Workshop "Tecnologie satellitari e analisi multi-rischio: l'esperienza dei progetti I4DP_SCIENCE e prospettive future"

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 # 1 – Foundation models for satellite-based landslide detection in cascading disaster scenarios

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Landslides triggered by earthquakes and intense rainfall pose a significant risk to infrastructure and populations, particularly in regions prone to natural disasters. These events often occur in a cascading manner, where an initial hazard, such as a strong earthquake, destabilizes the terrain, increasing its susceptibility to subsequent triggering factors like heavy rainfall. This cascading phenomenon was tragically exemplified by the 2021 Haiti earthquake, which weakened the terrain, making it more prone to landslides triggered by the subsequent heavy rains. Understanding these event chains is crucial to improving monitoring strategies and enhancing disaster response planning. Recent advancements in Vision Foundation Models (VFMs), such as the Segment Anything Model (SAM), have demonstrated remarkable segmentation capabilities across various domains, including computer vision and medical imaging. However, their direct application to remote sensing data, particularly for landslide detection, remains an open challenge due to the complexity of terrain variability and the need for expert knowledge in geospatial analysis. This study focuses on the use of optical satellite imagery for the automated segmentation of landslides using VFMs, assessing their ability to identify affected areas. Recent studies have already highlighted the potential of Foundation Models in improving segmentation accuracy compared to classical approaches, demonstrating their adaptability to different domains. Future work will also explore the integration of additional remote sensing sources, such as radar imagery, to enhance landslide detection in challenging conditions, including cloud-covered areas and densely vegetated regions. This research aims to demonstrate the effectiveness of Foundation Models in remote sensing for landslide detection, contributing to the evolution of AI-based analysis techniques, enhancing geospatial data processing, and optimizing emergency response strategies in the face of cascading natural hazards.

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 # 2 – A conceptual framework for on-board AI and Earth Observation in cascading hazard risk management

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Natural hazards often trigger cascading processes that amplify impacts and complicate emergency response. Events such as earthquake-induced landslides or floods caused by hydraulic obstructions highlight the interconnected nature of hazards, increasing vulnerabilities in exposed communities and infrastructure.

This research proposes a conceptual framework that integrates Earth Observation (EO) and on-board Artificial Intelligence (AI) for the management of cascading hazards. EO technologies, when combined with on-board AI, could autonomously detect and analyze hazards in real time, enabling rapid, data-driven disaster response.

Despite its transformative potential, several challenges remain. Current satellite missions lack autonomous AI-driven Synthetic Aperture Radar (SAR) processing. Overcoming these limitations requires new hardware, algorithm optimization, and rigorous validation. For instance, in an earthquake-induced flood event, SAR data would monitor ground deformation, while optical imagery assesses river and embankment conditions. AI enhances this process through region prioritization, object extraction, onboard classification, and change detection, supporting real-time risk analysis and prediction.

Traditional approaches treat hazards in isolation; this framework models their temporal evolution and compound effects.

In conclusion, this work lays the foundation for scalable, AI-enabled EO solutions to manage multi-hazard risks, contributing to more resilient and adaptive disaster response systems in the face of escalating environmental challenges.

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 # 3 – AI-based building damage detection using satellite and geospatial data: a case study on the 2023 Kahramanmaraş earthquake

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Natural disasters such as earthquakes demand rapid, accurate damage assessment to minimize human and economic losses. Remote sensing data are invaluable for evaluating building damage when factors like sensor type, spatial resolution, revisit time and access to pre-disaster data are considered. While very high-resolution optical imagery excels in clear-sky conditions, it may be unavailable in the immediate aftermath of a disaster. This study presents an innovative, SAR-based approach that exploits the COSMO-SkyMed (CSK) constellation alongside multi-source geospatial datasets for accurate monitoring of earthquake-induced building damage.

Our framework integrates CSK imagery at 2.5 m spatial resolution (HH polarization) with exposure attributes from the Global Earthquake Model (GEM), layers from OpenStreetMap's Humanitarian Data Exchange (OSM HDX), and a high-resolution Digital Surface Model (DSM) from CartoSat-1. A deep-learning architecture fuses these inputs, learning correlations between SAR-derived damage evidence and underlying vulnerability factors.

Applied to the 2023 Kahramanmaraş earthquake in Türkiye, our method utilizes CSK background acquisitions alongside dedicated tasking under the CEOS Geohazard Supersites initiative, resulting in a rich archive of SAR data. Damage assessments produced by our model are validated against high-resolution optical imagery, demonstrating high accuracy and consistency. Results show that integrating SAR imagery with multi-source data enables rapid, scalable damage mapping, even under adverse weather or limited access to optical data, providing a reliable alternative to manual field surveys and visual interpretation efforts. This approach supports near-real-time disaster response, informs recovery planning, and shapes disaster preparedness policies.

By combining deep learning with geospatial data, this work advances automated damage assessment and paves the way for scalable, global applications in earthquake response and recovery.

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 # 4 – Data Fusion and Change Detection Techniques Based on Optical and SAR Data EO for Damage Mapping and Multi-Temporal Assessment of the Recovery Process After Natural Disasters

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The assessment and appropriate analysis of risks associated with natural disasters, particularly those intensified by climate change, are essential for effective mitigation, preparedness, and long-term adaptation strategies. While rapid damage mapping during emergencies has improved, extended monitoring of recovery processes remains insufficient. This research presents a comprehensive methodology for integrating optical and Synthetic Aperture Radar (SAR) satellite data to evaluate both immediate impacts and subsequent reconstruction dynamics. Leveraging freely available Copernicus Sentinel-1 and Sentinel-2 time series—supplemented by Landsat collections and very high-resolution commercial imagery—this approach employs advanced multi-temporal data fusion and change-detection techniques to generate continuous, user-oriented geoinformation.

Two detailed case studies demonstrate the methodology's capabilities. The first examines Hurricane Matthew's impact on Haiti in 2016, where multi-temporal SAR backscatter analysis and optical vegetation indices were used to map urban infrastructure destruction, flooded agricultural zones, and natural reserve damage. Temporal profiles revealed differential recovery: significant rebuilding of priority urban areas and temporary shelter sites, contrasted with abandoned or repurposed farmland and uneven vegetative regrowth in protected forests. Land-use change detection further identified new constructions in hazard-prone zones, underscoring the need for informed planning.

The second case study focuses on the Mojana region in Colombia, which endured record flooding during La Niña in 2021 and a second major event in May 2024. Advanced image-fusion via machine learning in Google Earth Engine enabled precise mapping of prolonged inundation, soil saturation effects on rice paddies and pastures, and infrastructure deterioration. Comparative analysis of pre- and post-event imagery highlighted partial crop recovery versus long-term abandonment, alongside forest canopy degradation indicated by spectral shifts. These findings illustrate uneven resilience and the urgent requirement for adaptive policies.

The results underscore the critical role of continuous, multi-temporal satellite observation in guiding recovery strategies, land-use planning, and resilience-building in climate-vulnerable regions. Moreover, this research advocates for strengthening local capacity in EO data accessibility, processing infrastructure, and technical expertise—particularly in developing countries—to sustain informed post-disaster recovery and advance disaster risk management under evolving climate challenges.

This research was funded by ASI through a PhD studentship in the National Doctorate in Earth Observation (NDEO) / Dottorato Nazionale di Osservazione della Terra (DNOT), at Sapienza University of Rome.

 # 5 – Il progetto EcoTrack

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La stima della portata dei fiumi è uno degli obiettivi più importanti e frequenti per il telerilevamento applicato all'idrologia in quanto costituisce uno degli indicatori di rischio alluvioni. A rigore, l'unico metodo capace di misurare la portata è quello di utilizzare un secchio ed un cronometro, strumenti che consentono di quantificare esattamente il volume d'acqua raccolto in un certo lasso di tempo. Tale metodologia è ovviamente inapplicabile per indagini a larga scala. Pertanto, si ricorre a misurazioni approssimate attraverso l'utilizzo di strumenti locali. Tuttavia, ci sono ancora molti fiumi per i quali le stime della portata non esistono o non sono prontamente disponibili. Inoltre, è da segnalare che il numero di stazioni di misurazione funzionanti sta diminuendo a livello mondiale.

Recentemente, il telerilevamento satellitare sta entrando in queste pratiche, spinto dall'abbondante disponibilità di dati e da un crescente interesse della comunità scientifica. I sensori trasportati a bordo delle piattaforme registrano radiazioni elettromagnetiche, che vengono poi convertite in un segnale di interesse per l'idrologo.

L'obiettivo di questa presentazione è quello di dimostrare l'efficacia del telerilevamento satellitare nelle applicazioni relative alla stima della portata dei fiumi. In particolare, si mostrerà come informazioni estratte dalla banda del vicino infrarosso di acquisizioni Sentinel-2 costituiscano validi proxy della portata misurata alle stazioni da utilizzarsi come input di algoritmi di machine learning basati su regressione. La discussione sarà supportata da esempi relativi ad alcuni fiumi della regione Lazio, analizzati nell'ambito del progetto EcoTrack (finanziato dall'Agenzia Spaziale Italiana) in cui Latitudo40 collabora con SpazioFuturo. I risultati ottenuti dimostrano che metodologie basate su dati satellitari possono fornire stime della portata molto accurate anche in fiumi la cui larghezza è comparabile con la risoluzione del sensore.

 # 6 – Flood probability inferred from satellite image time series through a Bayesian model within the multi-hazard analysis of the GEORES project

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The GEORES project – Geospatial Application in Support of Environmental Sustainability and Resilience to Climate Changes in Urban Areas; ASI-UNIBA Agreement n. 2023-42-HH.0, funded by the Italian Space Agency (ASI) in the framework of "Innovation for Downstream Preparation for Science, I4DP_SCIENCE – is focused on the monitoring of multi-hazards (Floods, Fires, Landslides, Sediment Connectivity).
In this context, flood hazard maps were calculated using a Bayesian probabilistic approach and their effectiveness was tested through XAI (eXplainable AI). Over selected study areas in the Puglia Region, in Southern Italy, time series of synthetic aperture radar (SAR) satellite images from Sentinel-1 (C -band), as well as COSMO-SkyMed (X-band) and SAOCOM (L-band) constellations, and ancillary data such as Layover/Shadow masks, slopes, Height Above the Nearest Drainage (HAND), constituting the input data of the Bayesian framework, were acquired. Prior probability values were entered into the Bayesian model for each pixel, based on the ancillary data. The satellite images were preprocessed through calibration, geocoding, co-registration and removal of speckle through a nonlocal filter. Stacks of intensities and "cascaded" coherences, in multiple polarizations where available, were obtained, from which the respective conditional probabilities of flood and no-flood conditions were derived through Gaussian Process Regression-based temporal modeling of the variables. The prior and conditional probabilities were incorporated into the Bayesian model

resulting in various temporal stacks of posterior flood probability, interpreted as confidence maps. The information on the mean and standard deviation of these flood confidence maps represented part of the predictors selected for the realization of the GEORES model assessed through XAI. The target maps of XAI for the flood module are constituted by the flood probability maps of the Southern Apennines Flood Risk Management Plan (PGRA). The level 3 target maps were considered as hotspot areas within which the behavior of different geonalytics was analyzed. Results indicate a fair performance of the flood-related observables. Interesting insights can also be deduced by the analysis of XAI results pertaining to other hazard classes, pointing to interactions and feedbacks between different types of hazard.

 # 6b – An integrated approach for assessing urban wildfire risk using a multi-hazard framework

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The Fire Risk Map aims to identify areas subject to different levels of risk within a given territory, taking into account both anthropogenic factors—such as proximity to urban centers, infrastructure, and road networks—and natural factors, including the presence and accumulation of fine fuel, terrain morphology, and local climatic conditions that may favor the ignition and spread of wildfires. This integrated approach allows for a comprehensive, multi-level view of the spatial distribution of fire risk classes, categorized into four levels: null, low, medium, and high (hotspot areas). The analysis helps identify the most vulnerable and strategic zones from a prevention perspective. The production of this thematic map enables a more precise assessment of the territory's exposure to fire risk, thereby contributing to more effective territorial management, preventive planning, optimization of monitoring resources, and active response during critical events. In the GEORES project (ASI-UNIBA Agreement n. 2023-42-HH.0), the Fire Risk Map was developed using the Metropolitan City of Bari and the Gargano area in the Puglia Region, Southern Italy as case studies. The Fire Risk Map was obtained by integrating two maps developed in a previous stage of the GEORES project: (1) Hazard Map, produced using the Random Forest machine learning algorithm with several input data extracted from satellite images. For the scope, we used a combination of ESA Sentinel-1 (S1), Sentinel-2 (S2) and field inventory data (251 plots). N.164 S1 images were acquired in the Interferometric Wide Swath (IW) mode with two polarizations, VH (Vertical transmit Horizontal receive) and VV (Vertical transmit Vertical receive), at 10-m resolution with ascending orbit. N.218 S2 images were acquired and further processed to mask out cirrus, clouds, and shadows and finally used to extract the mean Normalized Difference Vegetation Index (NDVI) within each field plot. We then used a Random Forest model to identify the most important variables explaining fuel load spatial distribution in the study areas. (2) Danger Map, generated using the Generalized Linear Model (GLM) machine learning algorithm with input data including land use classes, geomorphological data, historical wildfire events, and meteorological data. These two maps were overlaid and merged by applying a normalization from 0 to 3 for the classification of different risk levels, completing the production of the final risk map. The integration of this information with other risk factors allows for the analysis of risk propagation dynamics and the development of more effective strategies for the prevention and integrated management of natural hazards. In this way, the Fire Risk Map contributes to strengthening the resilience of the territory and local communities to climate change and interconnected risks.

 # 7 – The Sediment Flow Connectivity Index (SfCI): A Supporting Tool for the Evaluation of the Susceptibility to Multi-Hazard Exposure

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The Sediment flow Connectivity Index (SfCI) aims to identify sediment hotspots within a watershed by evaluating sediment transfer processes, shaped by the physical continuity between landscape units (structural component) and the interaction of geomorphological and hydrological processes (functional component). This cascade system, linking upslope sources to downslope targets, is essential to understanding how sediment moves through the landscape. This integrated approach supports a comprehensive understanding of sediment dynamics, highlighting areas prone to sediment mobilization and accumulation. Calculating this geomorphological indicator also using Earth observation data helps assess susceptibility to surface changes associated with multi-hazard risk.

In the GEORES project (Geospatial Application in Support of Environmental Sustainability and Resilience to Climate Changes in Urban Areas; ASI – UNIBA Agreement n. 2023-42-HH.0 funded in the framework of “Innovation for Downstream Preparation for Science”, I4DP_SCIENCE), SfCI was applied to the Metropolitan City of Bari and Gargano promontory in Apulia region, southern Italy. A sediment connectivity map was produced, categorizing connectivity as low, medium, or high (hotspot).

This final map was derived using an algorithm that integrates input datasets—expressed as dimensionless indices representing rainfall, soil stability, land cover, slope, and surface ruggedness, to produce the Sediment Mobility (SM) map. SM is the product of two components: SM1 estimates the potential for sediment detachment, while SM2 evaluates the potential for mobilization of detached sediment toward adjacent areas. The SM map is incorporated into a flow accumulation algorithm to calculate sediment flux, propagated downslope along the steepest gradient paths. A smoothing step is applied, and results are classified into connectivity levels based on spatial patterns. This output provides a spatial representation of sediment transfer potential.

Within this framework, sediment connectivity is a key factor in the cascade of processes influencing risk propagation and also a valuable tool for analyzing sediment dynamics and improving understanding of interconnected natural hazards. It also offers insights into interactions with other GEORES-related risks, including flooding, slope instabilities, and wildfires.

 # 8 – Utilizzo di dati SAR in banda L (SAOCOM-1) per applicazioni MT-InSAR con algoritmo SPINUA: l'esperienza in GEORES sull'area test in Gargano, Puglia (Italia)

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Il presente contributo illustra i risultati conseguiti nel corso della sperimentazione condotta congiuntamente da GAP, CNR-IREA, UNIBA e ASI nell'ambito del progetto GEORES (Accordo ASI – UNIBA n. 2023-42-HH.0 finanziato da ASI nel programma "Innovation for Downstream Preparation for Science", I4DP_SCIENCE), sull'impiego della tecnica Multi-Temporal Interferometric Synthetic Aperture Radar (MT-InSAR), con particolare riferimento all'algoritmo SPINUA (Stable Point INterferometry even over Unurbanized Areas), per l'elaborazione di uno stack interferometrico di immagini SAR in banda L. La sperimentazione è stata condotta su un'area test localizzata nel promontorio del Gargano (Puglia, Italia), mediante l'utilizzo di 38 acquisizioni della costellazione argentina SAOCOM-1, raccolte nel periodo 2020–2024.

L'obiettivo principale è stato quello di studiare l'applicabilità della tecnica SPINUA ai dati SAR in banda L valutando le prestazioni, in termini di copertura spaziale, geocodifica e coerenza, in corrispondenza dei Persistent Scatterers (PS) identificati sulla scena. A tal fine, i risultati ottenuti elaborando lo stack interferometrico di immagini SAOCOM-1 sono stati confrontati con quelli derivanti da elaborazioni MT-InSAR eseguite su stack interferometrici di immagini SAR in banda C (Sentinel-1) e banda X (COSMO-SkyMed), acquisite sul medesimo territorio.

I risultati ottenuti evidenziano le potenzialità offerte dall'impiego di immagini SAOCOM-1 nell'ambito del monitoraggio geospaziale degli spostamenti del terreno. In particolare, si evidenzia l'ottima copertura spaziale in aree non urbanizzate che, associata a buone prestazioni in termini di geocodifica spaziale e coerenza del dato, nonché di disponibilità di stack con numero adeguato di immagini SAR sul territorio italiano, consente di disporre di un adeguato strumento di monitoraggio di fenomeni di spostamento del terreno a complemento delle attuali missioni in banda C e in banda X.

 # 9 – eXplainable AI (XAI) per l’analisi multirischio in GEORES

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La gestione dei rischi legati al degrado del suolo, come instabilità idrogeologica, alluvioni e incendi nell’interfaccia urbano-rurale, richiede un approccio interdisciplinare basato sull’integrazione di dati geospaziali multisorgente. Il progetto GEORES, Accordo ASI-UNIBA n. 2023-42-HH.0, promosso dall’Agenzia Spaziale Italiana (ASI) nell’ambito dell’iniziativa “Innovation for Downstream Preparation for Science (I4DP_SCIENCE), combina tecnologie di Osservazione della Terra (EO) con l’eXplainable AI (XAI) per analizzare dati da fonti diverse e valutare rischi ambientali in aree urbane e periurbane.

Il progetto ha portato allo sviluppo di un’applicazione geospaziale web-based, utile per comprendere le cause degli eventi estremi e supportare strategie di mitigazione basate sui dati. Il modulo di estrazione multi-rischio individua hotspot relativi a quattro fenomeni: alluvioni, land displacements, connettività del sedimento e incendi.

Per ciascun rischio è stato addestrato un modello di classificazione Random Forest, utilizzando indicatori derivati da modelli del terreno, indici idrologici, copertura vegetale e densità urbana, su una griglia da 100 metri. Il test si è concentrato sul promontorio del Gargano e della zona metropolitana di Bari. Le variabili target derivano da modelli predittivi o dati ufficiali.

Per una valutazione realistica, è stato adottato un metodo di cross-validation spaziale, evitando sovrapposizioni tra dati di training e test. L’analisi XAI tramite valori di Shapley ha permesso di identificare i fattori determinanti delle previsioni, fornendo mappe globali e locali utili per decisioni a livello amministrativo.

L’integrazione tra EO, XAI e strumenti digitali interattivi rappresenta un valido supporto per migliorare la resilienza urbana e favorire azioni mirate nella gestione dei rischi ambientali.

 # 10 – Volcanic Cloud Detection and Retrievals using Satellite, Ground-Based, and Airborne Systems: Validation and Improvement Opportunities with the Integration of LUCE and MAIA Measurements

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Volcanic clouds pose a significant hazard to aviation, human health and climate, demanding accurate and comprehensive detection and monitoring techniques to mitigate these risks effectively.

Over the last few decades, these techniques have included satellite, ground-based, and airborne systems (including balloon-borne sensors). Based on that, procedures have been developed for estimating key volcanic cloud parameters, such as altitude, ash total mass, sulfur dioxide (SO2) total mass, aerosol optical depth (AOD), and effective radius (Re) of ash particles. These procedures are now well-established.

However, several parameters remain challenging to obtain with high accuracy, including ash particle size distribution, ash cloud thickness, ash concentration, and other optical properties of ash particles. In this context, new satellite lidar missions like the ESA's EarthCARE and the ASI's future mission LUCE (Cloud and Aerosol Lidar for Global Scale observations of the Ocean-Land-Atmosphere), as well as the MAIA (Multi-Angle Imager for Aerosols) ASI mission, offer promising avenues for improving the accuracy of these challenging parameters. Indeed, the new available kind of data, such as lidar vertical profiles and multi-angular radiances, can be exploited in synergy with the information gathered by other well-established techniques to define novel operative procedures in support of volcanic emission surveillance.

This work describes the state of the art of volcanic cloud detection and retrievals, the description of the parameters still challenging to be estimated and the opportunities that the measurements coming from the already operative EarthCARE mission and the future LUCE and MAIA missions will offer for enhancing the volcanic cloud characterization.

 # 11 – ADATools for semiautomated geohazard detection from EGMS data

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Ground deformation analysis through satellite Multi-Temporal Interferometry Synthetic Aperture Radar (MTInSAR) techniques is a well-established practice. A significant breakthrough in this field was the Sentinel-1 (S-1) satellites launch in 2014, providing global, open-access, millimetre-accuracy data. This has paved the way for the European Ground Motion Service (EGMS), an unprecedented Land Monitoring initiative within the European Copernicus programme supplying free, homogenous, annually updated S-1 data. Despite its immense potential, EGMS data remain underexploited due to their volume and complexity of interpretation, particularly for non-expert stakeholders. To address this, the European research project EGMS RASTOOL (DG-HECHO), financed by the Union Mechanism of Civil Protection (UPCM) of the European Commission, has developed ADATools for maximising EGMS utility for geohazard detection and risk assessment. ADATools enable the semiautomatic identification and classification of Active Deformation Areas (ADAs). This study applies ADATools to the Lazio region (Italy), showing their structure and functionality in detecting areas affected by different types of ground movements. The analysis covers the whole region, with three case studies focusing on settlement, the most widespread deformation, landslides, and sinkholes, a well-known issue in the region. Results highlight the effectiveness of

semi-automatic methods for interpreting S-1 data, offering a replicable framework for geohazard analysis.

 # 12 – National-scale multi-risk mapping for cultural heritage preservation

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In recent decades, the increasing frequency and intensity of natural hazards have made the protection and preservation of cultural heritage more critical than ever. Given their role in community identity, resilience, and economy, multi-hazard risk assessments are essential for informed policies and effective protection strategies. In this context, geomatics and Earth observation technologies offer valuable tools to support multi-risk assessments at various scales. This work presents a national-scale multi-risk map for cultural heritage in Italy, integrating geospatial datasets and hazard information related to floods, earthquakes, landslides, and wildfires. The exposure layer, provided by the Italian Ministry of Culture, includes over 180,000 cultural heritage sites, grouped into three broad categories (Architectural, Archaeological, Green/Open Spaces) and further detailed into 393 specific typologies (e.g., abbey, archive, arch). A new taxonomy comprising 30 categories was developed, combining geometric attributes (e.g., height, underground positioning, shape) with structural typologies (e.g., defensive architecture, repositories of valuable content). Vulnerability levels for each class were assigned qualitatively based on expert judgment and existing literature. Hazard layers were sourced from authoritative national datasets: the Italian landslide inventory (ISPRA), flood risk management plans (Hydrographic District Authorities), peak ground acceleration maps (INGV), and wildfire hazard data (CIMA Foundation). The analysis was conducted within a GIS environment, where risk aggregation was performed at the municipal level to produce a composite multi-risk map. The use of geomatic techniques, especially spatial analysis, classification, and geospatial modelling played a central role in developing the framework. Moreover, satellite-based data are being considered to validate hazard layers and improve the delineation and characterization of risk areas. This direction is part of ongoing research that will be further developed at a finer spatial scale, where the integration of satellite-derived information is expected to enhance dynamic monitoring of hazards and exposed cultural assets.

 # 13 – Monitoring the Impact of Drought and Climate Change on Hydrological Ecosystems: A Satellite-Based Approach to the Southern Iraqi Marshlands

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Iraq and the Mediterranean Basin are among the regions in the world that are most suffering environmental challenges due to drought and climate change, with impacts on water resources, ecosystems, and human livelihoods. The Ahwar of southern Iraq, a UNESCO World Heritage Site known for its rich biodiversity and historical importance, is highly vulnerable. Located in the Tigris-Euphrates delta, these marshlands have experienced severe degradation over recent decades due to upstream dam construction, unsustainable water management, and the increasing effects of climate change. Rising temperatures and decreasing precipitation have exacerbated drought conditions, accelerating desertification and reducing freshwater availability. The critical state of these wetlands raises concerns about their potential disappearance if effective interventions are not implemented. In this context, satellite-based Earth Observation (EO) technologies have become essential for tracking and analyzing environmental changes. Remote sensing enables timely monitoring of inland waters and wetland extent, soil moisture levels, and long-term trends in water availability. This study examines the complex interactions between climate change, human activities, and the water cycle in Southern Iraqi Marshlands, where there is a real threat for desertification. A multi-sensor data approach was employed, analyzing time series of optical satellite data over 9 years. Optical datasets from Landsat and Sentinel-2 were used to assess land cover changes, vegetation health, and surface water resources. Normalized Difference Vegetation (NDVI), Normalized Difference Water (NDWI) and Moisture Indexes were applied for automated classification of land and water changes. The analysis revealed a steady decline of Iraq's southern marshlands, linked to a long-term drying and shrinking process driven by human interventions since the 1990s-2000s. Yearly maps show the severity of this hazard and allow for a quantitative assessment. The findings demonstrate the effectiveness of EO-based methods in understanding complex environmental trends and informing climate adaptation strategies. The longer-term perspective of this study is to consolidate the use of satellite-derived thematic products to document and investigate the ecosystem dynamics in arid and semi-arid regions, emphasizing the practical benefit of data-driven approaches to inform mitigation strategies to withstand adverse effects of climate change on fragile ecosystems.

 # 14 – Monitoring of surface and water levels of inland resources in central Italy using COSMO-SkyMed imagery

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Hydrological drought is one of the most severe impacts of climate change since it significantly reduces the availability water resources. This study proposes a workflow leveraging SAR data from COSMO-SkyMed STRIPMAP imagery to monitor water levels and surface extents, offering an alternative to conventional gauge stations measurements. The methodology for the estimation of water surface involves a radiometric algorithm analysing the differences in the backscattering coefficient assumed at the pixel level. Image quality was enhanced using histogram equalization and bilateral filtering, while Otsu and k-means classification techniques were tested to segment water, land, and border areas. The workflow was applied to Albano Lake in Italy as a first case study. Validation with manually digitalized reference masks showed high accuracy, with F1 scores of 0.997 for Otsu's method and 0.996 for k-means clustering, respectively. To estimate water levels, a novel physical model was developed to correlate the variations in water levels across different coastal regions with local morphology and the geometric characteristics of SAR data acquisition. After the coregistration between images, an image matching algorithm was applied to detect changes in the coastline's range direction between different epochs. These displacement values served as input to the model, which then estimated the corresponding water level variations over the observed period, as well as the average slope of the analysed coastline. Initial tests conducted on Lake Trasimeno in Italy demonstrated high accuracy of the level variations, with discrepancies between model estimates and gauge station measurements below 10 cm. This research was performed in the framework of the GRAW project, funded by the Italian Space Agency (ASI), Agreement n. 2023-1-HB.0, as part of the ASI's program "Innovation for Downstream Preparation for Science" (I4DP_SCIENCE).

 # 15 – Italian lakes water level monitoring through GEDI and SWOT data

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Inland water bodies provide vital freshwater for various purposes, including domestic use, industrial applications, and agricultural irrigation. Tracking their water levels is essential to assess the effects

of climate change and human intervention on these valuable resources. Traditionally, this monitoring has relied on gauge stations. However, deploying such stations on a global scale is impractical due to the high costs involved in their installation and upkeep, as well as the often remote locations of many reservoirs. Additionally, much of the collected on-site data remains inaccessible due to governmental limitations. Consequently, there is a pressing need for efficient, modern methods to uniformly monitor inland water levels on a broader scale. Advances in remote sensing technology now make Earth Observation (EO) a viable and cost-effective solution for large-scale, long-term monitoring of surface water resources.
This research is precisely included in this context, aiming to produce refined continuous water level time series for inland water bodies by analysing the data collected by two satellite altimetry missions: the Global Ecosystem Dynamics Investigation (GEDI) and the Surface Water and Ocean Topography (SWOT) missions. Therefore, understanding the limitations, accuracy, and precision of these two sensors is essential for ensuring a reliable integration of data from both sources, reducing also the overall revisit time, particularly as GEDI is scheduled for reactivation while SWOT continues monitoring water levels.

GEDI and inland water levels

GEDI [1,2] is a spaceborne LiDAR altimeter able to collect high-resolution measurements (25m footprint size) of Earth's surface, focusing on canopy and terrain. GEDI is hosted on the International Space Station and collects measurements within the latitude range of 51.6°N to 51.6°S. Its revisit time varies from a few hours to several days, depending on the location, spatial extent and orientation of the region of interest. GEDI's complete dataset, covering from March 2019 to March 2023, is available on Google Earth Engine (GEE), a cloud-based platform integrating multiple datasets with advanced analysis capabilities [3].

The first part of this study evaluated the accuracy of GEDI altimetric data for lake water level monitoring by comparing GEDI water level measurements with ground truth data and proposes a robust outlier detection methodology directly implemented within GEE. In particular, a selection of lakes across Italy was analyzed for the period from April 2019 to June 2022 [4].

The proposed outlier detection workflow consists of a two-step process. The first step involves the removal of invalid data relying directly on GEDI metadata: measurements flagged as invalid by the "quality_flag" (indicating signal anomalies) and "degrade_flag" (pointing or positioning degradation) are indeed removed. The second step consists of an iterative 3NMAD-based test: measurements outside the range of -/+3*NMAD (Normalized Median Absolute Deviation) from the spatial median of the epoch of each lake were classified as outliers and removed.

We first applied the developed workflow to 4 lakes in Northern Italy, for which the gauge measurements were available: Garda, Como, Iseo, and Maggiore. After the outlier removal, we observed an overall intrinsic precision (mean over the 4 lakes of the per-epoch spatial NMADs over all the available epochs for each lake) of 0.11 m for the studied period. Additionally, the methodology was applied to six smaller lakes in the Lazio region (Trasimeno, Bolsena, Nemi, Albano, Bracciano, and Martignano, 1–150 km^2), where no gauge measurements were available. GEDI successfully measured water levels for these lakes with an intrinsic precision (NMAD) better than 10 cm with an acceptable number of acquisitions (between 6 to 36 measurements, depending on the area of the lake).

SWOT altimetry and water surface elevation

The SWOT mission, led by NASA in collaboration with CNES, employs a Ka-band Radar Interferometer (KaRIn) as its principal instrument. This altimeter provides extensive global coverage, monitoring 86% of Earth's surface between 77.6° S and 77.6° N, with a 100 m pixel size with a revisit time of 21 days during its three-year mission [5].

The SWOT mission was launched in December 2022, unlike GEDI, with the primary objective to provide the first worldwide inventory of water resources, including rivers, lakes, and reservoirs, to observe the fine details of the ocean surface topography, and to measure how terrestrial surface water bodies change over time [5]. SWOT data acquisition started between April and August 2023, depending on the lake's location, aligning closely with the temporary decommissioning of the GEDI mission.

Considering the SWOT v2.0 product (SWOT_L2_HR_Raster_2.0) from April 2023 to September 2024, the sensor achieved a 92% correlation with in situ gauge measurements, detecting water level variations with an average precision of ~0.06 meters over lakes in Northern Italy and Switzerland. For ungauged lakes in Central Italy, the spatial NMAD of the SWOT pixels within the lake boundary for each epoch was under 10 cm, with the difference between the per-epoch spatial mean and the per-epoch spatial median below 15 cm for most of the epochs, indicating minimal outlier presence.

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 # 16 – Testing the potentialities of SAOCOM L-band data for retrieving superficial soil moisture at the field scale

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Agricultural drought is particularly challenging to monitor as its effects can only be detected months after its manifestation. It is indeed defined as a shortage of water availability in the soil and a subsequent loss of yield, the latter being generally estimated at the field scale. Soil moisture content is thus one of the main parameters for monitoring agricultural drought, but retrieving information on its evolution is particularly challenging.

High resolution soil moisture information can be estimated from SAR images. However, at these resolutions, the hypotheses that can be fulfilled at lower spatial scales may not be respected. Indeed, for working at the field scale, the seasonal evolution of the vegetation and the presence of dominating subsurface scattering should be accounted for and modelled while estimating the soil moisture.

In the frame of the GRAW project, funded by the Italian Space Agency (ASI), Agreement n. 2023-1-HB.0, as part of the ASI's program "Innovation for Downstream Preparation for Science" (I4DP_SCIENCE), this contribution presents a preliminary analysis on the modelling of the subsurface scattering and of the seasonal contribution of the vegetation for soil moisture retrieval purposes at the field scale. L-band data of the SAOCOM mission are used over a case study located in an agricultural area in Spain, where surface soil moisture measurements from the REMEDHUS network are available as reference data.

Given the presence of a not negligible geolocation error in SAOCOM data with respect to the spatial scale of analysis, a proper preprocessing workflow was applied to the data to correct their geolocation. After that, the presence of mixed surface and subsurface scattering was detected at the field scale, as previously detected over the same area by using C-band data of the Sentinel-1 mission, and the field scale seasonal contribution of the vegetation was analyzed.

 # 17 – Harnessing Earth Observation and AI for hot and dry multi-hazard risk assessment: a case study in the Adige River basin

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Multi-hazard events pose increasing challenges, presenting serious threats to populations, ecosystems and economy. Addressing these events and building disaster risk reduction capacity is crucial. This requires leveraging advanced technologies such as Earth Observation (EO) and Artificial Intelligence (AI) and integrating them into effective multi-risk assessment frameworks. This study, conducted within the ESA EO4MultiHazard project, aims to exploit EO data to investigate compounding and consecutive hot-dry events (heatwaves and droughts) and their impacts on crops in the lower Adige River Basin. The Adige River serves as a critical resource for the area's intensive agriculture, as its waters supply a dense irrigation network, making it especially vulnerable to reduced water availability during hot-dry conditions.

The methodology identifies spatiotemporal hazard footprints and assesses exposure, vulnerability and crop impacts. The multi-hazard analysis was adapted from MYRIAD-EU project and applied to the Adige River Basin to investigate hot-dry events in the timeframe (1981–2024) using the SCIA-ISPRA dataset. This analysis, based on DBSCAN clustering, enabled the identification of drought and heatwave trends, as well as the most severe and relevant events. The 2022 drought was selected to estimate risk and multi-hazard impacts on crops, combining EO (Sentinel-2) and in-situ information for irrigation network, irrigation districts, river discharge, and crop species at the field level. Vegetation stress responses to hot-dry events were analysed using satellite-based indexes (e.g., NDVI, NDWI, …) as proxies for crop impacts enabling the application of AI regressions (Random Forest, Neural Networks) and explainability frameworks (SHAP) to investigate the role of the different risk predictors. This approach identifies the most susceptible areas and the main risk factors, paving the way for future climate multi-risk assessment and adaptation strategies.

 # 18 – Estimation of Irrigation Needs by Monitoring Crop Rotations and Phenology of Tomato in Southern Italy

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The ASI funded research project "EarTH Observation for the Early forecasT of Irrigation needsS (THETIS)" (Agreement N. 2023-52-HH.0 in the framework of ASI's program "Innovation for Downstream Preparation for Science", I4DP_SCIENCE) aims to build a spatial decision support system (SDSS) capable of providing, at the watershed scale, estimates of crop water needs to water supply and management agencies with the goal of improving services to farmers.

The components of the SDSS are: a hydrological model; a crop growth model; earth observation data; artificial intelligence techniques.

Earth observation data were used to estimate the transplanting dates of processing tomato in the study area (Capitanata plain, Southern Italy). Sentinel-2 images were used to calculate the Leaf Area Index of tomato fields from 2000 to 2024, utilizing the biophysical processor in ESA's SNAP application. Additionally, in District 6/B of the Consortium, the crop rotations were studied to evaluate the occurrence of tomato.

The results of the phenological study showed that about 50% of tomato fields are transplanted around 15th May and the other half around 15th June.

Regarding crop rotation on an agricultural area of 14,075 hectares, an analysis of the past five years (2020-2024) showed the following distribution: almost half of the area (65.70%) was not cropped with tomato, 26.72% hosted tomato only for one year, 2.67% for 2 or 3 consecutive years, the remaining area hosted tomato for two times but with an interval of 2 years (2.21%), 1 year (1.90%) and 3 years (0.79%).

This study will allow early identification of likely tomato fields (spatial position and area) on 1st April of each year for the THETIS project; these fields are then associated with soil characteristic parameters and forecast weather data to start the simulation of the entire irrigation district with the Aquacrop crop model in the Python version, to simulate the predicted fields and estimate early irrigation requirements.

 # 19 – Early detection of soil salinization by means of EnMAP hyperspectral imagery and laboratory spectroscopy

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Soil salinization is the build up of soluble salts in the topsoil, measured as Electrical Conductivity (EC – dS/m). Progressively Increasing concentrations of salt in soil leads to crop productivity decreases and ultimately, soil sterility. In a global perspective, food production is predicted to increase by 62% by 2050, while soil salinization has increased by 16.8% in the period 1986-2016, posing a serious threat to the future of soil health and food production. Salt affected soils present complex spectral characteristics, with limited absorption features and strong modifications of surface reflectance. The entity and magnitude of spectral modifications is function of salt concentrations. The available literature shows how, successful salinity detection applications rely on very high salt concentrations (9.80 dS/m) to maximize salt spectral evidences and detection capabilities. With EnMAP deployment, its unprecedented radiometric and spectral characteristics have opened new possibilities for the detection of salt related spectral modifications. Therefore, we investigated EnMAP's detection capabilities for low levels of salinization, corresponding to the early stages of the phenomenon. To compare the prediction performance of spaceborne derived models, we adopted laboratory derived spectra modelling results as a benchmark. The area under analysis is located in central Italy, Tuscany region, in the province of Grosseto. Extensive agriculture combined with an evapotranspiration to precipitation ratio deficit of -400 mm resulted in an overexploitation of the groundwater reservoir. The area proximity to the coast and the numerous channels allow for seawater intrusion during storm surges, contributing, with other geological sources to the total cations and anions budget. We conducted field acquisitions at the apex of the dry season, in September 2023, to maximize the probability of surface salt efflorescence occurrence. Field samples were collected within 3 days from the EnMAP acquisition, with no rainfall occurrence. Soil samples were processed according to FAO (FAO. 2021. Standard operating procedure for soil electrical conductivity, soil/water, 1:5. Rome.) salinity assessment guidelines and EC was measured. For the same field samples, we acquired laboratory spectra according to the procedure described by Gholizadeh (Gholizadeh, A., Neumann, C., Chabrillat, S., van Wesemael, B., Castaldi, F., Borůvka, L., Sanderman, J., Klement, A.; Hohmann, C. (2021). Soil organic carbon estimation using VNIR–SWIR spectroscopy: The effect of multiple sensors and scanning conditions. Soil and Tillage Research, 211, 105017). Concomitantly, EnMAP image spectra were extracted for the location of the collected field samples. Both laboratory and EnMAP derived spectra were tested to define the best preprocessing – regression algorithm combination for salinization detection. The preprocessing methods tested included Savitzky-Golay filters, continuum removal, PCA and Norris gap derivatives. Similarly, the regression models used were PLSR, 2D Correlograms and a hyperparameter tuned Random Forest Regressor. Model results for laboratory derived spectra were considered as reference for maximum model prediction capability, allowing us to assess the satellite derived model predictions. Among the models tested, the correlogram derived best band – index combination resulted in a R^2 of 0.88 for laboratory data and 0.63 for EnMAP data. PLSR proved to have the worst performance on both datasets. Random Forest Regressor proved its capability in detecting complex spectral features, with R^2 scores of 0.72 for laboratory data and 0.60 for EnMAP. Considering only the EnMAP derived spectra, the best correlogram derived index, when applied to the whole spaceborne image resulted

in a poor generalization of the salinity spatial extent and concentration. Differently, the trained Random Forest Regressor upon deployment on the whole image was able to capture the spatial variability of the phenomenon, with concentration value predictions in accordance with field observations and expert knowledge. Overall, the results testify EnMAP data quality. Similar statistical performances of the models tested validates our hypotheses on the feasibility of spaceborne early detection for topsoil salinization. Considering the research outlook, the high spatial and temporal variability of salinity requires extensive field sampling efforts to capture the condition of the phenomenon. Consequently, validation of the predictions with new field evidences represents a challenge we will focus and tackle in future research developments. In addition, the acquisition of new and numerous salt affected soil spectra could be beneficial to increase the model prediction and generalization capabilities, potentially allowing a transition from a site-calibrated model to a model capable of generalizing dynamics across previously unseen areas.

 # 20 – Aligning Evapotranspiration from MOD16A2.061 Product to Ground Estimates in Piemonte (NW Italy): an analysis of temporal and spatial biases

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L’evapotraspirazione (ET), e in particolare l’evapotraspirazione di riferimento (ET_0), rappresenta un parametro chiave per la pianificazione agricola, la gestione dell’irrigazione e la distribuzione delle risorse idriche, soprattutto in aree soggette a scarsità idrica. Sebbene l’ET_0 venga normalmente stimata da dati meteo tramite il metodo FAO Penman-Monteith, i prodotti satellitari come MOD16 offrono una copertura spaziale molto più ampia, pur presentando differenze concettuali e metodologiche rilevanti. In particolare, MOD16 fornisce stime dell’evapotraspirazione potenziale (PET), che, a differenza di ET_0, dipendono dalle caratteristiche della vegetazione, e non da una superficie di riferimento standard.

Questo studio valuta la possibilità di utilizzare i dati PET del prodotto MOD16A2GF (versione 6.1) per stimare l’ET_0 in Piemonte (Italia nord-occidentale), una regione caratterizzata da elevata variabilità climatica e morfologica. I dati PET del periodo 2010–2022 sono stati confrontati con le stime di ET_0 calcolate da dati meteorologici a terra, applicando un metodo di correzione del bias basato su modelli di regressione lineare tarati su serie storiche locali. Il dataset corretto mostra un miglioramento significativo nella coerenza con le stime da terra, con una riduzione dell’errore assoluto medio da 10,06 mm/8 giorni a 2,48 mm/8 giorni (–75%). La correzione si è dimostrata solida su scala regionale e particolarmente efficace nei mesi estivi, quando una stima accurata dell’ET_0 è cruciale per l’irrigazione delle colture.

I risultati indicano che, con un’adeguata calibrazione locale, i dati PET di MOD16A2GF possono costituire una valida alternativa alle stime da terra dell’ET_0 in contesti a bassa disponibilità di dati. Ricerche future dovranno esplorare l’influenza di ulteriori fattori, come altitudine e la copertura del suolo, per affinare ulteriormente la precisione delle stime satellitari e migliorarne l’applicabilità in condizioni climatiche e territoriali diversificate.

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21 – Confronto di algoritmi per la classificazione delle colture nel contesto dei controlli per la PAC

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Nell'ambito della Politica Agricola Comune (PAC), gli Organismi Pagatori controllano che le dichiarazioni degli agricoltori finalizzate all'ottenimento dei contributi siano conformi con quanto è coltivato in ciascun appezzamento dichiarato. La Commissione Europea sostiene la missione satellitare Copernicus Sentinel-2 come uno dei principali strumenti per ottemperare alle verifiche delle dichiarazioni. A partire dai dati Sentinel-2 è possibile generare mappe di indici spettrali, come il. *Normalized Difference Vegetation Index* (NDVI); possono inoltre essere analizzate le relative serie multi-temporali al fine di monitorare la fenologia delle diverse colture. I profili multi-temporali così ottenuti possono essere utilizzati all'interno di opportuni algoritmi di classificazione (*supervised* e *unsupervised*) con lo scopo di identificare la coltura presente in campo. Nel lavoro proposto, sono stati confrontati diversi approcci e algoritmi classificativi come *rules based, minimum distance, random forest* e *artificial neural network*. A partire dall'interpretazione delle matrici di confusione ottenute dal confronto tra la classificazione e i dati di validazione a terra forniti dall'Agenzia Piemontese per le Erogazioni in Agricoltura (ARPEA) si sono infine valutate e confrontate le performance di ciascun algoritmo. Nel presente lavoro viene illustrata l'analisi preliminare per l'individuazione dei profili monomodali e bimodali all'interno dell'anno agronomico di riferimento (1° novembre – 30 ottobre) per la definizione di macro-classi colturali, come le monomodali annuali (invernali o estive), le bimodali e i prati su un'area pilota in Piemonte, con l'obiettivo futuro di definire una classificazione più dettagliati sull'intera superficie piemontese.

22 – Il monitoraggio dei cambiamenti della copertura nevosa nell'area delle Alpi Occidentali utilizzando i dati MODIS e Google Earth Engine

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In un'era segnata dall'emergenza climatica, l'osservazione e il monitoraggio della risorsa idrica, nelle sue diverse forme, rivestono un'importanza cruciale. Questa ricerca si focalizza sull'analisi della neve, un componente fondamentale del ciclo idrologico, con l'obiettivo primario di mappare e comprendere le variazioni nella sua persistenza a livello regionale, quantificando le tendenze nel tempo per supportare una pianificazione e una gestione strategica dell'utilizzo dell'acqua. Questa ricerca si concentra sul Piemonte e la Valle d'Aosta, con l'obiettivo di mappare i cambiamenti nella persistenza della neve (SP) e quantificarne le tendenze dal 2000 al 2023. Sono stati utilizzati dati giornalieri di copertura nevosa MODIS, processati tramite Google Earth Engine, trasformando la percentuale di copertura in ettari (Snow Cover Area, SCA). Una classificazione binaria (presenza/assenza di neve) è stata applicata per derivare la persistenza nevosa. La validità di questo approccio è stata confermata confrontando la SP derivata dai dati satellitari con le misurazioni delle stazioni nivometriche locali, ottenendo un errore medio di soli 10 giorni all'anno. Successivamente, lo stack di SCA è stato analizzato a livello di pixel utilizzando una regressione lineare in ambiente R per mappare il trend ventennale delle aree innevate, indicativo delle riserve idriche. Normalizzando il trend con l'offset della regressione, è stato possibile confrontare diverse zone. L'analisi multitemporale evidenzia le dinamiche nevose e le problematiche di stock idrico, fornendo un supporto cruciale per le istituzioni locali, in particolare nelle pianure e nelle valli dove i trend negativi risultano più evidenti.

 # 23 – Analyzing Crop Rotation in Flood-Prone Areas through Spatially Based Approaches Relying on Official Geographical Data

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Comprendere e studiare approfonditamente la rotazione delle colture è essenziale per ottimizzare la gestione agricola e monitorare i cambiamenti nel paesaggio agricolo, che limitano nel tempo l'affidabilità delle mappe colturali. Per la valutazione dei danni, è fondamentale considerare la frequenza di aggiornamento delle mappe al fine di generare stime accurate del valore agricolo esposto a potenziali danni. Pertanto, monitorare i modelli di rotazione delle colture e la loro evoluzione nel tempo è fondamentale per analizzare i cambiamenti nella gestione del territorio, fornendo preziose informazioni sull'esposizione delle aree agricole ai rischi di inondazione e siccità. L'area di studio corrisponde alle mappe di pericolosità dell'Autorità di Bacino Distrettuale del Fiume Po (AdBPo), che identificano le aree soggette a inondazioni.

Un'ulteriore fonte informativa è stata considerata grazie ai risultati del progetto MOVIDA *("MOdello per la Valutazione Integrata del Danno Alluvionale"*), che ha migliorato la valutazione dell'esposizione agricola al rischio di alluvione. La mappatura delle colture si basa sull'utilizzo delle GSAA (Geo Spatial Aid Applications), dichiarazioni colturali presentate dagli agricoltori in fase di richiesta contributi della Politica Agricola Comune (PAC). I dati di riferimento utilizzati riguardano le Regioni Piemonte, Lombardia, Emilia-Romagna e Veneto. L'obiettivo è valutare la rotazione colturale negli stessi appezzamenti nel tempo e identificare tendenze o cambiamenti significativi nei sistemi colturali. La metodologia prevede lo sviluppo di Mappe di Variabilità Colturale (CVM) per evidenziare la diversità spaziale e Mappe di Probabilità Colturale (CPM) per prevedere la presenza di colture in specifiche località. Inoltre, è stato mappato l'indice di Shannon-Wiener (ShI) per analizzare la diversità degli agroecosistemi e l'entropia agronomica con un approccio spazio-temporale. I risultati offrono indicazioni utili sulle tendenze colturali e sui fattori ambientali e socio-economici, supportando agricoltori ed enti regolatori nella pianificazione, gestione delle risorse e riduzione del rischio, per un'agricoltura più resiliente e sostenibile.

 # 24 – A Possible Role of NDVI Time Series from Landsat Mission to Characterize Lemurs Habitats Degradation in Madagascar

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La deforestazione è uno dei principali fattori del degrado ambientale globale. Il metodo "slash-and-burn", comunemente praticato per creare di nuovi terreni agricoli, interessa molte aree naturali del Madagascar che gli habitat dei lemuri. La riforestazione delle riserve naturali, utilizzando specie autoctone a crescita rapida (bambù), può sostenere il ripristino degli habitat e contribuire alla ripresa vegetativa. In questo contesto, l'identificazione dei disturbi forestali può supportare il ripristino vegetativo massimizzando i benefici ecologici. Questo studio si concentra su aree interne alla foresta di Maromizaha (Madagascar), analizzando le serie multi-temporali NDVI delle missioni Landsat (GSD = 30 m) nel periodo 1991–2022. L'obiettivo era identificare la posizione e la tempistica dei disturbi forestali, quantificare i danni e il recupero in ciascun sito disturbato. In particolare, lo studio si concentra sull'analisi degli effetti su 4 specie di lemuri, ovvero l'indri (*Indri indri*), il sifaka diadema *(Propithecus diadema)*, il vari bianconero (*Varecia variegata editorum*) e l'apalemure grigio (*Hapalemur griseus*). Il rilevamento dei disturbi è stato effettuato a livello di pixel analizzando i profili temporali NDVI (annuali). L'anno del disturbo è stato identificato considerando il valore minimo della derivata prima dell'NDVI, e la significatività del cambiamento NDVI è stata analizzata utilizzando la disuguaglianza di Chebyshev. Inoltre, sono stati mappati i seguenti parametri: i) anno del disturbo; ii) significatività del cambiamento NDVI; iii) livello di danno; iv) anno del recupero vegetativo; v) velocità di recupero. Le metriche di danno e recupero sono state utilizzate per stimare gli indici di resistenza e resilienza degli habitat forestali che ospitano i lemuri. Le tendenze temporali della perdita e del recupero forestale sono state poi analizzate per valutare i potenziali impatti sulle popolazioni di lemuri e sull'intero ecosistema della riserva.

 # 25 – Monitoraggio ad Alta Risoluzione delle Isole di Calore Urbane

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Nell'ambito dell'Iniziativa Città Verdi per l'Africa della FAO, abbiamo sviluppato un'applicazione avanzata che elabora dati termici orari provenienti da satelliti geostazionari per generare mappe di temperatura superficiale ad alta risoluzione. Sfruttando un sofisticato algoritmo di downscaling, il nostro sistema integra osservazioni satellitari a bassa risoluzione con dati ausiliari—come uso del suolo, velocità del vento e modelli digitali di elevazione—raggiungendo un errore quadratico medio (RMSE) di appena 1,86°C nello studio pilota di Abidjan.

La piattaforma è specificamente progettata per rilevare e caratterizzare le Isole di Calore Urbane (ICU) a intervalli orari, consentendo un'analisi dettagliata della loro formazione, dei gradienti di intensità e dell'evoluzione spazio-temporale. Questo monitoraggio ad alta frequenza offre informazioni cruciali per climatologi urbani e decisori politici che formulano efficaci politiche di mitigazione del calore nelle aree ad alto rischio.

La metodologia è statisticamente robusta, scalabile e facilmente trasferibile, offrendo una soluzione replicabile per utenti istituzionali in diversi ambienti urbani.

High-Resolution Urban Heat Island Monitoring

As part of the FAO's Green Cities Initiative for Africa, we have developed an advanced application that processes hourly thermal data from geostationary satellites to generate high-resolution surface temperature maps. Leveraging a sophisticated downscaling algorithm, our system integrates coarse-resolution satellite observations with auxiliary data—such as land use, wind speed, and digital elevation models—achieving a root mean square error (RMSE) of just 1.86°C in the Abidjan pilot study.

The platform is specifically designed to detect and characterize Urban Heat Islands (UHI) at hourly intervals, enabling detailed analysis of their formation, intensity gradients, and spatiotemporal evolution. This high-frequency monitoring offers critical insights for urban climatologists and decision-makers formulating effective heat mitigation policies in high risk areas.

The methodology is statistically robust, scalable, and readily transferable, offering a replicable solution for institutional users across diverse urban environments.