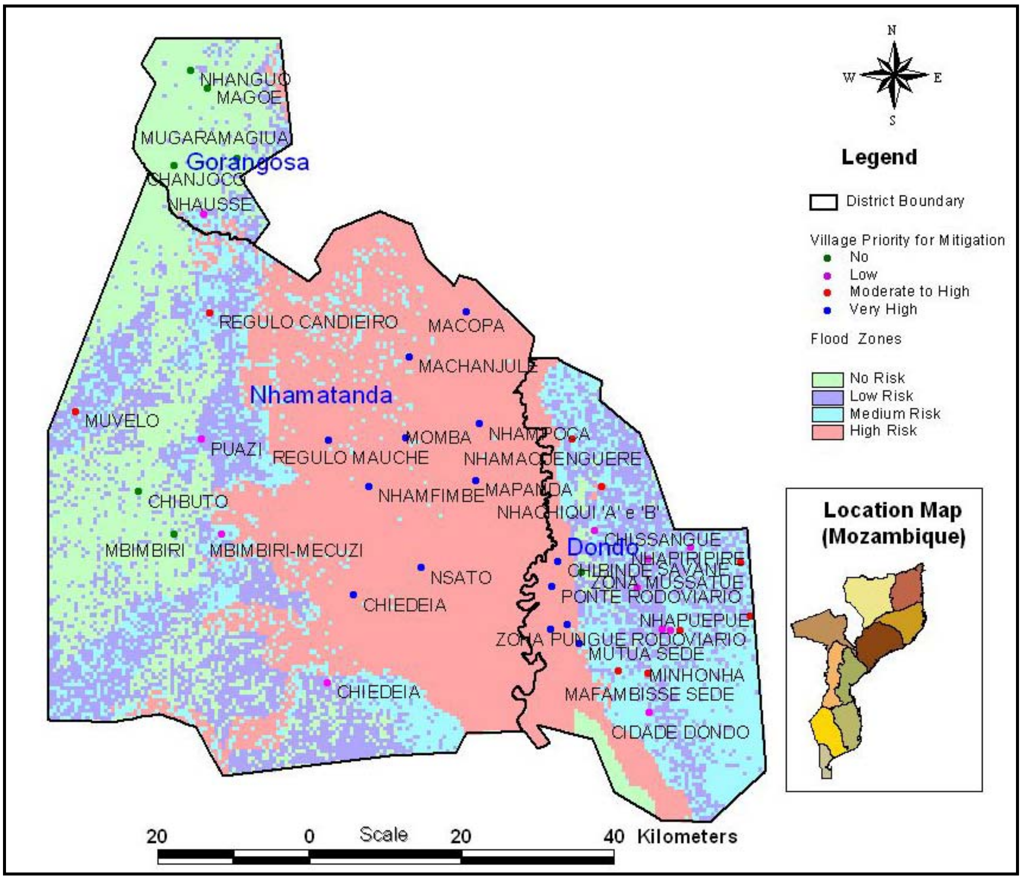


Fig.45. Flood risk zones and mitigation priority villages

4.14.2 Forest Fire Vulnerability Analysis

Forest fires, natural/human induced, have serious impact on bio-diversity and to the livelihood of the forest dependent communities in a long-term. Large-scale fires also contribute significantly to the global climate change by directly releasing carbon to the atmosphere and reducing the carbon sequestering potential of the vegetation.

Remote sensing data available at wide range of spatial and spectral resolution can be effectively utilized for locating forest fires on the ground and calculating their extent/magnitude. This can further be combined with several other contributing factors such as vegetation type and density, topography (slope, aspect and elevation), climate (rainfall, wind direction, wind speed), human influence (proximity to road or settlement), along with soil moisture content etc. to generate a model and simulate the same over the bigger area. This helps in estimating the magnitude of probable losses that may occur due to fire. In the present study forest fire vulnerability analysis was carried out using integrated geo-spatial approach.

Input:

- Slope map
- Aspect map
- Vegetation Map
- Road map
- Village map

Methodology:

- Land use land cover map derived from Landsat TM image was recoded into two classes i.e. Vegetation and non-vegetation. Vegetation classes consist of forests, shrubland and grassland combined together. Rests of the classes were classified as non-vegetation.
- The slope map was sliced into three classes, i.e, flat to very low slope, slight low and low to high slope.
- Aspect map was derived from DEM and sliced into four classes i.e east, west, south and north.
- A buffer was created along the roads by generating five rings of 1 Km each and rest of the area was classified into a separate class of more than 5 Km. This was done to incorporate human caused disturbances that may lead to forest fires.
- Similarly a buffer map for villages was also created by generating five rings of 1 Km each and rest of the area was assigned to a separate class of more than 5 Km
- All the above-mentioned maps were converted into grids and multi layer weighted analysis was carried out to generate fires risk map.

Table: Weightage used for Fire risk zonation

Layer name	Layer weightage	Class	Class weightage	Final Weightage
Slope	5	0-5	1	0.5
		5-15	3	1.5
		>15	5	2.5
Aspect	5	South	4	2.0
		East	3	1.5
		North	2	1.0
		West	1	0.5
Vegetation	7	Evergreen /Hygrophile	1	0.7
		Mixed/ Mesophile	2	1.4
		Dry/ Xerophile	3	2.1
		Bamboo	4	2.8
		Shrubland	5	3.5
		Grassland	6	4.2
Distance to road	3	<1000m	6	1.8
		1000-2000m	5	1.5
		2000-3000m	4	1.2
		3000-4000m	3	0.9
		4000-5000m	2	0.6
		> 5000m	1	0.3
Distance to villages	3	<1000m	6	1.8
		1000-2000m	5	1.5
		2000-3000m	4	1.2
		3000-4000m	3	0.9
		4000-5000m	2	0.6
		> 5000m	1	0.3

Output: Fire risk zonation map was obtained as a final output (fig.46.) Central region consisting of grasslands and shrubland and major settlements are found to be highly prone to fire. In the forest areas southwest reaches of Nhamatanda and western regions of Gorangosa shows high to medium levels of fire risk. As a preventive measure fire break line can be suggested either along the natural feature such as drainage etc. or a preventive line can also be created (plate 10) and watch towers can also be established to monitor any human induced fires.


Plate 10: Powerline serving as fire prevention line in Nhamatanda

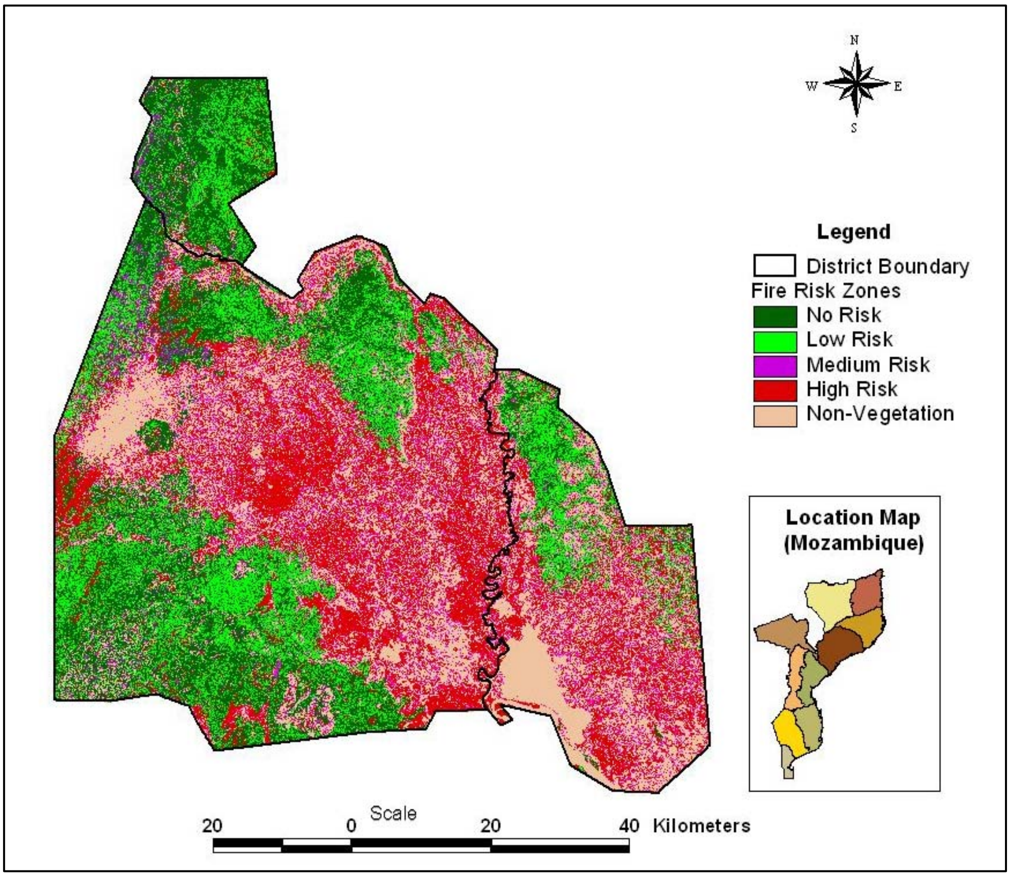


Fig.46. Fire risk zonation map of study area

4.15. Allied agriculture development activities

Agriculture and forest harvesting are the main sources of livelihoods for the communities in the Mozambique. However, experiences in the past show that modest gains from agriculture have been mainly due to area expansion instead of increase in productivity. If this scenario continues the forests will be lost due to over-exploitation and land clearing. The situation is further worsened due to the practice of shifting cultivation common among the tribal communities of Mozambique. Thus, there is an immediate need to focus on agriculture development activities. In the present study analysis have been done on some of the aspects related to irrigation potential in agriculture areas and alternative source of livelihood from fish farming.

4.15.1. Ponds and lakes based small irrigation

Mapping of ponds and lakes based small irrigation is very important for micro level planning activities. As these fresh water bodies are mostly very important from irrigation perspective, therefore, lakes were masked from Landsat TM based land use land cover map. In order to extract small ponds and lakes in the area, Land use / land cover map derived from LISS-IV images was also used. Inputs from both the images were combined together to obtain a final map showing lakes/ ponds in the study area. To be utilized for irrigation purposes, lakes having area more than 50000 m^2 have been represented in the final map (fig.47).

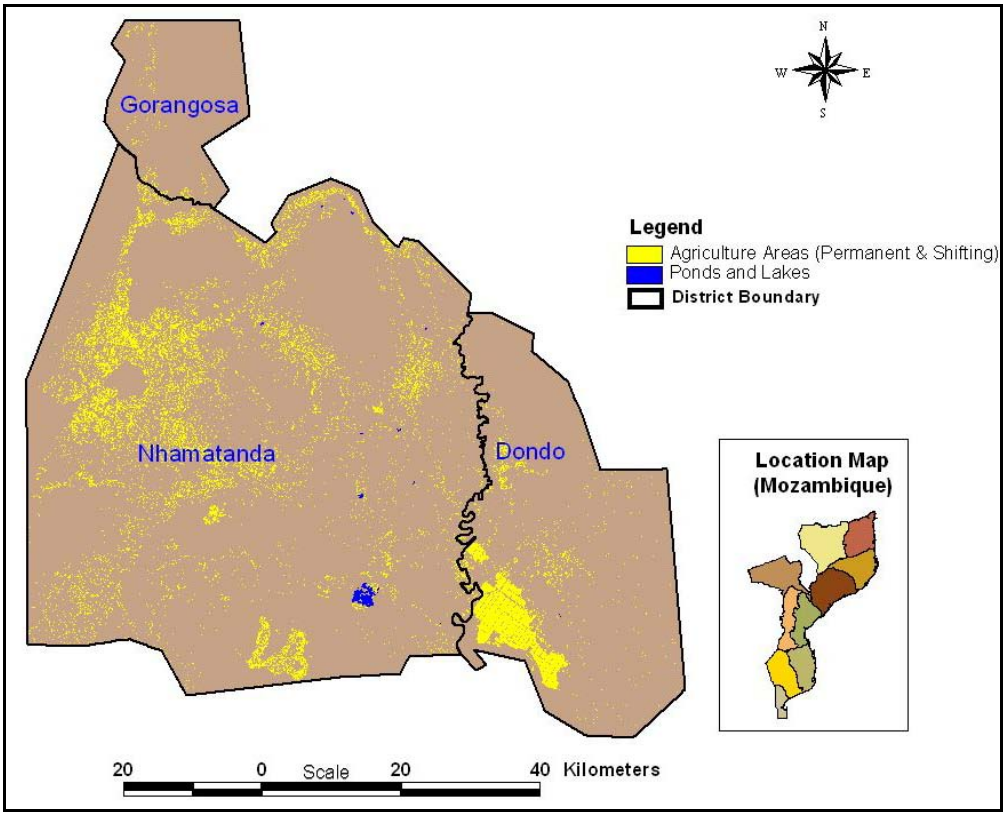


Fig.47. Pond and lakes based Irrigation

4.15.2. Potential Fish Farming Areas

Dried fish along with Maize meal constitutes staple foods in the Mozambique. Small fishes are also the source of livelihood to the rural communities. Freshwater wetlands in Mozambique including lakes (natural and artificial), rivers (including floodplains) and palustrine areas (swamps and dambos) provides habitat for various fishes as well as temporary habitat for migratory species during breeding seasons. Therefore, these wetlands provide much fish protein in Mozambique. Based on these observations potential fish farming areas were mapped on Landsat satellite image.

Input:

- Slope Map
- Landsat TM Image

Methodology:

- Low-lying areas with flat topography were identified on the Slope map.
- These areas were further masked on the Landsat image
- The masked image was classified using unsupervised classification
- Areas having high soil moisture content and no potential landuse (i.e. Grassland and Shrublands) from livelihood point of view were spectrally classified into potential areas for fish farming.

Output:

Potential Fish Farming areas map (fig. 48)

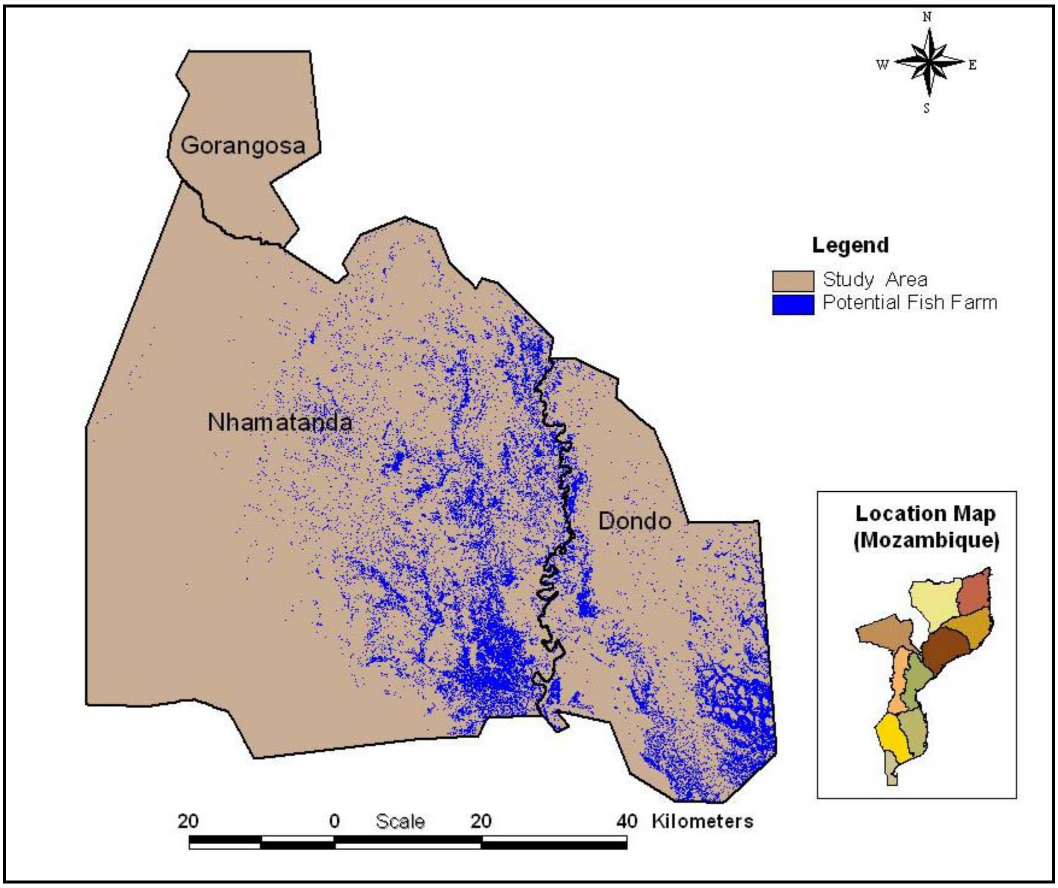


Fig. 48. Potential Fish Farming areas map

4.15.3. Mapping Irrigation potential for agriculture areas

Irrigation potential of agriculture areas has been carried out based on the assumption that there is equal distribution of rainfall in the area.

Input:

- Soil drainage map
- Soil Texture map
- Slope map
- Land use land cover map

Methodology:

- Soil texture map consisting of two classes i.e. sandy and sandy loam was used after converting into grid
- Soil drainage map having five classes was recoded into three classes
- Slope map was sliced into three classes based on their run-off level i.e. 1-3, 3-6, greater than 6.
- Multi-layer analysis was carried out using above-mentioned input layers and map was obtained
- To assess the irrigation potential with respect to agriculture, agriculture classes from land use land cover map were overlaid on the map obtained above and a final map was obtained (fig. 49).

Table: Weightage used for assessing irrigation potential of agriculture areas

Layer name	Layer weightage	Class	Class weightage	Final Weightage
Soil Drainage	30	Imperfect	4	1.2
		Moderate	3	0.9
		Good	2	0.6
		Little Excessive- Excessive	1	0.3
Soil Texture	30	Sandy Loam	2	0.6
		Sandy	1	0.3
Slope	40	0-3	5	2.0
		3-6	3	1.2
		>6	1	0.4

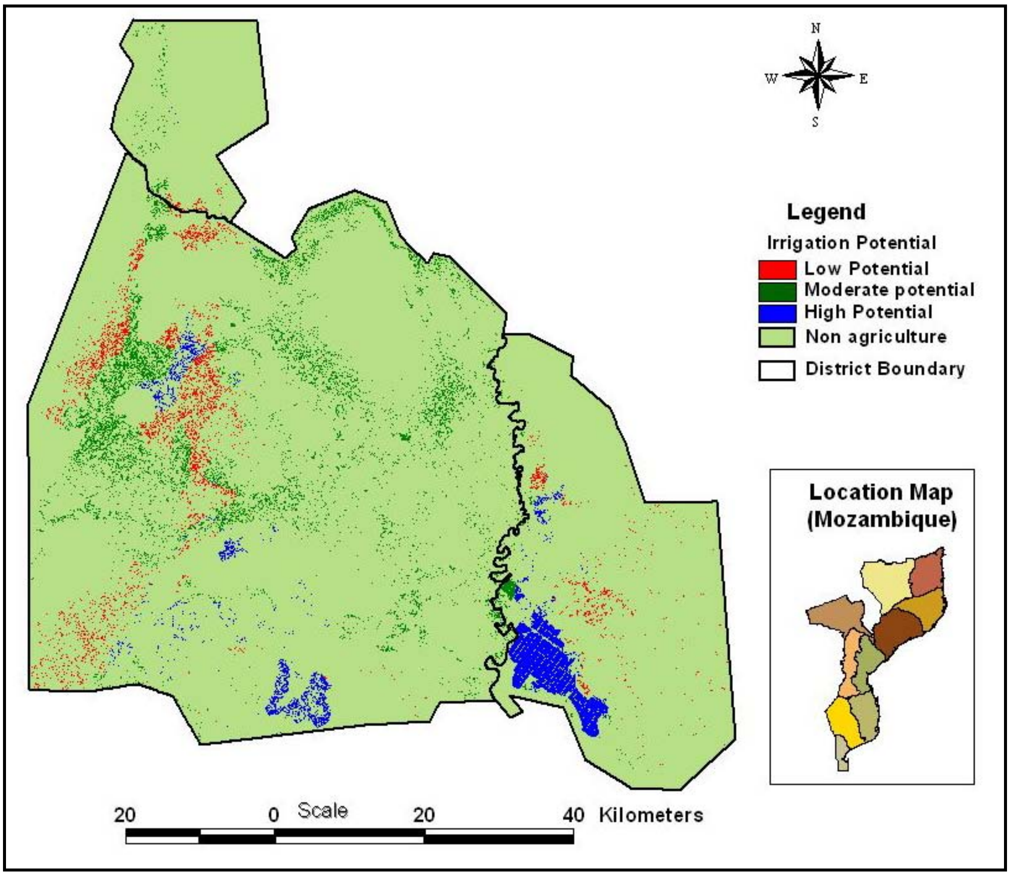


Fig.49. Map showing irrigation potential for year round agriculture

4.16. Allied forest activities

4.16.1 Conservation and Protected area Mapping for forests

According to the Modern Conservation theory, what is to be conserved is not so much the physical state of an ecological system as the ecological processes by which that state is created and maintained' (Australia, Resource Assessment Commission 1991) whereas, preservation refers to the action of reserving, protecting or safeguarding a portion of the natural environment from unnatural disturbance. Therefore, conservation measure deals with climax forests that can be sustainably harvested and the protection is carried out for the highly fragmented forests having lot of human interventions.

Input:

- Land Use Land Cover Map
- Grid/Mesh of 500m X 500m

Methodology:

- LULC map derived from Landsat TM was recoded into two classes i.e. forest and non-forest.

- For further analysis forests were assigned a value 1 and non-forests were given a value 2.
- It was converted into grid.
- This grid was overlaid with the mask grid of 500m X 500m.
- The output grid was tabulated for the values 1 and 2 within each pixel of 500m X 500m size of a mask grid.
- The resulting grid was analyzed based on standard deviation. The output map had a standard deviation values ranging from 0-0.5. Cells/pixels having standard deviation on a higher side (0.33-0.50) represent highly fragmented forests whereas areas with lower standard deviation (0-0.33) represent areas with less fragmented and intact patches.
- Based on these observations fragmented areas were suggested for protection measures and the intact areas were suggested for conservation.

Output: Conservation and protected area map of study area (fig.50)

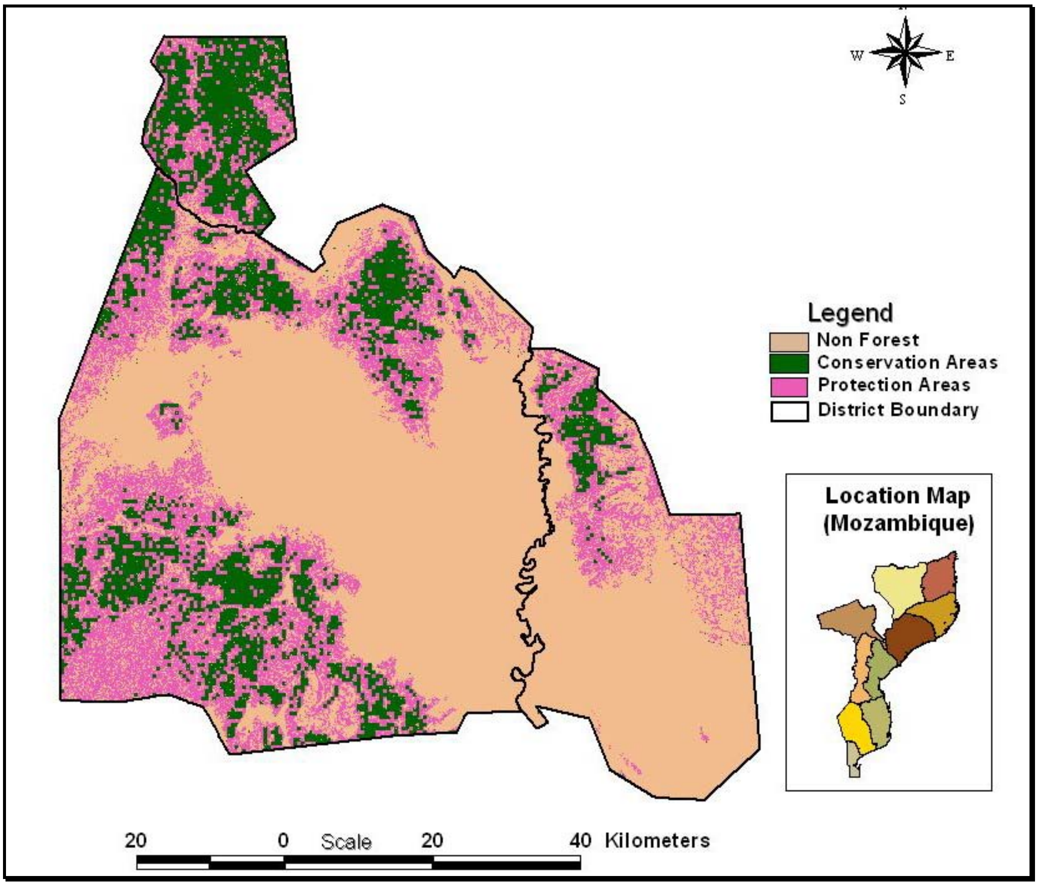


Fig.50. Conservation and protected area map of study area

4.17. Human development activity

4.17.1 Optimal Rural Market Location

Input:

- Village location map
- Attribute data of village population
- Road network map

Methodology:

- Buffer of 5.5 Km (single ring) was created with minimum overlap between the point locations of villages (fig.51)
- Overlapping buffers of villages were merged together to create clusters of villages in terms of their linear distances.
- A road buffer was created with five rings of 500 m each. It was further converted into grid.
- Each village within a cluster was also converted into grid (point map) based on human population in each village.
- In each cluster, analysis was done separately based on absolute population and accessibility from road. For final analysis high weightage was given to closest distance to road and highly populated villages.
- Finally villages in each cluster were ranked from highly suitable (3) to least (1) suitable and rank table was created

Output: Table below shows the ranking of villages for rural market development

Cluster	Village Name	Village Population	Weighted rank
Cluster1	NHANGUO	510	3
	MAGOE	413	1
	MUGARAMAGIUA	481	2
	CHANJOCO	1974	2
	REGULO CANDIEIRO	36044	1
	NHAUSSE	245	1
Cluster2	REGULO MAUCHE	8873	3
	NHAMFIMBE	18492	3
	MACHANJULE	6539	2
	MACOPA	1420	1
	NHAMPOCA	1938	2
	MAPANDA	1762	1
	MOMBA	1728	1
Cluster3	MBIMBIRI-MECUZI	9158	2
	CHIBUTO	3164	1
	PUAZI	2710	2
	MBIMBIRI	5201	1
	MUVELO	1317	3
Cluster4	NHAPIRIPIRE	881	1
	NHAMITENGUERE	389	1

	NHAPUEPUE	1199	2
	MILHA 6	265	1
	CIDADE DONDO	201	1
	SAVANE	1997	2
	NHAPALAPALA	355	1
	MUTUA	933	2
	MILHA	295	1
	MINHONHA	164	1
	MAFAMBISSE SEDE	30684	1
	NHAMACUENGUERE	407	1
	NHACHIQUI 'A' e 'B'	857	1
	CHISSANGUE	1445	2
	CHIBINDE	475	1
	ZONA PUNGUE RODOVIARIO	558	2
	ZONA MUSSATUE	2410	2
	UNIDADE NHAMATACA	403	1
	MUTUA SEDE	4600	3
	PONTE RODOVIARIO	492	1
Cluster5	CHIEDEIA	2107	1
	NSATO	18609	2
	CHIEDEIA	3801	1

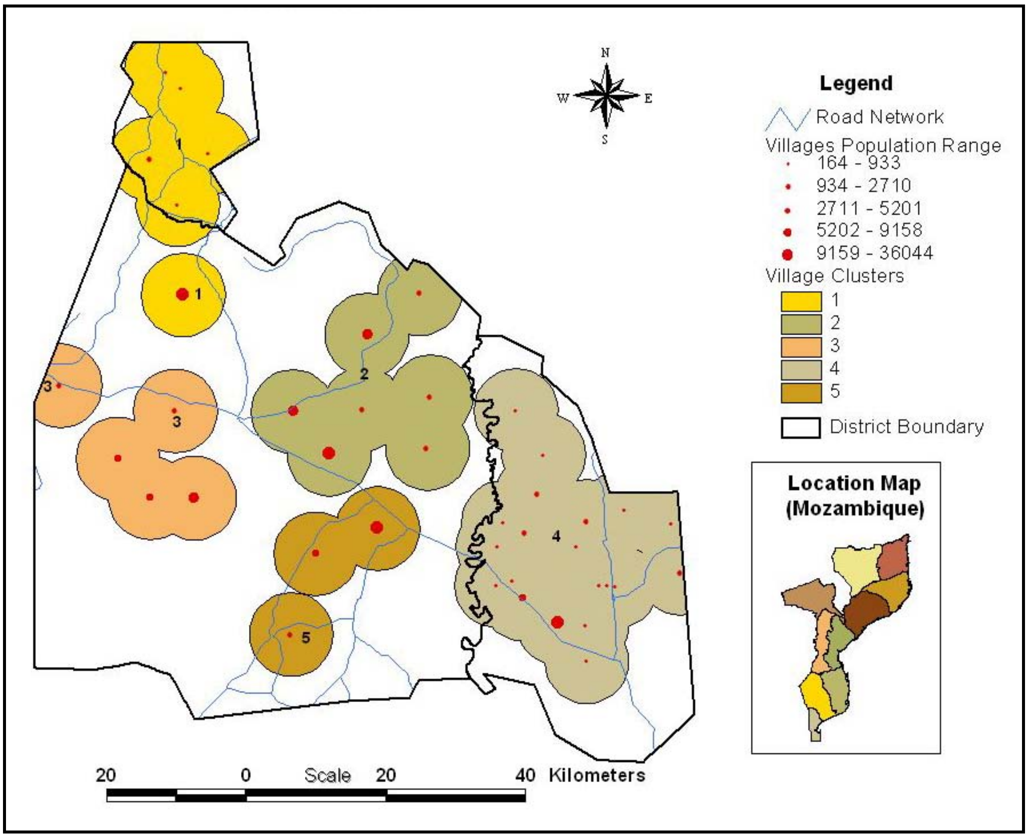


Fig.51. Distribution of Village clusters for rural market analysis

14.17.1. Industrial potential - food processing, cold storage etc.

Ideally Nhamatanda and Dondo are the most suitable locations for setting up industries. However tapping of resources at village level may lead to improvement in the quality of life of the rural poor. Keeping this in mind, one village is identified based on land use land cover classification of high resolution L4 image.

In Nsato Village and nearby areas there are widespread homestead trees and orchards. Also this village is well connected by road and railway line. In addition, it is also the third largest village in terms of total population. All these factors make it highly suitable for setting up food processing unit. In future high yielding varieties of fruit crops can be introduced in the farmlands for increased availability of raw material.

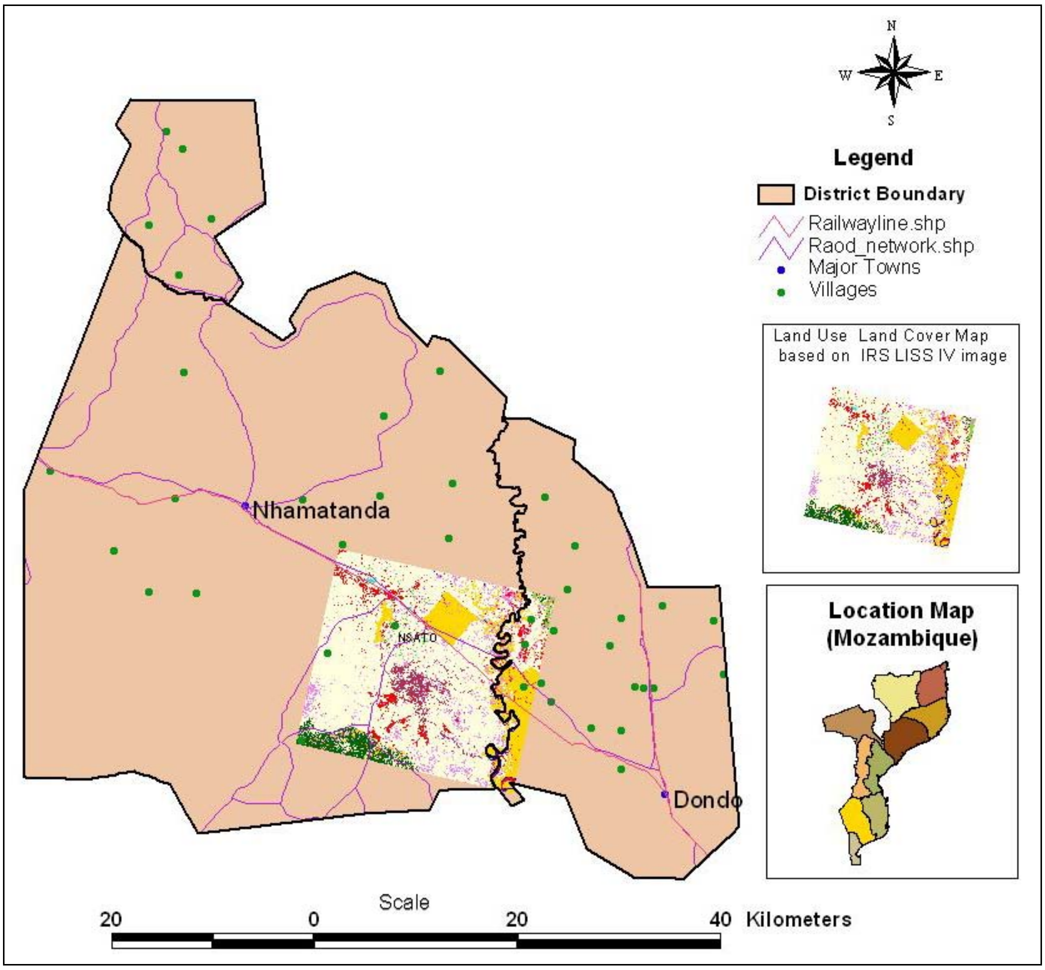


Fig.52. Suitability analysis for industrial or food processing unit

5.0. 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 be not 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. Before implementing the action plan validation of the analysis must be correlated in the field.

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 social-economic life of the people, therefore, use of GIS becomes imperative.

Once the action plan is implemented 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 monitored. Similarly the progress of certain industries and the locations for plantations suggested with the help of GIS can be evaluated after six months 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 their 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 as well since 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.

6.0. References

1. Campos Andrada, E. 1951. O problema das queimadas em Moçambique.
2. DFID, 1998.Sustainable rural livelihoods", UK Department for International Development, London, 1998.
3. Maundrate Nakala Oreste and Carla Cristina Cuemba, 1998; Forestry Data on Mozambique,in Proceedings Of Sub-Regional Workshop On Forestry Statistics SADC region, Mutare, Zimbabwe, 30 November - 4 December 1998.
4. *Rodel D. Lasco, Joveno S. Lales, Ma. Theresa Arnuevo, Ina Q. Guillermo, Agnes C. de Jesus, Reinero Medrano, Orlando F. Bajar, and Cirilo V. Mendoza*. 2000; Carbon Dioxide (Co2) Storage And Sequestration In The Leyte Geothermal Reservation, Philippines; Proceedings World Geothermal Congress 2000, Kyushu - Tohoku, Japan, May 28 - June 10, 2000
5. Trozzi, C. and R. Vaccaro 2002. Emission Inventories - Partnering for the Future Emissions estimate from forest fires: methodology, software and European case studies Techne srl -Via Zabaglia, 3 - Roma (Italy) - techneit@ techneit.com April 16-18, 2002 - Atlanta, GA
6. World Bank, March 2000; *A Preliminary Assessment of Damage from the Flood and Cyclone Emergency of February-March 2000.*
7. www.nabard.org
8. http://bamboocentral.org