Introduction to Remote Sensing for Decision Making

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Outline

➢ Information-based decision making

➢ Introductory remote sensing

➢ Remote sensing for decision making
  - Tools
  - Strategies
Ocean and coastal issues/challenges

- Resource depletion (e.g., overfishing, IUU)
- Climate change
- Erosion
- Pollution – coastal & offshore
- Vessel monitoring
- Piracy & maritime security
- Construction & coastal development

- Offshore drilling, Nigeria
- Oil spill
- Algal bloom
- West Africa maritime security activities
- Thermal pollution
Environmental decision making:

- selection of a course of action among several possible alternative options to yield a satisfactory or optimal solution

- decisions geared towards mitigating current problems and securing the blue planet for future generations.

- the A³ guide:
  - Awareness: What, Why, How
  - Assessment: Goals, Alternatives
  - Action: Decision, Implement
Approaches to decision making

1. Consider the situation as a whole.
2. Set objectives: identify the decision(s) that need(s) to be made
3. Classify objectives and place them in order of importance
4. **Collect data on the range of alternatives.**
5. Develop criteria for assessment of the alternatives.
6. Assess the alternatives against all the objectives.
7. Choose one alternative.
8. Monitor the outcome of the decision.
Environmental decisions historically relied too heavily on educated guesses but not hard facts.

This allows critics to dismiss the severity of environmental pollution and needs for resource management.

Objective, verifiable information allows for robust, unambiguous, and transparent environmental decision making.

Identify gaps and assess priority areas.

Better assess environmental change and performance for improved policy choices.

Information-based decision making improves environmental management processes.
Sources of ocean and coastal data/information

**In-situ data:**

- Images of researchers collecting data in the ocean.

**Modeling outputs:**

- Diagrams and models illustrating ocean and coastal temperature changes.

**Satellite data:**

- Images of satellite configurations and satellite observation systems.
Gathering ocean and coastal information is

time-consuming

often difficult

often expensive
Characteristics of good data

1. Accuracy
2. Integrity
3. Consistency
4. Completeness
5. Validity
6. Timeliness
7. Accessibility
Sources of ocean and coastal data/information

**In-situ data:**

**Modeling outputs:**

**Satellite data:**
Remote Sensing - basic physics and principles
**What is remote sensing:**
the art, science and technology of
- acquiring,
- processing, and
- interpreting
images and related data that are obtained from **ground-based, air-or space-borne instruments** that record the interaction between matter (target) and electromagnetic radiation.

Energy patterns derived from **noncontact sensor systems**

Remote Sensing: using electromagnetic spectrum to image the **land, ocean, and atmosphere.**
Remote Sensing: Primary components

- Energy- radiation
- Sensor
- Object

A. Energy Source
B. Radiation and Atmosphere
C. Interaction with target
D. Energy recorded by sensor
E. Transmission, reception, processing
F. Interpretation and analysis
G. Application of information
Importance of remote sensing

- Observes the distribution of certain surface properties in exquisite **spatial detail**: allows the true spatial structure to be examine

- Captures a “**snapshot**” of the spatial distribution. “Freezes” the continually changing environment

- Offers a **repeated view**: consistent measurements by a single sensor

- Observes part of the earth other methods miss
  - Shipping routes are concentrated in certain zones
  - Ships tend to avoid poor weather hazardous regions
  - Drifting buoys tend to avoid regions of divergent currents
Limitations of remote sensing

- Can observe only some of the earth’s properties and variables
- Measures only at or near the surface
  -- Although the surface is the most critical place to measure
- Measurements may be corrupted by the atmosphere
- Some satellites/methods cannot see through clouds at all
- Can make measurements only when the satellite is in the right place at the right time
- All measurements require calibration and validation using in situ data
Sources of energy for remote sensing

- The Sun
  - Visible waveband
  - Near Infra red waveband

- Thermal emission by the earth surface
  - Thermal infra red
  - Microwaves

- Energy source on the satellite
  - Microwaves (Radar)
  - Visible (Lidar)
The Sun produces a *continuous spectrum* of energy that continually bathe the Earth in energy.

The visible portion of the spectrum may be measured using wavelength (micrometers or nanometers) or electron volts (eV).

Electromagnetic radiation behaves in most circumstances as waves and can thus be characterized as waves.
Remote Sensor Resolution Considerations

- **Spatial** - the size of the field-of-view. e.g., $10 \times 10$ m.

- **Spectral** - the *number* and *size* of spectral regions (or frequencies) the sensor records data in, e.g., blue, green, red, near-infrared, thermal infrared.

- **Temporal** - how often the sensor acquires data. e.g., every 30 days.

- **Radiometric** - sensitivity of detectors to small difference in electromagnetic energy.
Imagery of Harbor Town in Hilton Head, SC, at Various Nominal Spatial Resolutions

a. 0.5 x 0.5 m.
b. 1 x 1 m.
c. 2.5 x 2.5 m.
d. 5 x 5 m.
e. 10 x 10 m.
f. 20 x 20 m.
g. 40 x 40 m.
h. 80 x 80 m.

Spatial Resolution

Variations of IFOV (spatial resolution) with view angle

Nadir IFOV

Oblique IFOV

Nominal Spatial Resolution (enlarged view)
Typical spectral signatures of specific land cover types in the VIS and IR region of the electromagnetic spectrum.
**Active and passive sensors**

**Active sensors** (microwave) create their own radiation with which to illuminate the target, and then observe the nature of the reflected signal.

**Passive** (sun, IR and visible wavelength) sensors which rely on naturally occurring radiation.

<table>
<thead>
<tr>
<th>Passive sensors</th>
<th>Wavelength</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible wavelength radiometers</td>
<td>400 nm - 1 µm</td>
<td>Solar radiation reflected by Earth surface</td>
</tr>
<tr>
<td>Infrared (IR) radiometers</td>
<td>about 10 µm</td>
<td>Thermal emission of the Earth</td>
</tr>
<tr>
<td>Microwave radiometers</td>
<td>1.5 - 300 mm</td>
<td>Thermal emission of the Earth in the microwave</td>
</tr>
</tbody>
</table>

**Active devices**

<table>
<thead>
<tr>
<th>Active devices</th>
<th>Wavelength</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altimeters</td>
<td>3 - 30 GHz</td>
<td>Earth surface topography</td>
</tr>
<tr>
<td>Scatterometers</td>
<td>3 - 30 GHz</td>
<td>Sea surface roughness</td>
</tr>
<tr>
<td>Synthetic aperture radars</td>
<td>3 - 30 GHz</td>
<td>Sea surface roughness and movement</td>
</tr>
</tbody>
</table>
A summary of sensor types & what they measure
The benefits of Earth Observations

Provide the right information,
in the right format,
at the right time,
to the right people,
to make the right decisions.
Remote sensing for decision making

- Less expensive
- Safety, piracy
- Remote sensing and GIS methods will be used to develop indicators of environmental change

Costs and delivery times

<table>
<thead>
<tr>
<th>Operation</th>
<th>Costs (US$/km²)</th>
<th>Time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase of satellite images</td>
<td>0.55</td>
<td>1</td>
</tr>
<tr>
<td>Image processing and interpretation</td>
<td>0.16</td>
<td>6</td>
</tr>
<tr>
<td>Field survey</td>
<td>0.09</td>
<td>0.5</td>
</tr>
<tr>
<td>Fuzzy relational calculus</td>
<td>0.08</td>
<td>4</td>
</tr>
<tr>
<td>Database construction-GIS</td>
<td>0.03</td>
<td>5</td>
</tr>
<tr>
<td>Map production</td>
<td>0.02</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>1.3</td>
<td>17.5</td>
</tr>
</tbody>
</table>
## Remote sensing for decision making

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Instrument</th>
<th>Spectral bands (μm)</th>
<th>Spatial resolution</th>
<th>Temporal resolution</th>
<th>Cost$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat 7</td>
<td>ETM+</td>
<td>3 Visible, 1 NIR, 2 SWIR, 1 TIR, 1 Panchromatic (B&amp;W)</td>
<td>30 m</td>
<td>16 days</td>
<td>$600 per scene</td>
</tr>
<tr>
<td>NOAA-K, L, M</td>
<td>AVHRR</td>
<td>1 Visible, 1 NIR, 1 SWIR, 1 MWIR, 2 TIR</td>
<td>All at 1.1 km</td>
<td>Daily</td>
<td>Free</td>
</tr>
<tr>
<td>Terra, Aqua</td>
<td>MODIS</td>
<td>1 Visible and 1 NIR, 5 Visible, NIR, SWIR, 29 Visible, NIR, SWIR, MWIR, TIR</td>
<td>250 m</td>
<td>1–2 days</td>
<td>Free</td>
</tr>
<tr>
<td>Terra</td>
<td>ASTER</td>
<td>2 Visible, 1 NIR, 6 SWIR, 5 TIR</td>
<td>15 m</td>
<td>16 days</td>
<td>Free</td>
</tr>
<tr>
<td>IKONOS</td>
<td>IKONOS</td>
<td>1 Panchromatic (B&amp;W), 3 Visible, 1 NIR</td>
<td>1 m</td>
<td>3 days</td>
<td>$10.50/km² for archived data (geo)</td>
</tr>
<tr>
<td>QuickBird</td>
<td>QuickBird</td>
<td>1 Panchromatic (B&amp;W), 3 Visible, 1 NIR</td>
<td>0.61 m</td>
<td>2–6 days</td>
<td>$18/km² for archived data (standard)</td>
</tr>
<tr>
<td>GOES</td>
<td>GOES Imager</td>
<td>1 Visible, 1 MWIR, 1 Thermal</td>
<td>1 km</td>
<td>30 min</td>
<td>Free</td>
</tr>
<tr>
<td>SeaStar</td>
<td>SeaWIFS</td>
<td>6 Visible, 2 NIR</td>
<td>All at 1.1 km</td>
<td>Daily</td>
<td>Free to NASA researchers</td>
</tr>
</tbody>
</table>

Satellites launched by NASA and other US organizations only are shown here. Visible = 0.4–0.7 μm, NIR = 0.7–1.3 μm, SWIR = 1.3–5 μm, MIR = 3–5 μm, LWIR (thermal) = 5–14 μm. Abbreviations: ASTER, Advanced Spaceborne Thermal Emission and Reflection Radiometer; AVHRR, Advanced Very High Resolution Radiometer; ETM+, Enhanced Thematic Mapper+; GOES, Geostationary Operational Environmental Satellite; MODIS, MODerate resolution Imaging Spectroradiometer; SeaWIFS, Sea-viewing Wide Field-of-view Sensor.
...enhance delivery of benefits to society in the following initial areas

- **Disasters**
  Reducing loss of life and property from natural and human induced disasters.

- **Energy**
  Improving management of energy resources.

- **Weather**
  Improving weather information, forecasting and warning.

- **Climate**
  Understanding, predicting, mitigating and adapting to climate variability and change.

- **Water**
  Improving water resource management through better understanding of the water cycle.

- **Health**
  Understanding environmental factors affecting human health and well being.

- **Biodiversity**
  Understanding, monitoring and conserving biodiversity.

- **Agriculture**
  Supporting sustainable agriculture and combating desertification.

- **Ecosystems**
  Improving the management and protection of terrestrial, coastal and marine ecosystems.
Challenges in creating such a system

• **Data policy** - assuring full and open data exchange and access

• **Observing scope** - achieving the needed spatial, temporal and spectral coverage

• **Data quality** - producing calibrated data sets in useful formats from multiple sensors and venues

• **Cost** - acquiring sufficient resources to deploy observing systems and manage the resulting data and information

• **Security** - assuring safe operations and peaceful uses of observing systems

• **Complexity** - creating a system equal to the task of delivering useful information about the very complex Earth system
Turning observations into knowledge products

- **Petabytes 10^15**
  - Multi-platform, multiparameter, high spatial and temporal resolution, remote & in-situ sensing

- **Terabytes 10^12**
  - Calibration, Transformation To Characterized Geo-physical Parameters

- **Gigabytes 10^9**
  - Interaction Between Modeling/Forecasting and Observation Systems

- **Megabytes 10^6**
  - Interactive Dissemination and Predictions

Advanced Sensors → Data Processing & Analysis → Information Synthesis → Access to Knowledge
Data Sources
Data Sources
Thank You

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