Nature of the Project and specific objectives

The Direcção Nacional de Terras e Florestas through the PIDA Program, financed by the Italian Cooperation, carried out the Interagted Assessment of Mozambican Forests (AIFM). The AIFM was funded with 2.5 million euros, and was executed by the consortium formed by Agriconsulting S.p.A (Italian) e Rural Consult Lda (Mozambican), between 2005 and 2007.

The main objective of AIFM was to evaluate the extent and composition of the forest resources of the entire country, in order to provide to the Mozambican Government updated information on the present state of such resources for a better protection, conservation and utilization.

The main results of the AIFM were the following:

<table>
<thead>
<tr>
<th>National and provincial assessment of forest resources</th>
<th>Other studies at national level</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Updated land cover map (2004-2005)</td>
<td>▪ Preliminary evaluation of wildlife distribution</td>
</tr>
<tr>
<td>▪ National Forest Inventory</td>
<td>▪ Preliminary evaluation of Non Timber Forest Products</td>
</tr>
<tr>
<td>▪ Two provincial forest inventories (Manica and Maputo)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Special studies in selected locations</th>
<th>Implementation of an Information System</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Assessment of wildlife in Machaze area</td>
<td>All spatial and statistical informations collected by AIFM were integrated in a comprehensive Information System (IS), in form a geo-database. The IS constitute perhaps the most valuable result produced by AIFM, since it is a flexible repository of multiple information layers that can be integrated to support strategic planning and decision making.</td>
</tr>
<tr>
<td>▪ Community forestry study in Inchope/Muda area.</td>
<td></td>
</tr>
</tbody>
</table>
The National Forest Inventory was designed to provide comprehensive information on forest resources, including:

**Quantitative information** (forest areas, total volume and commercial volume, etc.)

**Qualitative information** (species composition, structure of the forest, ecological zoning, wood quality, etc.)

The results allow a statistical analysis at national level and the precision estimated was of 10-15% for total volume.

For productive forests the following parameters were calculated:

- Commercial volume
- Commercial quality classes
- Annual allowable cut
Workflow of the remote sensing and land-cover component

**Remote sensing**

- Satellite imagery acquisition
- Digital image processing
- Geo-referencing
- Geo-corrected images
- Positional accuracy assessment

**Use of orthorectified satellite images and digital topographic maps**

**Land-cover interpretation**

- Preparation of legend
- Preliminary land-cover interpretation
- Use of ancillary digital data sets, orthorectified images and pre-sampling
- Field validation data set
- Thematic accuracy assessment
- Final land-cover interpretation and legend
- Technical report

**Ecological zoning & land cover/use integration**

- Baseline data set Forest Inventory stratification

**Component output**

Type of output:
- Data
- Report
Classification of the vegetation types

I - Use and cover

Florestas
(Cobertura of trees >10% altitude > 5 meters)

- Natural or semi-natural
- Plantations forestals

Outras formações lenhosas

- Mangals
- Arbustos
- Pradarias

Outras terras
(uso principal non forestal)

II - Fenology

- Sempreverdes
- (Semi-) deciduous

- Densas c. copas > 40%
- Abertas c. copas 10-40%

III - Density

- Forests of mountain
- Latifoliadas densas
- Forests of gallery
- Abertas
- Miombo dense
- Miombo open
- Mopane dense
- Mopane open
- Mangal dense
- Mangal open

IV - Floristics aspects

- Smallop forests
- Latifoliadas abertas
- Mangal open
- Mecrusse dense
- Mangal dense

Classes mixtas da agric. itinerante

Areas urbanas

Other

- Agriculture
- Agriculture
- Areas humidas
- Other

- Agricultural
- Arable
- Tandos de Marromeu
- Water areas

- Other lands
(usage primary non forestal)
Interpretation of land cover types using Landsat

- Broadleaved evergreen closed forest
- Miombo dense
- Miombo open
- Forest with shifting cultivation

Zone dominated by agriculture with shrubs and grasslands

Definition of the classes with the FAO/UNEP standard
The AIFM Project produced a land cover map based on interpretation of satellite imagery (LANDSAT 5 TM of year 2004-2005). The classification system was based on international standard (FAO, Land Cover Classification System –LCCS), modified according to the national requirements.

The map validation was carried out, whenever possible, with ground truthing, or high resolution images (ASTER).

Using statistical methods, the accuracy of the map was calculated, and ranged from 86% and 88% for the main classes and 90% for the forest classes.

The AIFM land cover map will constitute an updated reference for land cover and forest cover of Mozambique.
Using the land cover map described above the following areas for forests and other wooded formations were calculated

Around 70% of the country (65.3 million hectares) is covered with forests or other wooded formations.

The forests cover an area of 40.6 million hectares (51% of the country), while other wooded formations (thickets, shrubs and forests with shifting cultivation) cover around 14.7 million hectares (19% of the country).
Field inventory
## Stratification

<table>
<thead>
<tr>
<th>Main vegetation type</th>
<th>Stratum</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>Dense forest</td>
<td>341</td>
</tr>
<tr>
<td>Forest</td>
<td>Open forest</td>
<td>176</td>
</tr>
<tr>
<td>Other wooded land</td>
<td>Thickets / Shrubs</td>
<td>36</td>
</tr>
<tr>
<td>Other wooded land</td>
<td>Forest with shifting cultivation (long fallow)</td>
<td>97</td>
</tr>
<tr>
<td>Forests and OWL</td>
<td>Total</td>
<td>650</td>
</tr>
</tbody>
</table>
For each tree the following variables were recorded in the field:

- Species identification (local name and botanical name)
- Diameter
- Total height
- Commercial height
- Tree quality
- Health status

Each sampling unit was composed by a cluster of 4 plots (recording units). Each plot consisted of a line of 100 * 10 meters, where all trees with dbh > 10 were measured. The presence of regeneration (trees < 10 cm) was also measured in smaller sub-plots (5 * 5 meters).
Data processing

The following variables have been calculated for each sampling units and then expanded to values per hectare and per stratum

- Number of trees
- Basal area
- Total stem volume
- Commercial volume (bole height)
- Merchantable volume (based on presently commercial species and minimum cutting diameters)
- Volumes by species, quality and diameter class
## Inventory results - Volume

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Total stem volume (m$^3$/ha)</th>
<th>Commercial volume (m$^3$/ha)</th>
<th>Merchantable volume (m$^3$/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense forest</td>
<td>40.1</td>
<td>12.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Open forest</td>
<td>32.2</td>
<td>9.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Thickets / shrubs</td>
<td>18.8</td>
<td>5.6</td>
<td>1.9</td>
</tr>
<tr>
<td>Long fallow</td>
<td>20.6</td>
<td>5.7</td>
<td>1.9</td>
</tr>
</tbody>
</table>
### National Forest Inventory – Statistical analysis

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Vegetation type</th>
<th>Std error (%) num. of trees</th>
<th>Std error (%) basal area</th>
<th>Std error (%) total volume</th>
<th>Confidence interval (%) num. of trees</th>
<th>Confidence interval (%) basal area</th>
<th>Confidence interval (%) total volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Dense forest</td>
<td>2.1</td>
<td>3.0</td>
<td>3.6</td>
<td>3.5</td>
<td>5.1</td>
<td>6.1</td>
</tr>
<tr>
<td>4</td>
<td>Open forest</td>
<td>3.6</td>
<td>5.8</td>
<td>6.5</td>
<td>6.0</td>
<td>9.9</td>
<td>11.1</td>
</tr>
<tr>
<td>6</td>
<td>Thickets / shrubs</td>
<td>10.1</td>
<td>13.7</td>
<td>13.8</td>
<td>17.1</td>
<td>23.3</td>
<td>23.5</td>
</tr>
<tr>
<td>8</td>
<td>Long fallow</td>
<td>10.3</td>
<td>9.4</td>
<td>11.1</td>
<td>17.6</td>
<td>16.0</td>
<td>18.9</td>
</tr>
<tr>
<td>Total</td>
<td>Forests and other wooded land</td>
<td>2.1</td>
<td>2.8</td>
<td>3.2</td>
<td>3.6</td>
<td>4.8</td>
<td>5.4</td>
</tr>
</tbody>
</table>
## Information System and modelling

<table>
<thead>
<tr>
<th>Basic information</th>
<th>Auxiliary information</th>
<th>Combined information / Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land cover map</td>
<td>• Conservation areas</td>
<td>Timber production suitability</td>
</tr>
<tr>
<td></td>
<td>• Land units (geomorphology, lithology, slope, soils, etc.)</td>
<td></td>
</tr>
<tr>
<td>Land cover map</td>
<td>• Potential Vegetation Map (Flora Zambeziaca)</td>
<td>Ecological zoning</td>
</tr>
<tr>
<td>• Forest Inventory Results</td>
<td>• Land Units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Bio-climatic data (temperature, precipitation, length of the dry season, etc.)</td>
<td></td>
</tr>
<tr>
<td>Observations of wildlife at national level</td>
<td>Ecological zoning</td>
<td>Predictive models of large mammal distribution</td>
</tr>
<tr>
<td>• Volumes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Above-ground biomass</td>
<td></td>
<td>Woody biomass stock and supply/demand estimations</td>
</tr>
<tr>
<td>• Ecological zoning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Population pressure</td>
<td>Statistical analysis MODIS</td>
<td></td>
</tr>
</tbody>
</table>
Distribuição espacial dos LEÕES

Panthera leo

Inquéritos e relevações pontuais sobre a presença da espécie

Legenda
- Presença observada
- Presença não observada
- Limites provinciais
Model: Forest cover and population density – Deforestation analysis

Forest cover vs. population density

Observed values
Exponential regression line

\[ y = 85.599e^{-0.0148x} \]
\[ R^2 = 0.7941 \]
Model Productivity vs. Bio-climatic data

$y = 44.256 \ln(x) - 266.18$

$R^2 = 0.6976$

Volume per hectare (m$^3$/ha)

Average annual precipitation (mm)
Estimation of biomass from NFI data

The NFI data were used to estimate Total Above-ground Biomass for each field sampling unit. After an extensive review of the existing studies at national and regional level, the following estimation procedures were selected:

Models based on individual tree biomass, where Tree biomass = f (dbh)


Models based on Volume expansion factors

Where Biomass = VOB * WD * BEF
Comparison of biomass expansion factors

![Graph showing the comparison of biomass expansion factors with VOB (m3/ha) on the x-axis and biomass (t/a) on the y-axis. The graph includes data points for biom_sit_ha, biom_brow_ha, biom_tch_ha, and biom_expa.]
<table>
<thead>
<tr>
<th></th>
<th>Ecological zoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Florestas (semi)-sempreverdes úmidas de montanha, pradarias de montanha e miombo úmido</td>
</tr>
<tr>
<td>2</td>
<td>Florestas úmidas sub-litoral</td>
</tr>
<tr>
<td>3</td>
<td>Miombo medio</td>
</tr>
<tr>
<td>4</td>
<td>Miombo seco</td>
</tr>
<tr>
<td>5</td>
<td>Florestas secas deciduadas indiferenciadas</td>
</tr>
<tr>
<td>6</td>
<td>Florestas de mopane</td>
</tr>
<tr>
<td>7</td>
<td>Zonas sub-aridas e pradarias secas</td>
</tr>
<tr>
<td>8</td>
<td>Mosaicos de vegetação costiera e matagais e mangais</td>
</tr>
<tr>
<td>9</td>
<td>Areas inundadas</td>
</tr>
</tbody>
</table>
Calibration of biomass estimates - Results

Biomass (t/ha)

- Closed moist
- Open moist
- Closed dry
- Long fallow moist
- Open dry
- Shrub/Thickets
- Long Fallow dry
- Short fallow moist
- Short fallow dry

Biomass (t/ha)
Main source data used in the estimation process were:

- National forest inventory data.
- Land cover/ecological class groupings.
- Biomass expansion factors, wood density factors and chosen increment estimation equations.
- Stock and sustainable productivity of surveyed land cover classes. The estimation of (minimum, medium and maximum) biomass stock per hectare and productivity was done considering the individual land cover classes, the ecological regions where they occur (considering only meaningful land cover-region combinations) and the class combinations (primary, secondary and tertiary, with relevant internal proportions) that are actually represented in the final land cover map. This resulted in 2277 individual “biounits” (intended as multi-polygon entities) each of which carrying a certain biomass stock (t/ha) value.

The spatial distribution of woody biomass stock and sustainable biomass productivity was done using the MODIS Tree Cover Percent values as proxy of spatialization to represent the stock and productivity variance within the entire “biounit” category, according to the following formulation:

\[
\text{value in cell}_i \text{ of biounit}_b = \frac{\text{tree cover}_i}{\text{average tree cover of biounit}_b} \times \text{average value of } b_b
\]
Spatial distribution of biomass 2

BIOUNITS:
2277 unique combinations of land cover and land regions

Tree cover
Percent
High: 100
Low: 0

woody biomass
$t/\text{pixel}(6.25\text{ha})$

0
1 - 25
25 - 50
51 - 75
76 - 100
101 - 125
126 - 150
151 - 175
176 - 200
201 - 250
251 - 300
301 - 400
401 - 3,000
Accessibility is estimated as a function of:

- Distance from the roads
- Distance from populated places
- Slope
- Land cover
Balance at pixel level =
Potential production - local consumption
Summary of results by administrative unit (Posto Administrativo)

- Woody biomass consumption intensity
- Local balance
  - Commercial balance "liberal" variant
  - Commercial balance "conservative" variant
Woodshed analysis

Degradation / Deforestation risk zoning

- Low risk zone
- Medium risk zone
- High risk zone

Maputo
Conclusions and recommendations

The AIFM Project provided a major contribution to the knowledge of the forest resources of Mozambique. Based on the AIFM experience, the following recommendation can be made.

- **Continue the monitoring of the forest change processes taking place in the country.** This activity is essential for controlling the magnitude and location of deforestation and forest degradation processes. The methodology applied by AIFM in Manica Province, based on interdependent interpretation of Landsat imageries, which produces not only total changes but transition matrices as well, should be extended to the whole country.

- **Establish a network of permanent plots to estimate forest growth and yield, for a more precise estimate of Annual Allowable Cut.**

- **Strengthen the monitoring of forest concessions activities and facilitate the information flow between forest concessionaires and the UIF.** In particular forest inventory and other data collected by concessionaires should be integrated systematically in the AIFM Information System.

- **Develop sustainable strategies for forest/energy** (establishment of concessions for fuelwood and charcoal production, forest management for fuelwood production, urban-rural partnerships, rural markets for woodfuel, etc.)

- **The capacity building initiated by AIFM should be continued, taking advantage of the momentum created by the Project.**
Avaliação Integrada Das Florestas De Moçambique - AIFM