Land-Use/Cover Change Drivers, Impacts and Sustainability within the Water-Energy-Food Nexus

3rd joint EARSeL LULC & NASA LCLUC Workshop

Figure 1. Venetian Harbor of Chania

Background -

The UN FAO (United Nations Food and Agriculture Organization) in its State of the World's Land and Water Resources for Food and Agriculture (2014) confirmed that "land and water resources are central to agriculture and rural development, and are intrinsically linked to global challenges of food insecurity and poverty, climate change adaptation and mitigation, as well as degradation and depletion of natural resources that affect the livelihoods of millions of rural people across the world." They also projected that food production will need to increase by 70 percent to feed the world's growing population. Land and water resources are already under heavy stress from economic development, so that future agricultural production will need to be more efficient and sustainable. Land use is undergoing changes in many parts of the World and there is considerable interest in understanding the impacts of those changes and whether they are sustainable.

There have been a number of meetings and published reports on the Sustainable Development Goals (SDGs) adopted by the United Nations and on the Water-Energy-Food (WEF) nexus, which is one of the organizational contructs of the Future Earth global research platform. Land-use change is pervasive in many regions with major implications for the WEF and is integral to the SDG's. Satellite data can play an important role in providing up-to-date information in support of these initiatives, for example by providing underpinning data sets or monitoring progress towards the SDGs.

Workshop Focus -

The 3rd joint EARSeL-NASA LCLUC Workshop focused on water, food and sustainability research supported by Earth Observations and derived remote sensing products. The Workshop addressed innovative research on the relationships amongst natural processes (e.g. biogeochemical and hydrologic cycles) and social/behavioral processes (e.g. decision making and governance) as supported by remote sensing observations. Land-use change with an emphasis on forests and watershed management, urban areas flooding and water consumption, arable lands irrigation and combatting drought were some of the topics presented at this workshop.

The Workshop was jointly organized by EARSeL SIG LULC and NASA LCLUC Science Teams and held at the Mediterranean Agronomic Institute of Chania (MAICh) on July 11-12, 2018. In parallel, participants from the 38th EARSeL Annual Symposium had the chance to attend Workshop's sessions. As a result, over 200 scientists coming from over 26 countries discussed upcoming opportunities and challenges of LCLUC and remote sensing drivers, impacts and sustainability within the Water-Energy-Food nexus.

Figure 2. Sending our greetings to all of you, who could not make it!

Workshop Flow -

The welcome addresses were given by Chariton Kalaitzidis from MAICh, Garik Gutman (NASA LCLUC Program Manager), Klaus Komp (EARSeL Chairman) and Ioannis Manakos (EARSeL SIG LULC Chairman). Garik and Ioannis provided a short overview of the NASA LCLUC and EARSeL LULC activities, respectively, including their goals and plans.

The Workshop was organized around four sessions covering the latest advances, emerging methods and technologies and future challenges on the use and assimilation of remote sensing data, products and services including the topic of the water – energy – food nexus:

Session 1. Synergy of remote sensing technologies for land-use change monitoring
Session 2. The role of earth observations within the Water – Energy – Food nexus
Session 3. Social and behavioral aspects of land use supported by remote sensing observations
Session 4. Advances and outlook in the processing and analysis of remotely sensed data

Each session opened with presentations by two distinguished keynote speakers, who set the stage for an open discussion among all participants, followed by short oral presentations and in front of poster interaction. Sessions concluded with discussion wrapping up the key elements of the presentations and posters, aimed at identifying priority research areas and opportunities for collaboration.

Session 1 Initial Description -

Dynamic interactions among the hydrological cycle, the carbon footprint of land utilization and the demand for food production define our present and future well-being. Satellite observations and models can be utilized to support management and for land-use change scenarios, as well as help understand the balance between competing demands for land and water. Increased availability of free and open data from multimodal sources of remote sensing systems, is creating new opportunities to implement robust multi-level sampling strategies and generate spatially and temporally finer information by combining data from different sensors. This session provides insight into recent progress in the use of multi-source remote sensing data to study land-cover and land-use change.

Session 1 Wrap up -

Ursula Gessner (DLR) chaired the session. Pierre Defourny (University of Louvain) and David Roy (South Dakota State University) opened Session 1 with speeches on the synergy of remote sensing technologies for land-cover and land-use change monitoring. Pierre described approaches 'from annual global land cover to agriculture

Figure 3. Pierre Defourny

Figure 4. David Roy

practices monitoring at field scale thanks to the synergy of Sentinels time series', while David focused on the 'synergy of Landsat and Sentinel 2 data for change detection – mapping burned areas'. Vivid discussion points, upon which participants reflected with their opinions on, are:

- Validation protocols are critical given proliferation of products
  - ➢ revitalize awareness of *established* CEOS endorsed validation protocols (Stage 1/2/3/4, sampling, metrics);
  - ➢ need to think of champions to endorse validation protocols and standards for high resolution products over large areas or global (e.g., CEOS Cal/Val, GOFC/GOLD, GEO);
  - ➢ encourage validation protocol adoption as part of the journal peer review process;
  - ➢ further research is encouraged to develop a community high resolution / OBIA product validation protocol;
  - ➢ product quality assessment, metadata and demonstration are required in addition to validation.
- Independent reference data (i.e., test, calibration & training data)
  - ➢ advocacy to improve access to *existing* reference data (e.g., existing data can be anonymized), in particular from agencies regularly collecting data;
  - ➢ advocacy for agency funding of reference data collection as part of new product generation funding;
  - ➢ in particular, field campaigns for collection of *in-situ* data are important but oftentimes the necessary budget/effort is very underestimated;
  - ➢ encourage further reference data spatial and temporal sampling research;
  - ➢ recognition of new independent reference data sources including social media, phone, machine learning of street view, crowd-sourced, and other satellite LCLU products;
  - ➢ concerns regarding quality control and data policy regulations with respect to social media, mobile phone data, and crowd sourced data.
- Establish / Utilize community data portals with
  - ➢ sample satellite and training data for benchmarking classification algorithms and their parameterizations;
  - ➢ repository of georeferenced, temporally explicit, well distributed, LCCS class labeled samples;
  - ➢ (need to ensure quality control & long term maintenance of data portals).
- Provision of tool kits
  - ➢ recognition of the need and relevance of toolkits (e.g. ESA SNAP) that enable individuals to make own products
    - ▪ often appropriate for applications development and education,
    - ▪ can support democratic, transparent science that can be scaled with respect to computing;
  - ➢ concern over toolkits leading to the development of information and products that are not of high quality leading a loss of credibility.

- Provision of systematically generated products
  - recognition of the long-term need for provision and stewardship of systematically generated products (e.g. the global MODIS products) in support of science and informing climate/people/environment policy;
  - systematically generated products are necessarily
    - complex processing closely coupled to sensor calibration, geolocation and characterization activities,
    - quality assessed,
    - validated,
    - reprocessed as needed with versioning,
    - subject to academic scrutiny;
  - advocacy for archive reprocessing capacity development and continued production of systematically generated products;
  - need to establish which existing products are useful;
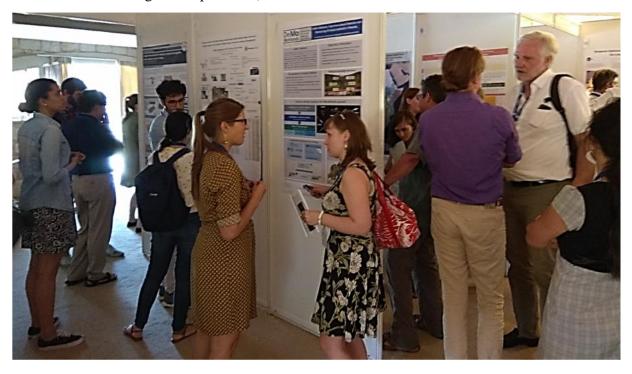 - need to establish which products are missing (given current and future remote sensing data capabilities);

Figure 5. Lively talks in front of the posters

Session 2 Initial Description -

Land-use change is integral to the study of the water-energy-food nexus. Remote sensing can provide information on land-cover change and associated abiotic/biotic variables, as well as the associated ecosystem functions and services. Environmental and resource management challenges are resulting from the need to balance increasing and competing demands for water, energy and food. Quantitative and verifiable mapping and change detection are needed. With the increased

availability of Earth Observation, data are being applied to address questions at the nexus. Latest achievements in this research area will be presented and discussed.

Session 2 Wrap up -

Dinka Dinkova (DG GROW, European Commission) chaired the session. Jiaguo Qi (Michigan State University) and Patrick Hostert (Humboldt University of Berlin) opened the second session with speeches on the role of earth observations within the water – energy – food nexus. Jiaguo described 'A WEF Nexus Approach to Addressing Regional

Figure 6. Jiaquo Qi

Figure 7. Patrick Hostert

Sustainability Issues in the Lower Mekong Basin', while Patrick presented 'Crete's grazing history – the perspective from space'. The following discussion points were outlined in this session:

- holistic perspective needed to identify win-win scenarios or minimize trade-offs;
- long-term EO is needed to map various attributes of water-energy-food systems;
- validation along internationally accepted standards and communication of accuracies is mandatory;
- communicating and engaging with the users/stakeholders is crucial to bridge the gap between data analysis and decision making;
- important to address the diversity of stakeholders, i.e. reflecting different end-user needs in RS-based products.

Regarding the way ahead, following points were highlighted:

- need for analysis-ready data (ARD) and MODIS-like products at Landsat/Sentinel2-resolution;
- Two steps:
  a) assessing previous success stories (e.g. based on MODIS) and
  b) gap analysis on what was missing in the past;
- EARSeL/NASA LCLUC perspective: pushing programs that allow joint research between European and US researchers;
- GEO may take the lead on pushing frameworks for open data and end-user-friendly information to high-level stakeholders.

Figure 8. Discussions during a break.

Session 3 Initial Description -

Land-use decisions are made by people. Social science can help provide an understanding of the decision-making process and the drivers of the land-use change that we detect using remote sensing. A number of research projects are now addressing issues such as governance, institutions, labor and land tenure, which raise questions beyond the traditional physical science and remote sensing of land-cover change. This session presents and promotes the amalgamation of remote sensing products and social science to address questions of land-use change.

Session 3 Wrap up -

Daniel Brown (University of Washington) chaired this session. Jefferson Fox (East West Center) presented the 'Twenty years after People and Pixels: Continuity and Change in what we do', while Ariane de Bremond (University of Bern) focused on 'Supporting identification of land system interactions in the SDGs: Integrating social science and earth observation for development transformations'.

Figure 9. Jefferson Fox

Figure 10. Ariane De Bremond

Discussion points, upon which participants expressed their opinions and interacted, are:

- Need for better access to social data
  - ➢ new data from social media and citizen science provide opportunities for new measurements and challenges for accuracy;
  - ➢ need address accessibility while also protecting privacy;

- ➢ Attendees provided specific examples of how social data have been combined with remotely sensed data to provide measurements (of ecosystem services, of tourism potential, of agricultural productivity).
- Moving RS observations to relevance to SS and decision makers
    - ➢ Need access to social science concepts and models to define relevant measurements and social actors to define measurements of relevance to problems.
- Training needed for socially relevant science work with remote sensing
    - ➢ some training programs provide integrated perspectives;
    - ➢ depth of expertise is important for individual scientists to contribute to expertise in advancing science;
    - ➢ ability to work and collaborate in teams is critical to addressing;
    - ➢ existing science programs (e.g., NASA LCLUC, EC Horizon 2020) provide funding for collaborative teams.
- Where accuracy of measurements is critical, collaboration across social and natural sciences, and across science and application, can sometimes result in compromises in rigor of individual measurements and science so that they can be integrated
    - ➢ measures of accuracy of integrated products are difficult to produce.
- RS products in social science and applications
    - ➢ Translating LC and other products to social science and applications can sometimes result in misuse. Communication of biases and uncertainties (thematically and geographically specific) is important to help guard against misuse.

Figure 11. Part of the audience during a speech.

Session 4 Initial Description -

With the significant increase in remote sensing satellite data volumes and associated processing needs, traditional methods and approaches to data processing, image analysis and standard software packages fall short of what is needed. High performance computing, high speed internet and cloud computing offer new solutions for processing and analysis of remotely sensed data to

extract land-cover/ land-use change and related information. However, such new developments come with their own set of challenges. This session examined recent trends and new approaches to processing and analysis of remotely sensed big-data and provided an opportunity for presenters to share their experience in their development.

Session 4 Wrap up -

Gilberto Câmara (new GEO Secretariat Director) chaired this session. Matthew Hansen (University of Maryland) was the keynote speaker of this session and proposed 'a strategy for global land change monitoring'. Discussion was moderated by the vision of the two esteemed chairs. The questions raised here included:

Figure 12. Mathew Hansen

- Golden age of Earth observations
  - How to operationalize EO applications in developing countries?
  - How to transition from research to operations?
  - Is it a question of the domain experts?
  - Who is endorsing the EO results?
  - How to make EO results reproducible, robust and endorsable?
- Sharing in-situ and ground truth data
  - Publishing data in trusted repositories?
  - Recovery of past data?

Figure 13. Gilberto Câmara (on the left) & part of the audience during a speech (on the right)

The program of the Workshop led to very intense discussions at all sessions, most of which, especially the evening ones, were extended as needed. The success of this Workshop suggests that it is desirable to organize a follow-up joint event in about every two years. At the closing session EARSeL has sponsored two awards for the best young scientists' contributions. The organizers are open for more ideas and suggestions and would be happy to receive them by email (imanakos@iti.gr).

Figure 14. During the Come Together Event

Worth to mention are the welcoming Come Together Event at the evening of the 10th of July at the centre of the Chania Venetian Harbor and the 'Spaced' exhibition about 'Using Earth Observations to Protect Natural Landscapes'. Twenty-five (25) panels were hosted at the KAM Center of Mediterranean Architecture providing the opportunity to visitors to view the beauty of the ECOPOTENTIAL protected areas in Europe and beyond. Wonderful pictures and satellite images, accompanied by short texts, illustrated how researchers and managers of protected areas are working together to study mountain, arid, coastal and marine ecosystems. Participants enjoyed socializing, and tasting local food and drinks.

Special thanks and acknowledgement to our sponsor, the European Space Agency, our highly qualified keynote speakers, to the contributors and participants for their vivid discussions, and to the scientific and organizing Committees. The Workshop was co-organized by the Mediterranean Agronomic Institute of Chania, Greece.

Sincerely,

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