

RestorEO

A transparent EO-based monitoring system for biodiversity and ecosystem restoration

Programm / Ausschreibung	ASAP, ASAP, ASAP 18. Ausschreibung (2021)	Status	abgeschlossen
Projektstart	01.09.2022	Projektende	31.08.2025
Zeitraum	2022 - 2025	Projektlaufzeit	36 Monate
Keywords	biodiversity, restoration, habitat, EO, CBD, reporting		

Projektbeschreibung

Der Verlust an biologischer Vielfalt, von der wir alle abhängen, schreitet schneller denn je voran. Im Zusammenhang mit dem Europäischen Green Deal und dem UN-Übereinkommen für die biologische Vielfalt wurde in der EU Biodiversitätsstrategie 2030 als einer der zentralen Inhalte die Erstellung eines EU-weiten Plans zur Wiederherstellung der Natur angekündigt. Im Rahmen dieses Plans wird die Europäische Kommission (voraussichtlich bis Ende 2021) rechtlich verbindliche Ziele für die Wiederherstellung der Natur formulieren. Diese Initiative wird zu dem Ziel der Biodiversitätsstrategie beitragen, Europas biologische Vielfalt bis 2030 und darüber hinaus auf den Weg der Erholung zu bringen. Über die Maßnahmen, Umsetzungen und die Erreichung dieser rechtlich verbindlichen Ziele müssen die Länder daher zukünftig auch entsprechend berichten. Für diese Berichte wird ein quantitatives und transparentes, rechtlich anerkanntes Monitoringsystem benötigt, das zuverlässige Informationen über den Biodiversitätsstatus liefert und imstande ist, die zuständigen öffentlichen Stellen bei ihren Monitoringverpflichtungen zu entlasten. Ein solches Monitoring gibt es derzeit noch nicht. Bestehende österreichweite Monitoring-Vorhaben (zB FFH-Art. 11 Monitoring, Biodiversitätsmonitoring) werden derzeit auf Basis von Stichproben durchgeführt. Solche statistischen Ansätze sind zwar großflächig (zB für ganz Österreich) präzise genug, um politikrelevante Aussagen treffen zu können. Für die Evaluierung lokaler Restaurationsprojekte sind sie aber nicht nützlich, weil es sehr unwahrscheinlich ist, dass eine ausreichende Stichprobe dieser Projekte (oder überhaupt eines dieser Projekte) in die bundesweite Monitoring-Stichprobe fällt. Weiters sind solche Stichprobenaufnahmen im Feld mit hohem Kosten- und Zeitaufwand verbunden, was einer häufigen Aktualisierung und damit der Bereitstellung von zeitlich aktuellen Informationen im Wege steht.

RestorEO will diese Lücke schließen, indem die bestehenden Feldarbeiten mit Copernicus und anderen Fernerkundungsdaten kombiniert werden, um ein flächenhaftes und quantitatives Monitoring des Degradationsstatus bzw. der Integrität von wichtigen Ökosystemen zu entwickeln. Für die Entwicklung und Pilotierung wurden Ökosysteme anhand von folgenden Kriterien ausgewählt: 1) Auf Basis der im Endbericht "Strategischer Rahmen für die Restauration von Ökosystemen" [Paternoster et al., 2021] durchgeführten Zustandsbewertung der Degradation von Ökosystemen und Landschaften und der identifizierten Prioritäten; 2) aufgrund des Potenzials von Copernicus und anderen Fernerkundungsdaten für das Monitoring dieser Ökosysteme und 3) aufgrund des CO2 Bindungspotentials dieser Ökosysteme. Dieser Auswahlprozess ist auch an den Prioritäten der Europäischen Kommission zur Wiederherstellung von degradierten Ökosystemen angelehnt. Aus diesen

Kriterien wurden drei Ökosysteme abgeleitet, die in RestorEO behandelt werden: Wald, Feuchtgebiete und Grasland-dominierte Kulturlandschaften.

Für das Ökosystem Wald sollen die existierenden Parameter zur Zustandsbewertung ausgehend von Durchschnittswerten pro Bezirksforstinspektion auf flächenscharfe Abbildung weiterentwickelt werden (Baumartenzusammensetzung, Fragmentierung). Zusätzlich werden weitere, für die Bewertung der Biodiversität wichtige Parameter, wie Vertikalstruktur oder Kronendimensionen abgeleitet. Für das Monitoring von Grasland-dominierten Kulturlandschaften sind das die Anzahl der Mähzeitpunkte und die Klassifizierung von Wiesentypen, die aus Sentinel-1 und -2 Zeitreihen abgeleitet und für die Entwicklung von Indikatoren herangezogen werden können. Für Feuchtgebiete spielt die raum-zeitliche Veränderung von Hydrologie und Vegetationsstruktur und die Beobachtung von Indikatorarten eine zentrale Rolle in der Entwicklung des Monitoringsystems. Für alle Ökosysteme gilt es, Veränderungen der Vegetation und der Landnutzung räumlich explizit und möglichst zeitnah abzubilden.

Das Gesamtziel ist es, die öffentliche Verwaltung auf allen Ebenen mit belastbaren Daten und Informationen bei der Berichterstellung zu unterstützen. Durch die räumlich differenzierten Ergebnisse können zusätzlich auch lokale Stakeholder wie Nationalparkmanager, Naturschutzbehörden o.ä. von den Resultaten profitieren, da auf Basis der durch das Monitoringsystems bereitgestellten flächenhaften Informationen zielgerichtete Maßnahmen vor Ort in die Wege geleitet werden können.

Abstract

RestorEO will employ Earth Observation (EO) data to support the National Restoration Plan for Austria. Following the European Green Deal (EGD) and the Convention of Biological Diversity (CBD), countries are obliged to report on their efforts to maintain and restore areas of high biological diversity. This will be further emphasized by the upcoming "EU Nature Restoration Law". For this reporting, a quantitative, objective, transparent and reproducible monitoring concept and its implementation is needed. Currently, monitoring is realized based on sample points, which are regularly visited in the field. This has been the case for example for the National Forest Inventory (NFI) for many years. This sample-based approach has two advantages: first, parameters are measured in the field and are therefore highly detailed. Second, the results for large areas, like for whole Austria, are statistically very accurate. However, sample-based approaches also have significant shortcomings: The regional or local situation can differ significantly from the overall result. Therefore, local estimates are often unreliable and do not allow to draw appropriate conclusions for the application of measures on the local or regional level. Moreover, the field assessments are time consuming and costly.

RestorEO will develop EO-based tools to generate wall-to-wall information for a quantitative monitoring of the status of important ecosystems. We selected the ecosystems due to the following criteria: first, the status of degradation and restoration needs as defined in the framework report by Umweltbundesamt; second, the potential to be leveraged by Copernicus EO data, and, last but not least, the potential to capture CO₂. This approach follows the current working document of the DG-Environment of the EU commission on legally binding restoration targets. This EU initiative focuses on areas with the most potential to: (i) capture and store carbon; (ii) prevent and reduce the impact of natural disasters; (iii) deliver further benefits, such as soil health and pollination; (iv) improve knowledge and monitoring of ecosystems and their services. Following the selection process, the three identified thematic focus areas of RestorEO are: (i) forests, (ii) wetlands, and (iii) grassland-dominated cultural landscapes (short 'grassland').

For forests, methods for the assessment of parameters like vertical structure, species diversity and spatial fragmentation as

well as for the detection of forest cover changes resulting from e.g. wind throws or bark beetle attacks will be developed. Such sudden changes are usually not well represented in sample plots as affected areas are too small. In addition the update cycles are very long for cost reasons and counter measures can therefore not performed on time. For grassland, methods for the assessment of mowing events and grassland types will be developed based on Sentinel-1 and -2 time series data. These parameters can be monitored over time and further used to generate relevant indicators. For wetlands, the water-regime as well as its changes over time and above ground vegetation structure will be investigated. For all habitat types, indicators for degradation like removal of vegetation, soil sealing, change into another land cover / habitat type can be spatially explicitly classified and quantified.

The overall aim is to support the public authorities both on the national and regional level with reliable quantitative data to generate the needed statistics and reports. Due to the spatially explicit nature of the generated results, also the local stakeholders such as national park managers will benefit for targeted measures on the ground.

Endberichtkurzfassung

Project Summary Results of RestorEO

The project RestorEO was designed to support the reporting requirements for the Nature Restoration Law (NRL) leveraging Earth Observation (EO) data and methods . Over the past years, RestorEO has closely followed the evolution of the NRL and continuously adapted to its changing reporting requirements. The project focused on three key land use categories - grassland, wetland, and forest ecosystems - chosen for their high potential in both carbon storage and EO implementation.

Grassland ecosystems

Reporting requirements: The measures taken within the NRL for agricultural ecosystems must lead to an increasing trend at national level in at least two of the following three indicators (cf. Art 11 (2)):

Grassland butterfly index;

Organic carbon stocks in cropland mineral soils; and

Share of agricultural land with high diversity landscape features.

In addition, the common farmland bird index must meet the values defined in Art 11 (3) as a result of these measures.

RestorEO contributions: For the share of agricultural land with high-diversity landscape features , we evaluated the Copernicus Small Woody Features (SWF) layer alongside other data sources, including biotope type maps, INVEKOS datasets, OpenStreetMap data, and the in-situ LUCAS dataset. While the SWF layer provides good spatial coverage, it lacks the thematic detail of biotope type maps, which, in turn cannot be updated frequently enough. Thus, a combination proved to be best suited. The LUCAS dataset, although detailed for sampled areas, does not adequately represent the Austrian landscape, leading to biased impressions of structural features in agricultural areas.

To address these limitations, we developed an alternative approach that evaluates agricultural lands by integrating dedicated features (e.g., hedges, single trees) and surrounding land cover types. For example, this method avoids classifying a meadow surrounded by forest as low in landscape features. Additionally, we created a nationwide system for mowing event detection that operates without training data, yielding results comparable to alternative methods that rely on large, costly training datasets. These results and data for Austria were published in the journal Remote Sensing [Miletich et al., 2025]. This information supports the indicator "grassland butterfly index" and contributes to FFH habitat assessment .

Wetland ecosystems

Reporting requirements: For wetland habitats, the regulation does not contain any specifications regarding the assessment of the degree of conservation of the habitat types. However, measures must be implemented to restore organic soils used for agriculture, including drained peatland soils . These measures must cover, in a first step at least 30% of such areas by 2030, with at least a quarter to be rewetted.

RestorEO contributions: We evaluated various EO datasets to monitor shrub and tree encroachment on peatlands. Sentinel-2 data was found to be too coarse for detecting wood encroachment, while airborne laser scanning (ALS) data performed better in identifying individual trees and shrubs. However, inaccuracies persisted due to small crown sizes and frequent ALS acquisition timing during the leaf-off season. Ultimately, drone-based LS emerged as the optimal EO data source for peatland monitoring both for shrub encroachment and drainage channel mapping for rewetting . Using a Riegl RiCopter, we achieved drainage channel mapping with an depth accuracy of 10 cm, except for channels with standing water. EO data thereby provides a reliable information source for monitoring peatland restoration efforts.

Forest ecosystems

Reporting requirements: The measures taken for forest ecosystems must achieve an increasing trend in the common forest bird index (see Article 12(2)) at national level, as well as at least six of the following seven indicators:

Standing deadwood

Lying deadwood

Share of forests with uneven-aged structure

Forest connectivity

Stock of organic carbon

Share of forests dominated by native tree species

Tree species diversity

RestorEO contributions : We evaluated Copernicus tree cover density data to assess forest fragmentation and connectivity . For lying deadwood , we prepared a field data database and tested the use of drone-based LiDAR for mapping. While automated approaches still lack sufficient accuracy, interpreting LiDAR point clouds from drones is significantly easier than field mapping, especially in rough or hazardous terrain.

We also calculated forest disturbances , including standing deadwood, using Sentinel-2 time series data. For forest structure , we applied multiple partial least squares regression to calculate the GINI index for DBH (diameter at breast height) and tree height variation. These parameters were rolled out for two districts in Styria (Deutschlandsberg and Voitsberg) and two time points (2012 and 2022) using available ALS data to highlight areas of increasing and decreasing structural diversity.

In addition to thematic and scientific advancements, we prioritized dissemination efforts. These included presentations at major scientific events such as IUFRO, Forum Alpinum, ESA Living Planet Symposium, and EARSeL Workshop, as well as science-to-public articles in media outlets like Der Standard and Kronen Zeitung . We also organized two dedicated stakeholder workshops with the final workshop attracting 47 participants from research, administration and businesses.

Conclusion:

The RestorEO project has successfully demonstrated the potential of EO data and methods to support the reporting requirements of the Nature Restoration Law with innovative and transparent monitoring systems.

Projektkoordinator

- Universität Graz

Projektpartner

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- JOANNEUM RESEARCH Forschungsgesellschaft mbH
- Umweltbundesamt Gesellschaft mit beschränkter Haftung (UBA-GmbH)