Satellite Data for Risk and Security: Tools and Approaches

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\[
\frac{\partial}{\partial x_i} (T_{ij} \frac{\partial h}{\partial x_j}) = S \frac{\partial h}{\partial t} + W
\]

\[
J = E + \varepsilon^i \sum_{i,j} w_{ij}^{m-m-1}
\]

\[
f(x) = \frac{1}{1 + e^{-rx}}
\]

\[
P(i|p) = \frac{p^{(i)}(p)p^{(i)}}{\sum_i p^{(i)}(p)p^{(i)}}
\]
Approach to Utilization of EO Tools for Risk Analysis

Multi-model optimization and planning for setting of adaptive risk analysis

- Observations & measurements
  - Data
    - Data extraction & analysis
      - Methods & algorithms
        - Risk assessment
          - Model-based Decision making
  - Response of system to extremely events
    - Vegetation models
    - Water balance & streams models
      - Soils models
      - Climate models
      - Signal models
    - Criteria & indicators
Integrated Approach to Security Analysis

Energy Security
- Modeling/calculation of energy for fertilizer production, harvest transportation & processing;
- Calculation of energy for food, feed, irrigation;
- Monitoring & control of biomass for bio-fuel production
- Monitoring of needs of energy for water processing & pumping;
- Control of water needs for hydropower generation;
- Calculation of energy for bio-fuel processing

Water Security
- Control of water resources vulnerability vs. disasters;
- Monitoring of infrastructure reliability monitoring of water resources vulnerability and accessibility;
- Monitoring & control of water contamination;
- Control of GHG emission & nitrogen pollution

Socio-Economic Security
- Control of water use for food, feed and fiber crops;
- Control of water use for bio-fuel crops;
- Control of GHG emission & nitrogen pollution

Food Security
- Control of water use for food, feed and fiber crops;
- Control of water use for bio-fuel crops;
- Control of GHG emission & nitrogen pollution

Nested multi-model stochastic welfare maximization
- Modeling/calculation of energy for fertilizer production, harvest transportation & processing;
- Calculation of energy for food, feed, irrigation;
- Monitoring & control of biomass for bio-fuel production

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Disaster Analysis & Decision Making

Natural and technological disasters

Separate types of natural disasters

Direct losses of natural disasters

Losses per capita GDP

Losses per capita GDP and population

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Comparison of emissions data from different sources

Estimation of components of uncertainty of vegetation productivity detection using satellite data

Carbon dioxide concentration satellite detected dynamics

Methane concentration satellite detected dynamics

GHG Emissions Satellite Control & Analysis

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Field test-site network for satellite and models calibration

In-Fields Research: Spectrometry by FieldSpec®3 FR for Crop Monitoring, Landscape Control & EO Calibration (data available since 2010)

Legend Description:
1 - Test-sites for satellite observations;
2 - Hydrogeological research areas;
3 - Hydrochemical test-sites;
4 - Geophysical research areas;
5 - Geography research;
6 - Marine research;
7 - Ore studies;
8 - Multi-purposes test-sites
Case Study: Local Landscape Fire Risk Assessment

Landscape fire risk calculated on 100m cell for Prypyat river middle basin (Northern-West part of Ukraine). Data used: Landsat TM& ETM data.

July 15 – August 15, 2006: mean 0.38

July 15 – August 15, 2007, mean 0.26
Regional and Local Flooding Risk Assessment

Local flooding risk calculated on 200m cell for Pripyat river middle basin (Northern-West part of Ukraine) for period March – June 2011. Data used: Landsat TM & ETM, MODIS.

Risks assessed in terms of probability of negative consequences of flooding events for 1-year period. Value of risk ≥ 0.5 means that for certain exceeding of mean seasonal precipitation level (integrated exceeding of month norm more than to 50% i.e. from 95-100mm) or corresponding exceeding of mean runoff (from 0.2 m³/sec km² reflected in exceeding of river water level to 1 – 1.8m) on the corresponding site will be fixed undeflooding (water table rising up to 0.3 – 0.8m). So value of risk ≥ 0.5 is means annual floods with probability 0.86 in view of registered climate trends.
Inundation Risks for 2025 - 2035

Legend: Inundations Risk

- < 0.2
- 0.3
- 0.5
- >0.75

Flood Risks on 50km cell for 2025 - 2035

Legend: Flood Risk

- < 0.2
- 0.3
- 0.4
- 0.5
- 0.6
- >0.75

Hydrological & Hydrogeological Disasters

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Case Study: Management of catastrophic floods in Tisza river basin

- Flood risks – model based approach
- Assessment of flood protection measures against multiple floods (structural, land use, financial)
- Efficiency of structural flood mitigation measures – Socio-economic impacts = *Influence on policy evaluation*
- Losses and loss reduction associated with certain flood events (heavy rainfall, dam break)

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![Map of the Tisza river basin](image)

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**I. Hazard:**
- water levels per return period

**II. Exposure:**
- elevation map
- land use type

**III. Vulnerability:**
- damage curves for various hazard extents per land use type

**IV. Losses:**
- flood damage estimates

**V. Insurance premiums:**
- representation of different stakeholders’ goal functions
- their constraints
- location specific risks
- stochastic optimization solution (rather than average damage based premium)
Recent case study in the Netherlands (Risk Analysis Journal, 2016) on the analysis of alternative insurance mechanisms is also important for Ukraine as Ukraine develops alternative insurance mechanisms.

### Areas outside the main protections system

**Flood and damage characteristics**

| Government does not guarantee any safety standards. Actual return periods vary between 1:5, 1:10 years to 1:100, 1:1000 years or less frequent (e.g. 1:10000 for new harbor areas) |
| Probability of flood is location-specific and may be much higher than the official safety standard in the neighboring protected areas. |
| One homogeneous safety standard for the whole dike-ring. |
| Properties are elevated above sea level, i.e. on dunes, man-made high elevation grounds, etc. |
| Many developments inside dike rings are below sea level (up to -6 meters). |
| Flood water comes with low velocity and goes away quickly. |
| Flood water comes with high velocity and stays for a long period. |

### Flood protection and roles of different parties

| Developments are at the risk on individuals (households or firms). Municipalities may prohibit some socially-vital activities in these areas, e.g. hospitals. |
| Government is responsible to assure safety standards prescribed by law. |
| Individuals are responsible for their own protection and damage in the case of flooding. |
| Government refund any possible damage from a flood event. |
| Flood insurance does not exist but is argued to be financially feasible. |
| Flood insurance did not exist. First contracts to insure flood risks became available in 2013 (3). The issue is debatable since some consider it unfeasible (30), (32) while others think it is feasible under various reinsurance schemes (1). |

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**Losses, 10-yr. flood**

**Losses, 1000-yr. flood**

**Robust annual premiums**

**Premiums as percent of the 100-year flood damages**
Water quality degradation risk calculated on 50km cell using satellite data.

Air quality degradation risk

Soil quality degradation risk
Bioprodutivity Degradation Risk

Projected year 2025

Projected year 2050

Legend: Risk of Bio-productivity Losses on 50km cell

- < 0.25
- 0.3
- 0.5
- 0.6
- > 0.7

Build-up Sites
Surface Water Bodies
Analysis of optimal agricultural productivity using EO data toward climate change

- **Wheat**
  - Land, ha
  - Below 100 000
  - 100 000 -- 200 000
  - 200 000 -- 300 000
  - Above 300 000

- **Sunflower seed**
  - Land, ha
  - Below 50 000
  - 50 000 -- 100 000
  - 100 000 -- 200 000
  - Above 200 000

- **Rapeseed**
  - Land, ha
  - Below 10 000
  - 10 000 -- 50 000
  - 50 000 -- 100 000
  - Above 100 000
Losses Distribution & Vulnerability Assessment

- Probability of affect vs. personal income (max expected 0.81)
  - Curve 1: injured
  - Curve 2: missed
  - Curve 3: killed

- Probability of affect vs. education level
  - Personal injuries
  - Personal missing
  - Personal death

- Probability of affect vs. education level

- Map of vulnerability of local communities in level of relative losses
  - <0.1
  - 0.1-0.2
  - 0.2-0.3
  - 0.3-0.4
  - >0.45
Problem Areas, Gaps & Needs

**Water Resources**: assessment of availability, accessibility and vulnerability of surface and ground waters – for agriculture, energy, and support of quality of environmental services;

**Vegetation & Climate**: Multiparametric control of vegetation productivity in changing environment – for agriculture, ecology, food security, and energy;

**Disasters & Climate**: Catastrophic risk management tools – systemic risk analysis in view of local and regional climate and environmental change;

**Land use analysis** tools – for risk analysis & management in changing environment on regional and local scale.
Thank you for all your courtesies

Sincerely,
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