The ENDELEO project

Development of a remote sensing derived tool to assess the impact of conservation policy measures and drought on East African ecosystems
Introduction

- Drought in East-Africa is a natural recurrent phenomena (~1/7 years).

- However: the intensity and impact on the environment and people has increased the last decennia.

- Overexploitation and degradation of natural ecosystems results in an increased vulnerability to drought.

- Vulnerable ecosystems in East-Africa include rangelands and montane forests.
Introduction

- Possible drivers leading to change in rangelands and forests:
  - Anthropogenic:
    - Policy changes
    - Market forces
    - Population dynamics
  - Natural:
    - Climate
    - Disasters
Introduction

- Analysis of
  - Remote sensing (RS) information
  - Ancillary information on possible drivers
- Linkage between the degree and extent of change ecosystems and the drivers
- Evaluation of effectiveness of policy measures

- Problem for continued monitoring:
  Lack of access to regularly updated information on the location and extent of changes.
Concept and objectives

- **Data**
  - LR data (e.g. SPOT-VGT, MODIS, etc.)
  - HR data (e.g. Landsat, SPOT-HRV, etc.)

- **Users**
  - Conservation groups
  - Government agencies

- **ENDELEO**
  - Techniques
  - Methods

- **Research**

- Enhancing the understanding of ecosystem management issues in drought vulnerable areas
- Development of a remote sensing based monitoring tool
## Project partners

- **Ghent University, laboratory of Forest Management and Spatial Information Techniques (FORSIT)**
  - Coordination
  - Analysis of high resolution data

- **VITO**
  - Analysis of low resolution data
  - Set up information system

- **UNEP**
  - Contact with users
  - Inventory of policies
Project flow

1. Stakeholder workshop

2. Analysis of test areas with low and high resolution RS data, and ancillary data

3. Development of a prototype remote sensing based monitoring system

4. Validation of results/ evaluation of monitoring system

*Strong user involvement!*
The ENDELEO Planning Workshop

Nanyuki, Kenya, July 2\textsuperscript{nd} – 3\textsuperscript{rd} 2007

\textbf{Objectives}

- Identification of drivers that might have impacted the state of rangeland and forest ecosystems
- Identification of information needs and formats, suited for environmental monitoring
- Evaluation of the strengths and shortcomings of current monitoring tools
- Identification of target areas for test cases
The ENDELEO Planning Workshop

Participants
The ENDELEO Planning Workshop

Represented organizations

Agricultural Research Foundation (AGREF)
Centre for Training and Integrated Research in ASAL Development
Kenya Forest Working Group (KFWG)
Northern Rangelands trust (NRT)
African Wildlife Foundation (AWF)
Save the Elephants
Lewa Wildlife Conservancy
The Kenya Camel Association
Department of Resource Surveys and Remote Sensing (DRSRS)
The ENDELEO Planning Workshop

**Day 1**

- Presentation by participants on their organization and activities:
  - Organization
  - Function of participant in the organization
  - Mandate
  - Activities
  - Geographical areas
  - Place of remote sensing in the organization
The ENDELEO Planning Workshop

Day 1

- **Forest** and **rangeland** work group discussions
  - Ecosystem management problems?
  - Geographic areas of interest?
  - Observed ecosystem changes (timescale)?
  - Drivers of changes?
  - Information needs?
  - Your expectations of remote sensing?
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Day 2

- Introduction to basic concepts in remote sensing, available data products, existing projects
- Demonstration on possibilities of remote sensing for ecosystem management
- Formulation of conclusions
The ENDELEO Planning Workshop

**Workshop Conclusions**

- Ecosystem management topics of interest
  
  **Forests**
  
  - Link between socio-economic data and forest cover change
  - Changes in forest structure and species.
  - Trends in forest land cover classes.
  - Fire risk.
Workshop Conclusions

Rangelands

- Relationship between livestock population numbers available vegetation biomass.
- Impact of trampling by livestock near boreholes.
- Quality of rangelands: annual/perennial grass cover.
- Settlement patterns and increased sedentarisation.
- Encroachment of grasslands by bush.
The ENDELEO Planning Workshop

**Workshop Conclusions**

- **Recommendations for monitoring system**
  - Different levels of products should be supplied, ranging from raw data to processed data, reports and hard copies.
  - The data should be in a simple format, so that land managers should be able to interpret the data.
  - Sustainability of the system is an important requirement (potential for systems like VGT4Africa).
The ENDELEO Work plan

- The ENDELEO work plan contains planned research for the topics formulated by the users in the ENDELEO Planning workshop:
  - Can remote sensing data products contribute to an improved ecosystem management for the different topics?
  - Which remote sensing products and techniques are best suited for environmental monitoring?
  - How can the selected monitoring techniques by incorporated in a monitoring tool?
Data distribution system

- Final system:
  - to be defined
  - User-driven -> feedback is necessary !

- Currently:
  - LR data from VGT & MODIS (soon)
    - NDVI, DMP, VPI, NDWI
  - HR data when available
  - MSG: sunshine duration

- Soon: results
Prelim data distribution

- You register for a number of products ([link1](#), [link2](#)) ([explanation](#))
- Each month a new set of products will be produced. These products are placed on the ftp-site of the ENDELEO-project. We notify you through e-mail that the product you registered for is available. This e-mail also contains a quicklook of the concerning image.
- You can download the image from the FTP-site.
Current LR products

NDVI

NDWI

Sunshine duration

VPI

DMP
- Products can be customised
  - E.g. NRT
Distribution of results
Demonstration cases in Newsletter

- For example: destruction of Mau forest
Observations of forest decrease in South West Mau Forest from Landsat ETM+ images of 2007 and 2008.
Region: KENYA
Period: February, 2008
Theme: Normalised Difference Vegetation Index (NDVI)
  Historical probability VI (HPVI = VPI)
Source: SPOT-VEGETATION
NDVI for March 2008 lower than any other NDVI value in the time-series.
VGT4Africa & ENDELEO

- **VGT4Africa**
  - Distribution of VGT-derived products to the African user community

- **ENDELEO**
  - Value-added products specific for Kenyan land managers.
  - Can be based on VGT4Africa products, but also other products.
Preliminary results

Forests
- Land cover/land use classification
- Forest cover extent & trends
  - High/low spatial resolution

Rangelands
- Indicators for differentiation between managed rangelands (NRT conservancies) and surrounding areas with no grazing management
High spatial resolution forest classification

2 methods:

- Supervised classification:
  - Production of reference forest cover maps
  - Time consuming

- Update of reference forest map:
  - Can be automated
  - Can be incorporated in monitoring system
High spatial resolution forest classification

- Test area: Aberdares and Marsabit
- Image data:
  - High resolution: Landsat, ASTER, SPOT
- Reference data:
  - KIFCON land cover within forest boundaries (KIFCON, 1994)
  - Africover land cover classes (FAO - Africover, 2003)
  - Forest disturbance observations collected during aerial survey by UNEP in 2002 (Lambrechts et al., 2002)
Method 1: Supervised classification

- **Methodology:**
  - Georectification
  - Cloud/ cloud shadow removal (manually)
  - Selection of training and validation pixels for each class
  - Supervised maximum likelihood classification
  - Post-processing
  - Accuracy assessment
Landsat ETM+ SWIR color composite image (21.02.2000) of Aberdare forest range
Supervised classification result

Landcover/land use map of Aberdare Forest Range
Supervised classification: forest cover maps

- Forest cover maps for:
  - 1987
  - 2000
  - 2002
  - 2005
  - 2007

→ Reference database
Forest cover trends
Forest cover trends

<table>
<thead>
<tr>
<th>Division</th>
<th>1987</th>
<th>2000</th>
<th>2007</th>
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<tbody>
<tr>
<td>Ndaragwa</td>
<td>22.5</td>
<td>20.8</td>
<td>22.7</td>
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<td>Kieni East</td>
<td>12.4</td>
<td>10.7</td>
<td>7.5</td>
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<tr>
<td>Kieni West</td>
<td>39.1</td>
<td>36.0</td>
<td>37.9</td>
</tr>
<tr>
<td>Kipipiri</td>
<td>14.9</td>
<td>13.0</td>
<td>17.9</td>
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<td>Aberdare Forest/national Park</td>
<td>54.0</td>
<td>49.3</td>
<td>54.7</td>
</tr>
<tr>
<td>Municipality</td>
<td>10.3</td>
<td>10.8</td>
<td>8.6</td>
</tr>
<tr>
<td>Othaya</td>
<td>38.8</td>
<td>36.9</td>
<td>38.9</td>
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<tr>
<td>Kangema</td>
<td>38.5</td>
<td>37.5</td>
<td>39.0</td>
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</table>
Method 2: Update of reference classification map

- Procedure:
  - Create NDVI difference image
  - Calculate average NDVI difference and variance within each lclu class
  - Detection of ‘no change’ pixels for each class based on thresholding
  - Use the ‘no change’ pixels for training
  - Classification of complete image
Automatic procedure to update Iclus map

NDVI 2007 – NDVI 2000

No change:
> average – T*sdv AND < average + T*sdv

Histogram for Forest Class

<table>
<thead>
<tr>
<th>Summary Statistics</th>
<th>Mean</th>
<th>Actual min</th>
<th>Actual max</th>
<th>N</th>
<th>Std deviation</th>
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<tbody>
<tr>
<td>Class width</td>
<td>0.02</td>
<td>0.247</td>
<td>1</td>
<td>1128893</td>
<td>0.099</td>
</tr>
</tbody>
</table>

change | no change | change
Automatic procedure to update Iclu map

2007 classification result: Method 1

2007 update with automatic procedure: Method 2
Comparison of 2007 forest cover maps

**Method 1**

**Method 2**

Kappa index of Agreement = 0.9088
Sub-pixel classification of forest

**HR data:**
- Time consuming
- Small areas
- Limited to specific years
- Accurate location of forest

**LR imagery:**
- Automatisation
- Large areas
- Each year
- Percentage of forest cover in a LR pixel
Sub-pixel classification

HR: Yes/No

LR: % in 1x1km pixel
- Neural Network: trained to extrapolate results in time (other years) and space (other areas)
Sub-pixel classification of forest

- Year specific: good results
- Extrapolation to other years
  - Under investigation
  - Large influence of other land-cover classes
  - Large influence of rainfall variability
Landsat false color composite of Marsabit Mountain

01.05.1986

21.02.2000
<table>
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<th></th>
<th>1986</th>
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<td>Water</td>
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<tr>
<td>Farmland</td>
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<tr>
<td>Other</td>
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<td>113360</td>
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Rangelands
Indicators for grazing management

- Differentiation between managed rangelands (NRT conservancies, reserves) and surrounding areas
- Based on 12 monthly SPOT-VEGETATION NDVI values for one year
- Method: Linear Discriminant analysis (LDA)
- LDA tested for 3 years: 1999-2000 (normal year), 2002-2003 (wet year), and 2005-2006 (dry year)
Landcover according to AFRICOVER
Indicators for grazing management

- High variation in climate and vegetation cover within the studied area influence on NDVI
- Stratification according to climate and vegetation zones
- LDA performed for regions with same climate characteristics and vegetation cover
### Vegetation and climate zones

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<tr>
<th>Vegetation type</th>
<th>Description</th>
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<tbody>
<tr>
<td>9</td>
<td>Open woody + shrubs</td>
</tr>
<tr>
<td>16</td>
<td>Open shrubs + herbaceous</td>
</tr>
<tr>
<td>17</td>
<td>Very open shrubs + herbaceous + sparse trees</td>
</tr>
<tr>
<td>18</td>
<td>Very open shrubs + herbaceous</td>
</tr>
<tr>
<td>21</td>
<td>Herbaceous + shrubs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Climatic zone</th>
<th>Moisture availability ((r/E_0)) / temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>25-40 Semi-arid / 22-24</td>
</tr>
<tr>
<td>54</td>
<td>25-40 Semi-arid / 18-20</td>
</tr>
<tr>
<td>61</td>
<td>15-25 Arid / 24-30</td>
</tr>
<tr>
<td>62</td>
<td>15-25 Arid / 22-24</td>
</tr>
<tr>
<td>71</td>
<td>&lt;15 Very arid / 24-30</td>
</tr>
</tbody>
</table>
Correctly classified pixels for herbaceous + shrubs

<table>
<thead>
<tr>
<th>Zone</th>
<th>conservancy</th>
<th>reserve</th>
<th>other</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>normal</td>
<td>wet</td>
<td>dry</td>
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<tr>
<td>Zone 71</td>
<td>-</td>
<td>91.3</td>
<td>68.52</td>
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<tr>
<td>Zone 62</td>
<td>60</td>
<td>75</td>
<td>84.97</td>
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<tr>
<td>Zone 61</td>
<td>97.01</td>
<td>94.12</td>
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<tr>
<td>Zone 54</td>
<td>-</td>
<td>-</td>
<td>100</td>
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</tbody>
</table>
Percentage of correctly classified pixels for each conservancy/ reserve based on NDVI data for 2005-2006
Which monthly NDVI values contribute most to separation?

- First results:
  - NDVI values of April - May and October - November contribute most to separation
  - NDVI values after period of drought

- Further analysis is ongoing
Mission to Nairobi
26-30 May 2008

Else Swinnen, Toon Westra
Objectives

- Meet with number of participants of workshop July 2007
  - Feedback on ENDELEO activities
  - Detailed insight of their activities + where and how we can contribute
  - Datasets for validation

- Meet with other organisations working in the same field
Organisations

- Agricultural Research Foundation, AGREF, Dr. Sam Chema
- Regional Centre for Mapping of Resources for Development, RCMRD, Dr. Tesfaye Korme
- International Livestock Research Institute, ILRI, An Notenbaert
- Department of Resource Surveys and Remote Sensing, DRSRS, Patrick Wargute & Frank Msafiri
- Kenya Forest Working Group, KFWG, Michael Gachanja
- Northern Rangeland Trust, NRT, Juliet King
- Mpala Research Station, Dr. Margaret Kinnaird
General conclusions

- Positive response
- People are interested, but results do not cover their area of interest.
- Relevant topics were identified at workshop of July 2007
- Data distribution: too general
- More direct communication, in addition to general e-mails and newsletters
- Make data distribution user-specific
- Work on clearly defined case studies that are of immediate interest of a number of users
Themes

- Forest cover: extent, trends, classification
- Rangeland monitoring ~ livestock numbers
- Carbon sequestration
- Detection of hot spots of change (degradation) in water catchments
- Estimation of soil moisture
For each theme:

- Data needs
- Background
- Who?
- Data sets available
- Contribution of ENDELEO
Forest cover

- Extent, trends and classification
- Understand past changes
- Conservation of water towers
- Carbon sequestration

- AGREF, KFWG, DRSRS, UNEP, etc.
Forest cover: specific interest

- **AGREF:**
  - Mount Kulal
  - Huri Hills
  - Mount Marsabit

- **KFWG:**
  - Ol Bollosat
  - Bahati
  - Menengai
  - Kirisia forest
  - Coastal forests (tbd)

- **DRSRS:**
  - Mount Kenya (next year)
Contribution of ENDELEO

- HR forest mapping for specified areas
- Methodology to automate classification procedure
- LR sub-pixel classification on VGT and MODIS for additional trend analysis
Rangeland monitoring

- Relation between biomass and livestock
- Estimation of biomass for grazing management
- Effect of land use/cover change on shifts in wildlife numbers and species
- NRT, Mpala Research Station, DRSRS, AGREF
Data sets available

- **DRSRS:**
  - Livestock numbers from aerial surveys for various districts
  - Can perform additional surveys on demand

- **Mpala Research Station:**
  - Livestock numbers
  - Wildlife numbers
  - Settlements
  - Grass cover
  - Forest cover

- **NRT:**
  - Vegetation transects in conservancies
  - Delineation of conservancies
Contribution of ENDELEO

- Analyse difference in biomass w.r.t. grazing management, rainfall, vegetation type
- Derive parameters on rangeland quality - > tbd with NRT and Mpala Research Station
- Link vegetation transects data with HR & LR imagery
Carbon sequestration

- Conservation
- REDD: Reduced Emissions from Deforestation in Developing Countries
  - World Bank
- AGREF
  - Extensive field survey -> validation
  - PhD starting + several masters
- Contribution of ENDELEO
  - NPP/NEP estimates from LR remote sensing
Detection of hot spots of change

- **Hydropower**
  - Masinga Dam: ~50% of Kenya electricity output
    - Siltation
    - Interest from World Bank
  - Sondu river
    - Deforestation in upper catchment

- **Tourism**
  - Mara
    - Deforestation in upper catchment
Contribution of ENDELEO

- Analyse anomaly time series
  - VGT, MODIS
  - NDVI, fCover, LAI
  - Decreased trend in VI
  - Abrupt decrease in VI
  - Possible validation with HR imagery

- Analysis of sediment plumes in Masinga dam after rainfall events
  - Method from Sterckx et al. (VITO)
  - Identify which river contributes most
Soil moisture

- Analysis of historical data + actual yields (interviews)
- Identification of suitable crops for various regions
- AGREF: area around Mount Marsabit
- Contribution of ENDELEO:
  - Apply methodology to estimate soil moisture from MODIS and provide soil moisture maps