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Earth Observation for Land and Emergency Monitoring Core Services

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The Copernicus programme is Europe's flagship operational Earth Observation programme. It is comprised of a number of core services aiming at specific user groups. Many policies and international initiatives rely on Earth Observation to deliver information services. The downstream development of new satellite applications is a rapidly growing global market and creates jobs, economic growth and prosperity for societies.

The Copernicus initiative is delivering many core monitoring services of the oceans, the land surface, air quality, climate change and the polar ice sheets. It is a laudable programme in its aspiration to provide operational long-term observations of critical parameters from space. However, it has limitations and there is room for developing new and improved innovative information services around the existing Copernicus service portfolio.

The initial operations of the European Copernicus programme from 2011 to 2014 have delivered a comprehensive range of satellite applications in support of sustainable forestry. The Geoland-2 project has established the operational Copernicus land monitoring core service, which is now implemented with a global, European, local and in-situ component. Global data products to support sustainable agriculture and forestry include surface albedo, fractionally absorbed PAR (FAPAR), fraction of PAR absorbed by vegetation for photosynthesis processes, Leaf Area Index (LAI), Top of Canopy spectral reflectance, Fractional cover (Fcover), Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), Vegetation Productivity Indicator (VPI), Dry Matter Productivity (DMP), burnt area, active fires, land surface temperature, soil moisture, areas of water bodies, water level (lakes and rivers), and vegetation phenology at 1 km resolution.

At the European scale, the vector-based CORINE land cover (reference year 1990) is being updated (last produced in 2000 and 2006, and currently being updated to 2012). It consists of 44 land cover classes and uses a Minimum Mapping Unit (MMU) of 25 ha area, or a minimum width of 100 m for linear landscape structures. Land cover changes are mapped with an MMU of 5 ha by visual interpretation of high-resolution satellite imagery. CORINE has a wide range of applications, underpinning the European

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Communities policies in the domains of environment, but also agriculture, transport, spatial planning etc. The High-Resolution-Layers (HRL) at 100 m spatial resolution include two forestry data products: tree cover density and forest type. In GIO-land an additional two forest products are being produced for the European Commission's Joint Research Centre (JRC): tree cover presence/absence, and dominant leaf type at 25 m spatial resolution. The tree cover density dataset maps the level of tree cover density in a range from 0–100%, has no MMU (minimum number of pixels to form a patch) and a minimum mapping width of 20 m. The forest type products in their original 20 m resolution version consists of the dominant leaf type (MMU of 0.5 ha, 10% tree cover density threshold applied), and a support layer showing trees under agricultural use and in urban contexts (derived from CORINE and imperviousness 2009 data). For the final 100 m product trees under agricultural use and urban context from the support layer are removed.

This book introduces the reader to the outcomes from four years of research in support of the Copernicus Land Monitoring Core Service and the Emergency Monitoring Core Service.

The research was funded by the Marie Curie PEOPLE programme in Framework Programme 7, as an Initial Training Network. The GIONET project established a European Centre of Excellence in Earth Observation Research Training in 2011, when Copernicus was called "GMES" (Global Monitoring for Environment and Security), and just entered into its GMES Initial Operations phase (GIO).

GIONET trained 14 PhD researchers in academia, industry, and research centres in advanced remote sensing skills, accompanied by interpersonal, entrepreneurship and management skills. Seven organizations from five European countries employed the researchers and were supported by a large group of associated partners.

This book is structured into thematic chapters, covering Forest Monitoring (Part I), Land Cover and Land Cover Change Monitoring (Part II), Coastal Zone and Freshwater Monitoring (Part III), Land Deformation Mapping and Humanitarian Crisis Response Strategies (Part IV) and Earth Observation for Climate Adaptation (Part V). A Conclusions chapter summarizes the main findings presented in the book.

The UN initiative "Reducing Emissions from Deforestation and Forest Degradation" (REDD+) provides a strong user pull for forest information from space. In Part I on forest monitoring a concept for global forest biomass mapping is presented, making use of geographically varying forest allometric models, spaceborne profiling LiDAR (ICESAT-GLAS) and Synthetic Aperture Radar (SAR). Synergies between multi-temporal and multi-frequency interferometric radar and optical satellite data for biomass mapping and change detection are discussed and a SAR mapping application to the Congo Basin presented.

Conceived in 1985 as the CORINE programme, land cover monitoring is the most operational element of the Copernicus programme. The methodology remains largely unchanged. Part II on land cover and land cover change monitoring presents approaches that go beyond the current implementation of largely optical/near-infrared based land cover monitoring methods. Classification methods with multi-frequency, multi-temporal SAR data over semi-arid and forested African landscapes are explained and contrasted against the capabilities of optical-near-infrared high-resolution satellite images. A methodological framework for multi-scale remote sensing concludes this chapter.

The European Water Framework Directive requires monitoring of the ecological status and water quality of all major water bodies and their habitats. Earth Observation is only beginning to influence this application area. In Part III on coastal zone and freshwater monitoring, a study of salt marsh habitats in Wales is presented. Salt marshes are regarded as effective buffers against sea level rise and can be mapped with multi-sensor data to support Integrated Coastal Zone Management. Freshwater applications focus on the ecology of emergent and submerged macrophytes in Lake Balaton, Hungary, using airborne hyperspectral and LiDAR remote sensing to map the extent of reed dieback syndrome, and satellite remote sensing to map and monitor optically active water quality parameters, such as chlorophyll-a as a proxy for phytoplankton biomass and blooms.

The recent past was characterized by many humanitarian crises and natural disasters. Part IV of this book describes the use of radar interferometry for land deformation mapping applications and demonstrates the use of machine learning algorithms in the context of humanitarian crisis response strategies. After a short review on radar interferometry, a new hybrid method using Differential SAR Interferometry/Persistent Scatterer Interferometry for ground-motion monitoring from spaceborneSAR data is demonstrated and applied to different land cover types. Chapter 12 describes the use of spaceborne SAR and ground-based radar interferometry for mapping landslide displacements in the Swiss Alps. New methods for the detection of small-scale land surface feature changes in complex humanitarian crisis situations are demonstrated, transferring machine learning algorithms to environmental remote sensing.

With an increasing likelihood that mankind is unable or unwilling to respond effectively to the causes of climate change, there is a widening recognition that we will have to adapt to its impacts. In Part V on Earth Observation for climate adaptation, a study on remote sensing of wetland dynamics as indicator of water availability in semi-arid Africa is presented, using time series of optical and SAR satellite imagery. Satellite observations of drought events and crop stress in Europe conclude this chapter.

The book presents a collection of original research findings interspersed with selected review chapter and intends to serve as a compendium on the state-of-the-art in remote sensing in support of land and emergency monitoring going beyond the current operational monitoring services in Copernicus.

I am grateful to the GIONET team for the inspiring and productive work over the past four years, in particular to my colleagues at the University of Leicester, UK, Airbus Defence and Space (formerly Astrium GEO-Information Services), UK, Gamma Remote Sensing AG, Switzerland, the Institute of Geodesy and Cartography (IGIK) in Warsaw, Poland, Friedrich-Schiller-University in Jena, Germany, the Hungarian Academy of Sciences – Centre for Ecological Research and the German Aerospace Center (DLR), and the associated partners in the Joint Research Centre of the European Commission in Ispra, Italy, University of Stirling, UK, University of Padova, Italy, the National Observatory of Athens, Greece, Chalmers University in Sweden, and the companies Trimble, Germany, EXELIS Visual Information Solutions Ltd., UK, SpectoNatura, UK, BlackBridge, Germany, DANKO Plant Breeding in Poland, Envirosense, Hungary, and Earth Observation Services in Germany.

It has been a privilege and a pleasure to coordinate the international team of 14 early-stage researchers who were working towards their doctoral degrees in this unique international research environment.