The use of GIS and remote sensing for environment statistics

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Outline

• Introduction
• Concepts
  – Environment statistics
  – Remote sensing
  – GIS
• Examples of using RS and GIS
• Conclusion
Climate change should be added...
Ongoing dialogue between data demand and data supply...
“Environment statistics are statistics that describe the state and trends of the environment, the media of the environment, the biota within the media, and human settlements.”

Environment Statistics bring together:
- Human activities
- Natural events
- Impacts of activities and events on environment
- Social responses to impacts
- Quality and availability of natural assets
Environment statistics (2)
Scope of Environment Stats

Perception of major users and producers

Socioeconomic and environmental policies

Specific to particular conditions

Courtesy: Dozie Ezigbalike (UNECA)
The challenge of producing environment statistics

- Access
- Environment
- Conditions
- Human
- Settlements
- and
- Environmental
- Health
- Extreme
- Events
- and
- Disasters
- Residuals
- Resources
- and
- Their
- Use
- Environment
- Protection,
- Management
- and
- Engagement

Figure 1. The FDES components
The Framework for the Development of Environment Statistics (FDES) 2013, including the Core Set of Environment Statistics, as well as an Action Plan for putting the FDES to work, were endorsed by the 44th session of the Statistical Commission (New York, 26 February–1 March 2013)*

Environment statistics for policymaking

The demand for environment statistics is increasing in step with the continued environmental challenges faced by modern society. The recognition that human well-being depends on the environment has led to an increasing emphasis on environmental and sustainability concerns on which decisions and actions need to be taken. Paramount to these actions is the regular production of environment statistics of the highest possible quality to support evidence-based policymaking by enabling the identification of environmental policy issues and allowing their objective quantification.

Environment statistics portray key information about the state of the environment and its most relevant changes through space and time. They strengthen assessments through quantitative techniques, making analyses more robust, timely and progressively harmonized at the international level. Environment statistics are necessary for producing environmental assessments, state of the environment reports, environmental compendia, environmental indicators, indicators of sustainable development, as well as to facilitate environmental-economic accounting.

The member States of the United Nations have addressed this challenging area during the Rio+20 Conference in June 2012. The outcome document, “The Future We Want” contains various references that are relevant to the work of the United Nations Statistics Division (UNSD) in this regard. This document frequently mentions the importance of data, in particular, environmental data, as well as information and indicators. The Framework for the Development of Environment Statistics (FDES 2013), including the Core Set of Environment Statistics, provides an appropriate means for addressing these information needs as they relate to the environmental dimension of sustainable development. The FDES has been recognized by the 44th session of the Statistical Commission as a useful tool to adequately respond to the increasing demand for information in the follow-up to Rio+20 and the post-2015 development agenda (including Sustainable Development Goals).

The challenge of producing environment statistics

Environment statistics cover a wide range of information and are interdisciplinary in nature. Their sources are dispersed over a variety of data producers, and similarly numerous methods are applied in their compilation. To effectively produce environment statistics, specific statistical and environmental expertise, scientific knowledge, institutional development capabilities, and adequate resources are equally necessary. Many countries still require substantial technical assistance and capacity building. Environment statistics therefore require a proper framework to guide their development, coordination and organization at all levels.

* The United Nations Statistical Commission is the apex entity of the global statistical system bringing together the Chief Statisticians from member states from around the world. It is the highest decision making body for international statistical activities especially the setting of statistical standards, the development of concepts and methods and their implementation at the national and international level.
Remote sensing: definition

- Remote sensing is the collection of information about an object without being in direct physical contact with the object.

- Remote Sensing is a technology for sampling electromagnetic radiation to acquire and interpret non-immediate geospatial data from which to extract information about features, objects, and classes on the Earth's land surface, oceans, and atmosphere.

  - Dr. Nicholas Short
Elements involved in Remote sensing

1. Energy Source or Illumination (A)
2. Radiation and the Atmosphere (B)
3. Interaction with the Object (C)
4. Recording of Energy by the Sensor (D)
5. Transmission, Reception and Processing (E)
6. Interpretation and Analysis (F)
7. Application (G)

Courtesy: Dozie Ezigbalike (UNECA)
Satellites can detect a wide range of reflected or emitted frequencies of electromagnetic radiation.

Chaque objet au sol est caractérisé par une signature spectrale (réponse spectrale dans différentes parties du rayonnement électromagnétique).

Schéma représentant les principes de la télédétectio passive et active.
Sources de données

- Imagerie satellitaire
  - Météosat, MODIS
  - NOAA
  - LANDSAT
  - SPOT
  - Corona
  - QuickBird…

Niveau de collecte

- Prises de vue aériennes
  - Photographie aérienne
  - Vols systématiques de reconnaissance
  - Vidéographie aéroportée

- Études de terrain
  - Inventaires
  - Mesures GPS
  - Enquêtes
<table>
<thead>
<tr>
<th>Sensor</th>
<th>Resolution</th>
<th>Coverage</th>
<th>Cost</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat-7 ETM+</td>
<td>15m, 30m, 30m</td>
<td>1999-2003</td>
<td>free</td>
<td></td>
</tr>
<tr>
<td>IRS RESOURCESAT</td>
<td>23.5m, 23.5m, 23.5m</td>
<td>2003-present</td>
<td>$2500</td>
<td></td>
</tr>
<tr>
<td>IRS 1C/1D</td>
<td>5m</td>
<td>1998-present</td>
<td>$2500</td>
<td></td>
</tr>
<tr>
<td>IKONOS</td>
<td>1m, 4m, 4m</td>
<td>2003-present</td>
<td>approx. $377</td>
<td></td>
</tr>
<tr>
<td>OrbView-3</td>
<td>1m</td>
<td>2003-present</td>
<td>approx. $1800</td>
<td></td>
</tr>
<tr>
<td>Quickbird</td>
<td>.67m, 2.44m</td>
<td>2001-present</td>
<td>$600</td>
<td></td>
</tr>
<tr>
<td>Airborne DMSV</td>
<td>0.3m, 2m</td>
<td>1999-present</td>
<td>$20-25k</td>
<td></td>
</tr>
<tr>
<td>RADARSAT</td>
<td>8m (Fine Beam)</td>
<td>1995-present</td>
<td>$3750</td>
<td></td>
</tr>
</tbody>
</table>

1 Based on 2004 prices from various online vendors.
Benefits from remote sensing data

- Very useful where areas are inaccessible or where the cost of collecting spatial data over extensive areas is prohibitive.
- Provide good “pictures” for convincing the public of the value of participating in environmental assessment.
- Provide data over large areas that have standard format.
- Are available on a repetitive basis and has been used to provide data for areas over a long time basis.
- May be used to monitor the progress of environmental projects.
- Faster extraction of GIS-ready data.

Disadvantages

- Needs ground verification.
- Doesn’t offer details.
- Not the best tool for small areas.
- Needs expert system to extract data.
Application of Remote sensing

- **Urbanization & Transportation**
  - Updating road maps
  - Asphalt conditions
  - Wetland delineation

- **Agriculture**
  - Crop health analysis
  - Precision agriculture
  - Compliance mapping
  - Yield estimation

*Courtesy: Bodruddoza Mia*
Application of Remote sensing (2)

Aerosol measurements from space

<table>
<thead>
<tr>
<th>Year</th>
<th>TOMS/</th>
<th>MISR/</th>
<th>MODIS/</th>
<th>CALIOP/</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>Nimbus 7 (78-93)</td>
<td>Terra</td>
<td>Terra, Aqua</td>
<td>CALIOP/ CALIPSO</td>
</tr>
<tr>
<td></td>
<td>Meteor-3 (91-94)</td>
<td></td>
<td></td>
<td>Extinction profiles</td>
</tr>
<tr>
<td></td>
<td>ADEOS (96)</td>
<td></td>
<td></td>
<td>Global coverage 16+ days</td>
</tr>
<tr>
<td></td>
<td>EP (96-05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991-95</td>
<td></td>
<td></td>
<td></td>
<td>Solar backscatter instruments that retrieve an aerosol product:</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td></td>
<td></td>
<td>SCIAMACHY/ Envisat (2002-)</td>
</tr>
<tr>
<td>1999-2002</td>
<td></td>
<td></td>
<td></td>
<td>OMI/ AURA (2005-)</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>AOD+</td>
<td></td>
<td>GOME-2/ Metop-A (2007-)</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td></td>
<td>AOD+</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Aerosol Index
- Global coverage ~daily

AVHRR/
- TIROS NOAA (78-)
- Metop-A (2006-)
- AOD ocean
- Global coverage ~daily

POLDER/
- ADEOS-1, ADEOS-2, PARASOL
- AOD+ Global coverage ~daily

(A)ATSR/
- ERS-1, ERS-2, Envisat
- AOD+ Global coverage ~daily

Figure 15 - Aerosol measurements from space

Courtesy: Bodruddoza Mia
Le traitement des données journalières de l’imagerie MODIS a permis de faire des synthèses mensuelles et annuelles des statistiques concernant les feux de brousse. Ces synthèses sont utilisées pour une meilleure compréhension des évolutions temporelle et spatiale du phénomène des feux de brousse.
Image Processing

• **Image Pre-Processing**
  - Image Restoration
  - Sensor Calibrations
  - Atmospheric Corrections
  - Solar Illumination Corrections
  - Topographic Corrections
  - Geometric Corrections

• **Image processing**
  - Spatial enhancement
  - Spectral enhancement
  - Classification
  - Feature Extraction

*Courtesy: Bodruddoza Mia*
Image Processing Software

- ERDAS Imagine
- ENVI
- ILWIS
- ArcGIS
- PCI Geomatica

*Courtesy: Bodruddoza Mia*
Monitoring vegetation degradation in Mau Forest on the Mau escarpment, Kenya. – 1986 (top), 2001 bottom

Threat to the further deterioration through logging in the forest in 2001 was exposed by using remotely sensed images.

Vegetation cover of Mau Forest, 1986 (above)
Vegetation cover of Mau Forest 2000 (below)
GI S

✓ GIS for Data combination

GIS (Geographic Information System) is used to input, store, retrieve, manipulate, analyze and output geospatial data, helping for planning, natural resource, urban facilities...

✓ GIS for Visual Presentation
Basic Functions of GIS

• Data Acquisition and prepossessing

• Database Management and Retrieval

• Spatial Measurement and Analysis

• Graphic output and Visualization

Courtesy: Bodruddoza Mia
Benefits of GIS

• Geospatial data are better maintained in a standard format.

• Revision and updating are easier.

• Geospatial data and information are easier to search, analysis and represent.

• More value added product.

• Geospatial data can be shared and exchanged freely.

• Productivity of the staff improved and more efficient.

• Time and money are saved.

• Better decision can be made.

Courtesy: Bodruddoza Mia
GIS Use

Locations - What is at…?

Objects - Where is…?

Patterns - Which things are related…?

Models - What if…?

Trends - What has changed since…?

Courtesy: Bodruddoza Mia
The basic elements of a GIS

- A GIS is a 5-part system:
  - People
  - Data
  - Hardware
  - Software
  - Procedures

Six Functions of a GIS:
- Capture data
- Store data
- Query data
- Analyze data
- Display data
- Produce output

Courtesy: Bodruddoza Mia
<table>
<thead>
<tr>
<th>Area</th>
<th>GIS Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities Management</td>
<td>Locating underground pipes &amp; cables, planning facility maintenance, telecommunication network services</td>
</tr>
<tr>
<td>Environmental and Natural Resources Management</td>
<td>Environmental impact analysis, disaster management and mitigation</td>
</tr>
<tr>
<td>Street Network</td>
<td>Locating houses and streets, car navigation, transportation planning</td>
</tr>
<tr>
<td>Planning and Engineering</td>
<td>Urban planning, regional planning, development of public facilities</td>
</tr>
<tr>
<td>Land Information</td>
<td>Taxation, zoning of land use, land acquisition</td>
</tr>
</tbody>
</table>
GIS can be found in most any field

... but generally can be grouped into four basic categories:

- **NATURAL RESOURCE MANAGEMENT**
  - Forest & Wildlife
  - Hydrological
  - Minerals

- **URBAN & REGIONAL MANAGEMENT**
  - Land Use Planning/Environmental Impact
  - Public Works
  - Emergency Response
  - Legal Records

*Courtesy: Bodruddoza Mia*
Application of GIS (3)

- COMMERCIAL
  - Market Area Analysis
  - Site Selection
  - Routing

- AGRICULTURAL MANAGEMENT
  - Field Records
  - Animal Management
  - Climate Change / Human Impact

Courtesy: Bodruddoza Mia
GIS Geographical Information System

Well-considered combination of mutually referring **data sets** of various kinds of **position-bound thematic data** (database), software inclusive

**Requirement:**
the information layers match geometrically

===> OVERLAY STRUCTURE

GIS file:

1. topography
2. soils
3. geology
4. precipitation
5. land cover
6. vegetation
7. remote sensing data
8. surface temperature
9. hydrology
10. population
11. nature conservation
12. environment
13. digital terrain model
14. topographical map
15. --------------
16. --------------
17. --------------

field data (point measurements)
vector data
raster data
Food Security Modeling using Landcover

Total Potential Food Supply

Water Vulnerability

GeoCover LC Integrated into each model

Capacity

(food + water vulnerability) x (capacity)

Africa Geospatial I&W: Regions at Risk Population (Food-Water) Risk Surface

Very High (Stress)

Very Low (Stress)
Appui au suivi de la campagne agricole

Dates des premiers semis

Comparaison entre les dates des premiers semis en 2002 et en 2001

Urbanisation of Cap Vert Peninsula: Dakar, Senegal

Labour force: West African cities. Dakar, Senegal’s capital city, has grown dramatically over the past several decades. Growth in population has continued. While life expectancy has begun to decline, overall growth will continue to exceed the growth in population. In addition, Dakar experienced a large increase in urban population beginning in the 1960s. This increase followed declines in agricultural production in the region. By 2000, more than 60% of the city’s population was employed in the urban sector.

VCI (Vegetation Condition Index) en mi-Août 2004

Standardized Precipitation Index SPI en juin 2007
Changes of the agrocultural sector evolution from 1900 to 2000.

Fig. 2. Evolution of the “Peanut Basin” in Senegal—co-evolution of the railroad network (update of Porteres report, 1952).
<table>
<thead>
<tr>
<th>Classe</th>
<th>Superficie (ha)</th>
<th>Evolution des superficies</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savane boisée</td>
<td>6275,02</td>
<td>4162,57</td>
<td>397,36</td>
</tr>
<tr>
<td>Savane arborée</td>
<td>44300,65</td>
<td>11606,49</td>
<td>13092,73</td>
</tr>
<tr>
<td>Savane arbustive à arborée</td>
<td>95550,42</td>
<td>85888,83</td>
<td>28762,20</td>
</tr>
<tr>
<td>Savane arbustive</td>
<td>8686,51</td>
<td>11061,41</td>
<td>24227,33</td>
</tr>
<tr>
<td>Steppe arbustive à arborée</td>
<td>19781,01</td>
<td>28296,15</td>
<td>63991,98</td>
</tr>
<tr>
<td>Steppe arbustive</td>
<td>10293,18</td>
<td>14583,71</td>
<td>19184,04</td>
</tr>
<tr>
<td>Culture/Jachère</td>
<td>15380,78</td>
<td>44676,35</td>
<td>50466,79</td>
</tr>
<tr>
<td>Mare</td>
<td>613,18</td>
<td>579,81</td>
<td>541,37</td>
</tr>
<tr>
<td>Cuirasse</td>
<td>242,55</td>
<td>554,33</td>
<td>561,92</td>
</tr>
<tr>
<td>Sol nu</td>
<td>1146,63</td>
<td>834,25</td>
<td>1006,77</td>
</tr>
<tr>
<td>Habitat</td>
<td>127,13</td>
<td>153,15</td>
<td>164,56</td>
</tr>
</tbody>
</table>
Un outil spatial adapté à la surveillance de la (FVR) -1

Suivi spatio-temporel des mares, donc des gîtes larvaires

Composition colorée

indice NDPI

Mare

<table>
<thead>
<tr>
<th>Date</th>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>26/08/2003</td>
<td>26.7 ha (100%)</td>
</tr>
<tr>
<td>17/10/2003</td>
<td>8.9 ha (33%)</td>
</tr>
<tr>
<td>27/10/2003</td>
<td>6.6 ha (25%)</td>
</tr>
<tr>
<td>18/11/2003</td>
<td>3.8 ha (14%)</td>
</tr>
<tr>
<td>19/01/2004</td>
<td>0.3 ha (1%)</td>
</tr>
</tbody>
</table>
The right data to tackle the issue at the correct scale!

Breeding sites
Correct pond cartography
100 ha (1 pixel) water bodies identified

Pond detection in Ferlo area (Senegal) using NPD
Conclusion

- Remote sensing can be useful for applications regarding environment statistics.
- Remote sensing allows the collection of detailed data about bio-physical characteristics that cannot be collected by questionnaires.

Courtesy: Dozie Ezigbalike (UNECA)
GIS allows the data, even questionnaire data, to be visualized graphically.

GIS also provides for interpolation of values from spatial samples, and complex combination of data based on their location.

Strong need of capacity building regarding remote sensing data process, and GIS tools and softs.

Dozie Ezighalike (UNECA)
Aknowledgements

United Nations Nations Unies

OFFICE OF THE DIRECTOR
STATISTICS DIVISION (UNSD)

CSE

Centre de Suivi Ecologique

Questions ?

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