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Editorial

Land Degradation Assessment with Earth Observation

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For decades now, land degradation has been identified as one of the most pressing problems facing the planet. Alarming estimates are often published by the academic community and intergovernmental organisations claiming that a third of the Earth's land surface is undergoing various degradation processes and almost half of the world's population is already residing in degraded lands. Moreover, as land degradation directly affects vegetation biophysical processes and leads to changes in ecosystem functioning, it has a knock-on effect on habitats and, therefore, on numerous species of flora and fauna that become endangered or/and extinct.

By far the most widely used approach in assessing land degradation has been to employ Earth observation (EO) data. Especially during the last decade, with technological advancements and the computational capacity of computers on the one hand, together with the availability of open access, remotely sensed data archives on the other, numerous studies dedicated in the study of the various aspects of land degradation have been undertaken. The spectral, spatial and temporal resolution of these studies varies considerably, and multiscale, multitemporal and multisensor approaches have also evolved.

This Special Issue (SI) on "Land Degradation Assessment with Earth Observation" provides 17 original research papers with a focus on land degradation in arid, semiarid and dry-subhumid areas (i.e., desertification) but also temperate rangelands, grasslands, woodlands and the humid tropics. The studies cover different spatial, spectral and temporal scales and employ a wealth of different optical, as well as radar sensors: from the finest spatial scale of an Unoccupied Aerial Vehicle (UAV), to PlanetScope, Sentinel-1 and -2, Gaofen, Landsat, MODIS, PROBA-V, SPOT VGT and AVHRR. Some of the ancillary datasets included in the methodological framework of a number of the papers are also derived from remotely sensed imagery, e.g., the SRTM digital elevation model or the Climate Hazards group Infrared Precipitation with Stations (CHIRPS) precipitation estimates. Many studies incorporate time-series analysis techniques that assess the general trend of vegetation or the timing and duration of the reduction in biological productivity brought about by land degradation (e.g., Mann—Kenndall test, Theil–Sen's slope, BFAST, TSS-RESTREND, LandTrendR). A number of papers employ statistical approaches in their analyses (e.g., principal components analysis, ordinary least squares or geographically weighted regression) or machine learning classification/regression techniques (e.g., Random Forests, Support Vector Machines). As anticipated from the latest trend in EO literature, some studies utilise the cloud computing infrastructure of Google Earth Engine to deal with the unprecedented volume of data that current methodological approaches entail.

Geographically, the papers of this SI are mostly related with areas within Africa (9 papers), which is unsurprising, as the African continent is the most severely affected by land degradation. The Asian region is also well represented with seven papers, and one paper is focused on an area in North America. In terms of the processes addressed, both abrupt and more salient changes and degradation processes are covered, with the most studied theme being the different aspects of vegetation degradation:

- Tomaszewska and Henebry [1] investigate pasture degradation in the Kyrgyz Republic, using spatiotemporal phenometrics with MODIS land surface temperature (LST) and Landsat Normalized Difference Vegetation Index (NDVI) data;

- Meng et al. [2] study grassland degradation in the Tibetan Plateau (China) with UAV and Gaofen data;
- Gedefaw et al. [3] look at rangeland degradation in New Mexico (USA) through a time-series analysis of the Global Inventory Modeling and Mapping Studies (GIMMS) NDVI and the Parameter elevation Regressions on Independent Slopes Model (PRISM) precipitation data;
- Wanyama et al. [4] study vegetation condition in the Mount Elgon ecosystem (Kenya and Uganda) with MODIS NDVI and CHIRPS precipitation data and a combination of trend and breakpoint analysis methods;
- Barvels and Fensholt [5] also look at vegetation condition. They use Landsat NDVI time-series and CHIRPS rainfall estimates with trend analysis techniques to assess greening and browning trends in the highlands of the Ethiopian Plateau;
- Adenle and Speranza [6] investigate degradation in the Nigerian Guinea savannah by combining MODIS-derived land degradation status estimates from a previous study with spatial data on different drivers of land degradation to identify socio-ecological archetypes of land degradation;
- The paper by Urban et al. [7] focuses on monitoring shrub encroachment in the Free State Province (South Africa) by incorporating a dense time-series of both radar (Sentinel-1) and optical (Sentinel-2) data;
- Li et al. [8] look at the spatial differences of vegetation response and associated land degradation due to multiple mining activities in northwestern China. They use Landsat imagery, monitor vegetation change using time-series analysis techniques and estimate the spatial heterogeneity of the change related specifically to mines.

Another common theme of the Special Issue is land degradation related to drought:

- Verhoeve et al. [9] study vegetation resilience under increasing drought conditions in two districts of Nothern Tanzania. They employ the National Oceanic and Atmospheric Administration (NOAA) Climate Data Record (CDR) AVHRR NDVI data together with Climate Research Unit (CRU) temperature and a combination of CenTrends and CHIRPS precipitation estimates;
- Kimura and Moriyama [10] look into drought conditions in Mongolia. They examine the trends in AVHRR- and MODIS-derived NDVI, as well as in an aridity index calculated using surface reflectance and LST data from MODIS, and propose a method to monitor land-surface dryness;
- Akinyemi [11] investigates the relationship between drought severity and land use/cover change in 17 constituencies in Botswana. She employs NDVI data from SPOT VGT and PROBA-V and land cover information from the European Space Agency's (ESA) Climate Change Initiative (CCI) and the Copernicus Climate Change Service (C3S-LC).

Soil erosion also appears as one of the land degradation processes of interest in the Special Issue:

- The study by Phinzi et al. [12] over an area of South Africa compares different classification algorithms and resampling methods to identify the optimal combination for the mapping of complex gully erosion systems, using PlanetScope data from the wet and dry seasons;
- Wang et al. [13] bring together MODIS NDVI and Land Aerosol Optical Depth data, climate assimilation and ancillary spatial data to develop a Google Earth Engine-based model for the delineation of the wind erosion potential of the entire Central Asian region (i.e., Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan and Tajikistan).

Land degradation related with the salinisation of the soil is also addressed in this Special Issue:

- Yu et al. [14] use Landsat data and integrate the salinization index, albedo, NDVI and the land surface soil moisture index to establish the salinized land degradation index (SDI) and apply their approach in an area that runs through Turkmenistan and Uzbekistan;

- Moussa et al. [15] compare a salinity index to an approach that employs Sentinel-2-derived NDVI time-series for detecting salt-affected soils in irrigated systems in an area of Niger.

One of the papers of the Special Issue deals with the humid tropics. In their study, Liu et al. [16] propose a framework for the improved accounting of reference levels (RLs) for the United Nations' Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme. They combine the Intergovernmental Panel on Climate Change's (IPCC) Good Practice Guidance on Land Use, Land Use Change and Forestry with a land use change modelling approach and apply this to an area in southern China. Finally, the paper by Reith et al. (2021) focuses on the issue of land degradation monitoring and the methodology suggested by the United Nations Charter to Combat Desertification (UNCCD) to inform the sustainable development goal (SDG) 15.3.1 (i.e., "Proportion of degraded land over total land area"). Aiming to optimise the land degradation neutrality (LDN) efforts of the UN, Reith et al. [17] compare the land degradation assessments for an area in Central Tanzania derived using the coarser spatial-resolution MODIS and the finer Landsat data.

A clear message stemming from this SI is the ever-increasing relevance of Earth Observation technologies when it comes to assessing and monitoring land degradation. With the recently published IPCC AR6 Working Group II Report (https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FinalDraft_FullReport.pdf, accessed on 3 March 2022), informing us of the severe impacts and risks to terrestrial and freshwater ecosystems and the ecosystem services they provide, the EO scientific community has a clear obligation to step up its efforts to address any remaining gaps—some of which have been identified in this SI—in order to produce highly accurate and relevant land degradation assessment and monitoring tools.

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