Policy Paper
Closing the Grassland Monitoring Gap via Earth Observation

Earth Observation solutions for drought resilience, sustainable grazing and climate adaptation

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1 Highlights

The Issue: Grasslands cover one-third of Europe's agricultural area but remain poorly monitored due to complex terrains, resulting in operational data gaps that threaten drought resilience and farm sustainability.

The Findings: Fusing Sentinel-1 SAR, Sentinel-2 MSI, and thermal data allowed the ScaleAgData workflow to accurately map Leaf Area Index (R2 = 0.79) in Alpine meadows and biomass (R2 = 0.95) in Mediterranean agrosilvopastoral systems—successfully navigating complex tree-grass interactions, seasonal water scarcity, and severe drought impacts (biomass drops >40%).

The Recommendations: The European Commission and Member States should establish dedicated funding to support Earth observation methods for heterogeneous grasslands, sustain long-term regional demonstration sites, and finance pilot implementation schemes. Building also on Copernicus base data, they should foster the local development of higher-level EO products and services by research institutions, regional service providers and SMEs.

The Impact: Implementing these tools protects pasture carrying capacity under Mediterranean climate uncertainty, minimizes insurance basis risk (already protecting ~200 farms in Bolzano), counteracts land abandonment, and satisfies calls for results-based policy evidence.

2 Context of the Issue

Policy Landscape: The European Union is currently shaping the post-2027 Common Agricultural Policy (CAP) while simultaneously implementing the Vision for Agriculture and Food, the Water Resilience Strategy, the Nature Restoration Regulation, and the EU Climate Adaptation Strategy. Additionally, the European Commission is developing a dedicated livestock strategy to foster competitiveness, resilience, and sustainability across the EU agri-food chain. These sweeping initiatives require robust, transparent, and objective monitoring tools to support climate adaptation, sustainable grazing, and preventative risk management.

The Challenge: Grasslands account for roughly one-third of Europe’s agricultural area and provide essential ecosystem services, including high-quality livestock production, biodiversity conservation, carbon storage, and water regulation. However, climate change is actively increasing the frequency and severity of droughts, making timely information on grassland productivity a matter of ecological and economic survival. Between 2010 and 2020, the number

of extensive and mixed-livestock farms in Europe plummeted by more than 70%. Without intervention, Alpine and Mediterranean grassland management face severe threats from land abandonment, alongside subsequent shrub and forest encroachment.

Project Gap: Despite their importance, grasslands are among the least accurately monitored ecosystems in Europe. Existing operational Earth Observation (EO) products fail in highly heterogeneous landscapes—such as mountain meadows and Mediterranean savannas—where steep topography, fragmented management, mixed vegetation, and tree-grass interactions drastically reduce the reliability of standard satellite-derived indicators.

3 Policy Recommendations

Recommendations

1. Launch Dedicated Funding Programs for Heterogeneous Grassland Methodologies

- Action: Direct targeted funding to develop, scale, and validate advanced EO methodologies specifically engineered for complex grassland ecosystems.
- Urgency/Impact: High. Current operational state-of-the-art products suffer from severe limitations in fragmented or topographically challenging areas.

2. Support Long-Term Demonstration and Validation Sites

- Action: Establish and maintain robust validation infrastructures across representative European grazing landscapes, specifically targeting mountain meadows/pastures and Mediterranean silvopastoral systems.
- Urgency/Impact: High. This directly improves the operational uptake and cross-regional reliability of Copernicus services and future thermal EO products.

3. Fund Pilot Implementations for CAP and Insurance Integration

- Action: Provide financial backing to integrate satellite-derived grassland indicators directly into CAP monitoring systems, regional drought preparedness frameworks, and index-based agricultural insurance schemes.
- Urgency/Impact: Medium. Transitioning these models into institutional pipelines bridges the gap between research and real-world farm resilience.

4. Promote Operational Uptake within Regional, National and European Monitoring

- Action: Institutionalize advanced EO workflows within European, national, and regional public monitoring frameworks, while fostering the integration of specialized research institutions, regional service providers and SMEs with strong technical expertise and close links to local communities. This will ensure that existing and future Copernicus services are complemented by high-resolution, context-specific preprocessing, processing and validation capabilities that adequately represent complex grazing landscapes.
- Urgency/Impact: Medium. Embeds advanced EO workflows together with complementary scientific and regional expertise into long-term agricultural monitoring and governance, improving the representation of heterogeneous grazing systems within future Copernicus services.

Considerations

- **Economic & Governance:** Transitioning from ex-post financial compensation for climate losses to forward-looking, preventive risk management reduces public budget exposure to climate shocks. It addresses the European Court of Auditors (ECA) demand for robust, objective evidence of policy performance.

- **Social & Environmental:** These recommendations support a fair transition toward transparent, results-based CAP funding tied directly to biodiversity conservation, carbon sequestration, and climate resilience. Operationally, it prevents land abandonment, helping sustain vulnerable extensive farming communities in the Alps and Mediterranean.

4 Evidence and Analysis

Key Results: Our research proves that advanced satellite observations and modeling can successfully conquer the technical barriers of monitoring complex grassland systems across two distinct, climate-sensitive "living laboratories":

- **Mediterranean Oak Savannas (Agrosilvopastoral Systems):** Tailored EO products reproduced field-observed grassland biomass with sufficient precision (R2 = 0.95; RMSE = 224 \ kg DM ha-1). The models successfully captured sharp spatial and interannual shifts, detecting biomass reductions exceeding 40% under severe drought conditions. This allowed researchers to safely derive farm-level production ranges categorized for favorable, average, and unfavorable years.

- **Alpine Meadows**: An enhanced Leaf Area Index (LAI) product successfully mapped seasonal vegetation dynamics and distinct management practices (e.g., mowing). It demonstrated strong alignment with field observations (R2 = 0.79; RMSE = 1.36 m2/m2).

- **Smarter Drought Insurance**: When integrated into a Grassland Productivity Index, the LAI product effectively mapped year-to-year productivity variations, including the severe 2022 agricultural drought. In the Province of Bolzano, this tool forms the baseline of an index-based drought insurance scheme covering roughly 200 forage-production farms, dramatically minimizing "basis risk" (the discrepancy between insurance payouts and actual forage losses) compared to older systems reliant on sparse weather stations.

Visual Aids

The project developed and validated the structured workflow illustrated below to move from raw data to operational field decisions:

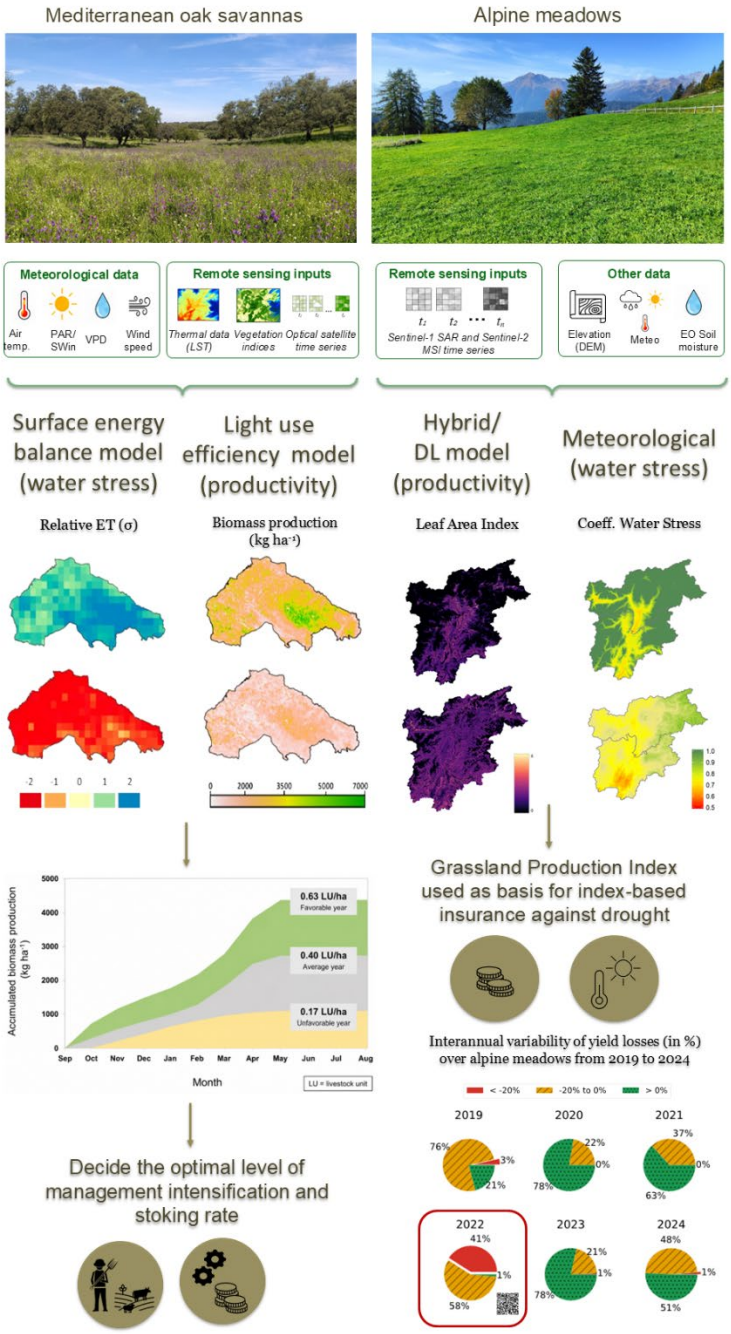

Figure 1. ScaleAgData workflow integrating Earth Observation, meteorological, and ancillary data to generate operational grassland indicators supporting decisions on management intensity and stocking rates in Mediterranean oak savannas, and index-based drought insurance in Alpine meadows.

Methodology: The ScaleAgData workflow fuses diverse data streams to bypass traditional monitoring bottlenecks. For Mediterranean tree-grass systems, it couples meteorological variables (Air temperature, Photosynthetically Active Radiation/Shortwave Radiation, Vapor Pressure Deficit, and wind speed) with satellite inputs (Thermal Land Surface Temperature, vegetation indices, and optical time series) through a combined Surface Energy Balance model and a Light Use Efficiency model. For steep Alpine meadows, the architecture utilizes a Hybrid/Deep Learning (DL) model driven by Sentinel-1 SAR and Sentinel-2 MSI time series, augmented by Digital Elevation Models (DEM), localized meteorology, and satellite-derived soil moisture to isolate leaf development and water stress indicators.

Limitations: While highly accurate, these localized models are highly reliant on high-quality ancillary data inputs (such as precise local meteorology and digital elevation metrics). Current operational Copernicus services still feature systemic limitations in resolving tree-grass interferences or extreme mountain fragmentation outside of these custom, specialized ScaleAgData pipeline configurations, necessitating further scaled demonstration and investment.

5 Strategic Alignment

Green Deal / Farm to Fork: This methodology delivers the objective verification framework needed to transition toward transparent, results-based CAP funding models. By accurately mapping permanent grassland metrics, it supports Green Deal environmental targets regarding biodiversity preservation, active carbon sequestration monitoring, and terrestrial ecosystem restoration.

SDGs

This work directly advances several United Nations Sustainable Development Goals:

- SDG 2 (Zero Hunger / Sustainable Agriculture): By optimizing pasture carrying capacities and protecting livestock systems from collapse.
- SDG 6 (Clean Water and Sanitation / Water Resilience): Through the integration of water stress indexing and alignment with the Water Resilience Strategy.
- SDG 13 (Climate Action): By embedding preventive climate risk management (via Climate-ADAPT frameworks) directly into long-term farm management planning.

Partnerships: The workflow scales the Copernicus/Sen4CAP CAP monitoring approach by actively closing the long-standing grazing-land data gap. It directly aligns with European initiatives like the "Agriculture of Data" partnership by showcasing how next-generation fusion models can be operationalized for complex agricultural ecosystems, satisfying the policy mandates of CAP Article 76 for enhanced risk-management tools.

6 References

European Environmental Agency (EEA), 2026. European Commission analysis on extensive and mixed-livestock farm structural declines (2010–2020).

MacDonald, D., et al., 2000. Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response. Journal of Environmental Management.

ScaleAgData Consortium, 2026. Technical Report on Earth Observation Solutions for Grassland Management and Drought Resilience. [Link to Technical Report Annex]

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