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Geospatial modelling of land multi-degradation at global and European levels

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International Conference "Environment at CrossrOads: SMART approaches for a sustainable future – ECOSMART", November 17-18, 2023, Bucharest, Romania

- ***General objective***: *exploring the geospatial convergence/incidence of multiple land degradation processes (land multi-degradation) across the global and European agricultural environments;*

- ***Structure:***

  - *the general concepts of land degradation and land multi-degradation;*
  - *the methodological framework of the present research;*
  - *the geospatial results of land multi-degradation in global and European agricultural landscapes;*
  - *conclusions;*
  - *references.*

❑ *Land degradation concept:*

- ***land degradation**: reduction or loss of biological or economic productivity of lands, due to many degradation processes, such as water/eolian soil erosion, physical/chemical/biological/economic land deterioration, or long-term loss of vegetation (UNCCD, 1994);*

❖ *a prolonged decline of ecosystem functions and services of land systems (soils, vegetation, water resources) (Prăvălie, 2016, 2021);*

❖ *land degradation = **desertification** if it occurs in dryland systems (except for hyper-arid areas) (UNCCD, 1994; Reynolds et al., 2007; Prăvălie, 2016, 2021) (Fig. 1);*

❖ *most / all land degradation processes – so far **analyzed in a singular manner (the "uni-degradation" perspective)** across the globe;*

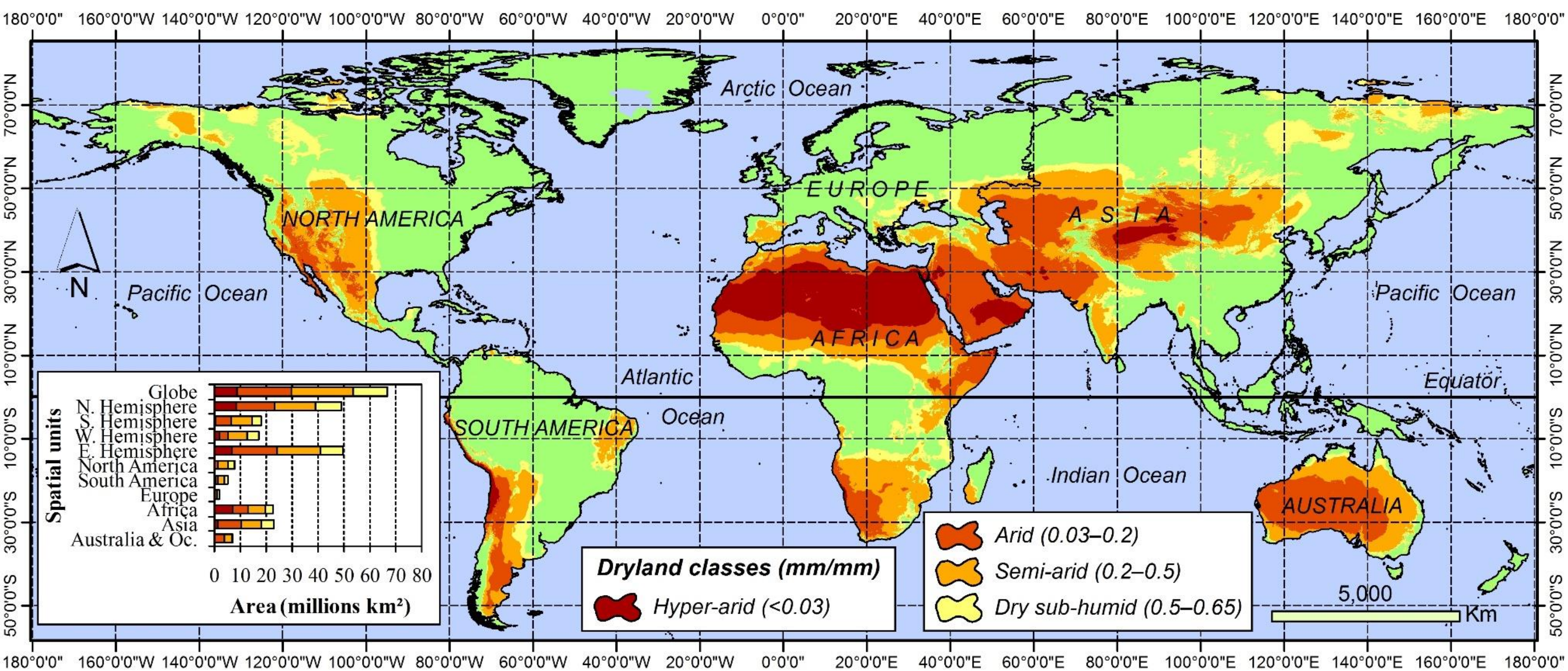

Fig. 1. Spatial representation of the global dryland systems (after Prăvălie, 2016).

- *to fill the gap of the **land multi-degradation** approach, a synergistic analysis of multiple degradation processes is needed;*

- *land multi-degradation (land degradation occurring through multiple convergent processes) – studied for the first time at the planetary level in Prăvălie et al. (2021a);*

- *5 processes from the entire spectrum of land degradation pathways (Fig. 2) were selected and analyzed in Prăvălie et al. (2021a);*

- *the selection was made according to certain relevant criteria, such as global spatial footprint, data availability or impact on arable systems (Prăvălie et al., 2021a);*

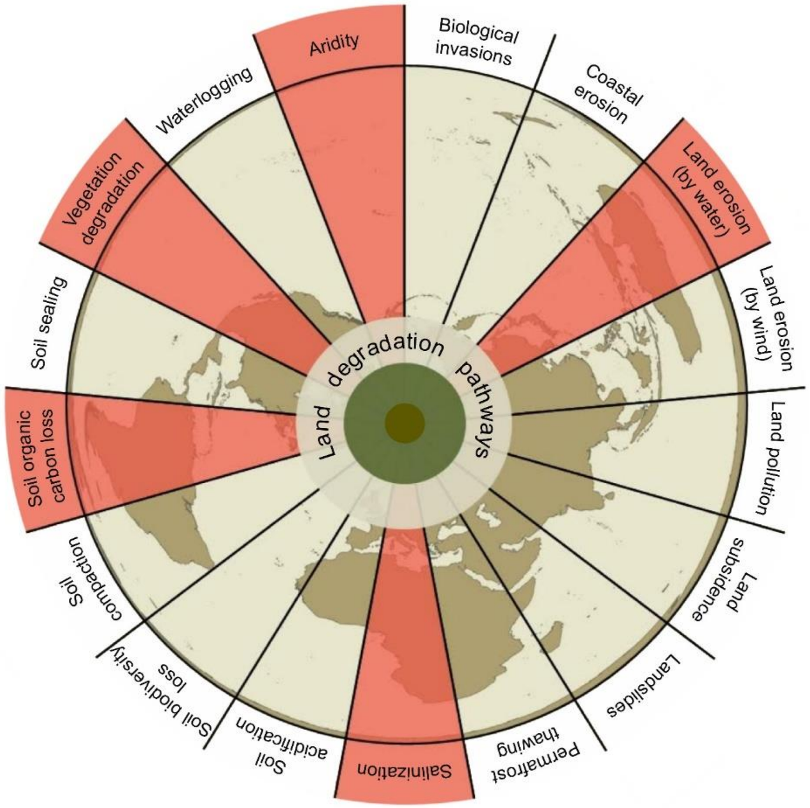

Fig. 2. *Schematic approach to land degradation pathways currently occurring globally (after Prăvălie, 2021).*

- *the global spatial data of the 5 processes were collected from various sources, processed (classified) (Figs. 3–7) and intersected via GIS (Geographic Information Systems) techniques within global arable lands (Fig. 8).*

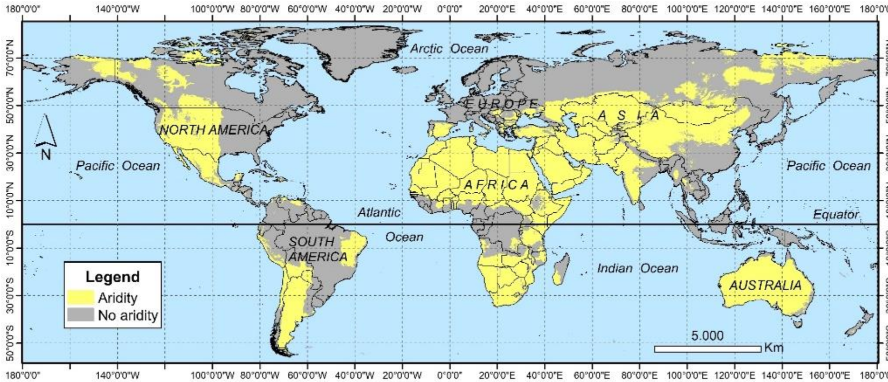

Fig. 3. Global spatial representation of aridity (Aridity Index values < 0.65 mm/mm) (data processing after Trabucco and Zomer, 2009).

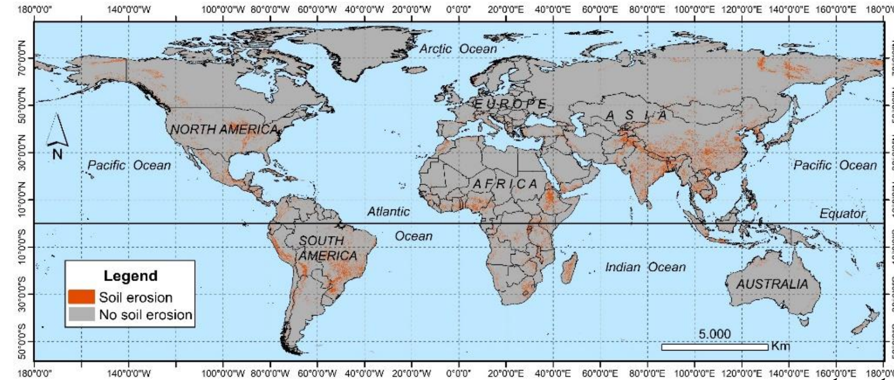

Fig. 4. Global spatial representation of soil erosion by water (>10 t ha^{-1} yr^{-1}) (data processing after Borrelli et al., 2017).

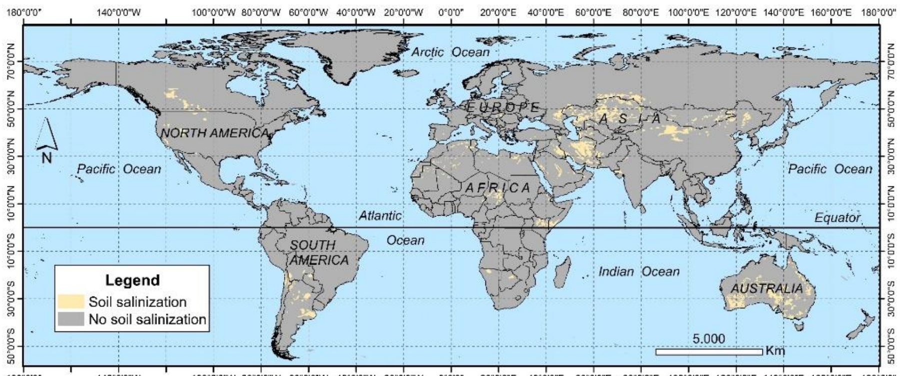

Fig. 5. Global spatial representation of soil salinization (Solonchaks, Solonetzs and salt-covered areas) (data processing after FAO, 2014).

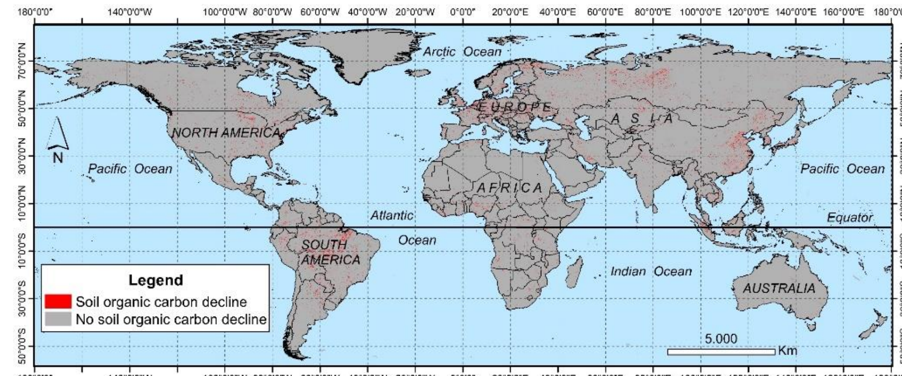

Fig. 6. Global spatial representation of soil organic carbon decline (negative trends of the soil organic carbon stock) (data processing after Prăvălie et al., 2021b).

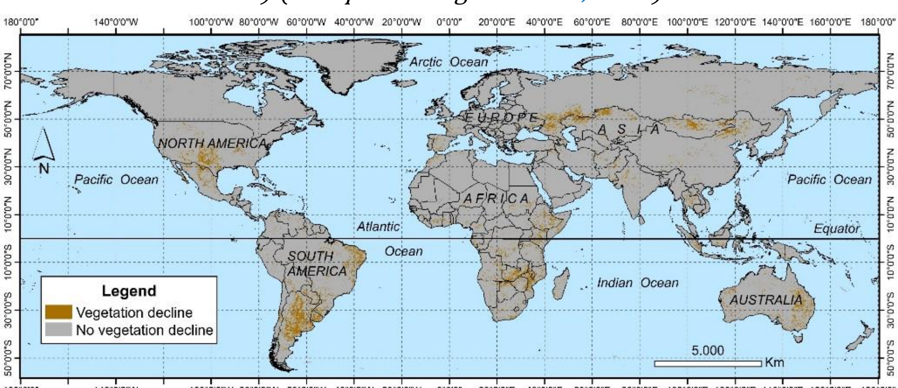

Fig. 7. Global spatial representation of vegetation decline (negative trends of biomass in areas exposed to drought conditions) (data processing after Ivits et al., 2014, 2016).

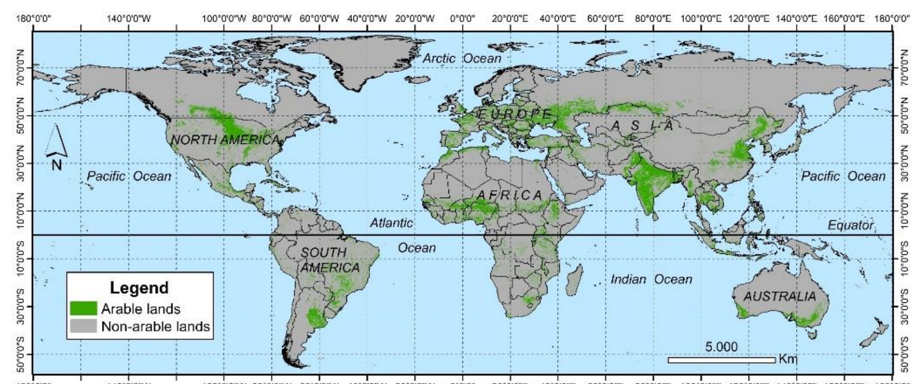

Fig. 8. Global spatial representation of arable lands (data processing after Borrelli et al., 2017).

❑ *Global spatial pattern of arable land multi-degradation:*

- ❖ *arable lands – generally affected by at least one degradation process on all continents (Figs. 9, 10);*
- ❖ *the simultaneous presence of two degradation processes – the major form of arable land multi-degradation across the world (Figs. 9, 10);*

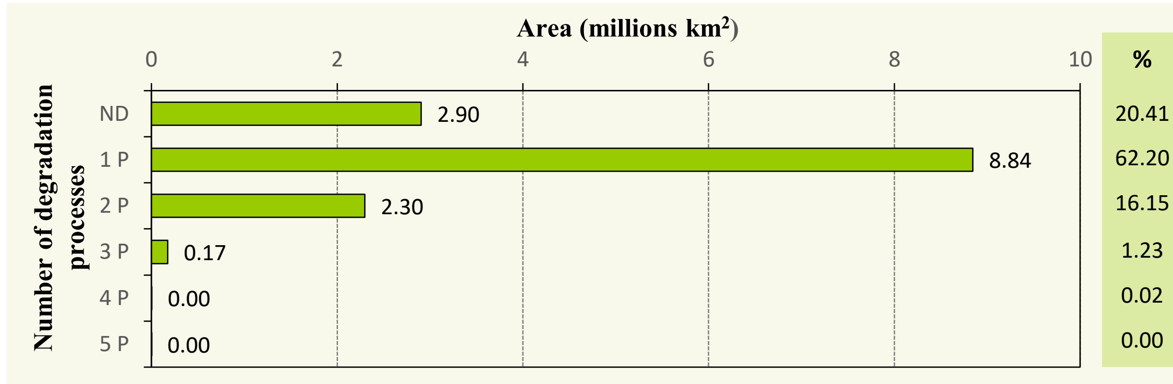

Fig. 10. *Areas (in km^2/%) covered by the number of land degradation processes in global arable lands (after Prăvălie et al., 2021a).*

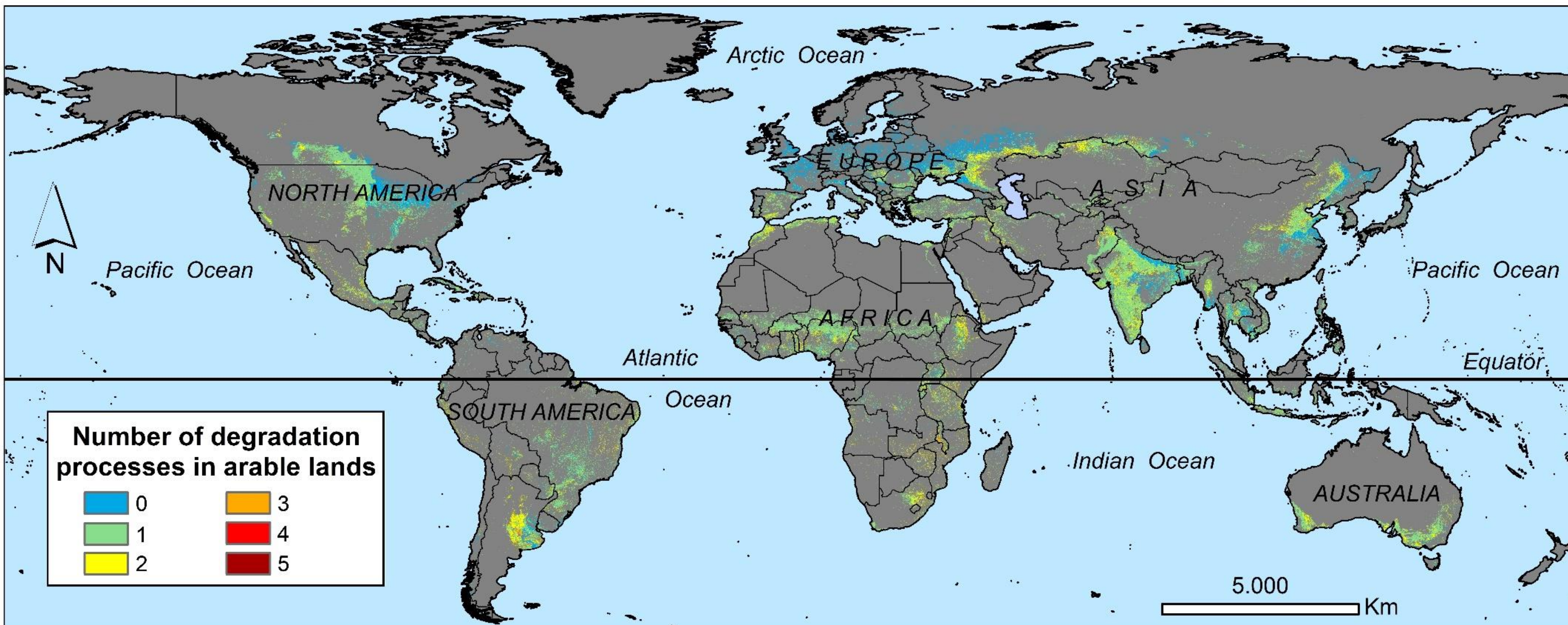

Fig. 9. *Global spatial representation of the number of land degradation processes in arable systems (after Prăvălie et al., 2021a).*

- *aridity (A) – the global dominant vector of arable land uni-degradation (Figs. 11, 12);*
- *soil erosion (E) – also a notable form of uni-degradation globally (Figs. 11, 12);*
- *aridity and soil erosion – the dominant pathways of multi-degradation in arable systems (Figs. 11, 12).*

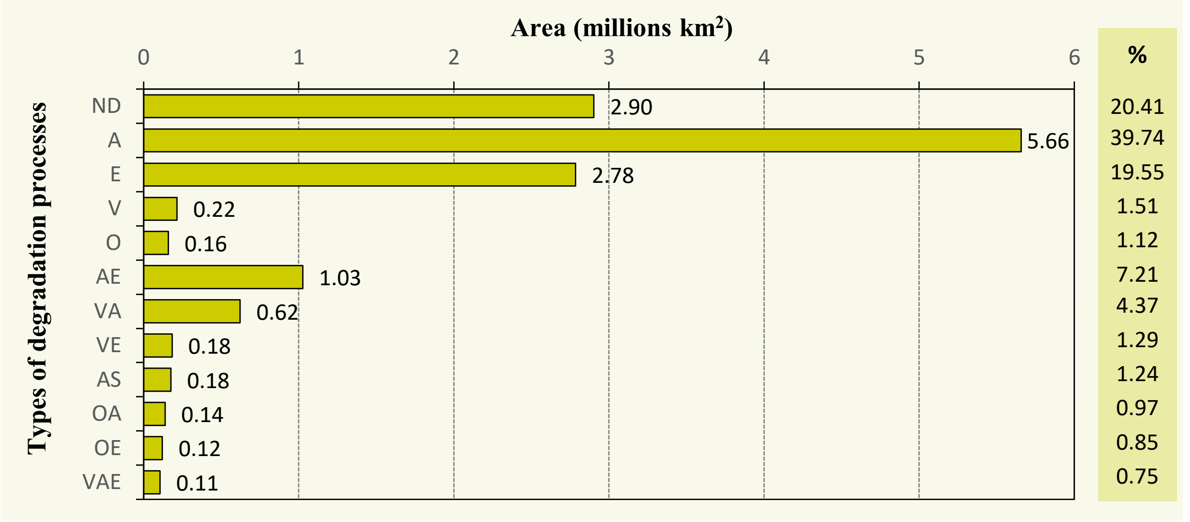

Fig. 12. *Areas (in km²/%) covered by the type of land degradation processes in global arable lands (after Prăvălie et al., 2021a).*

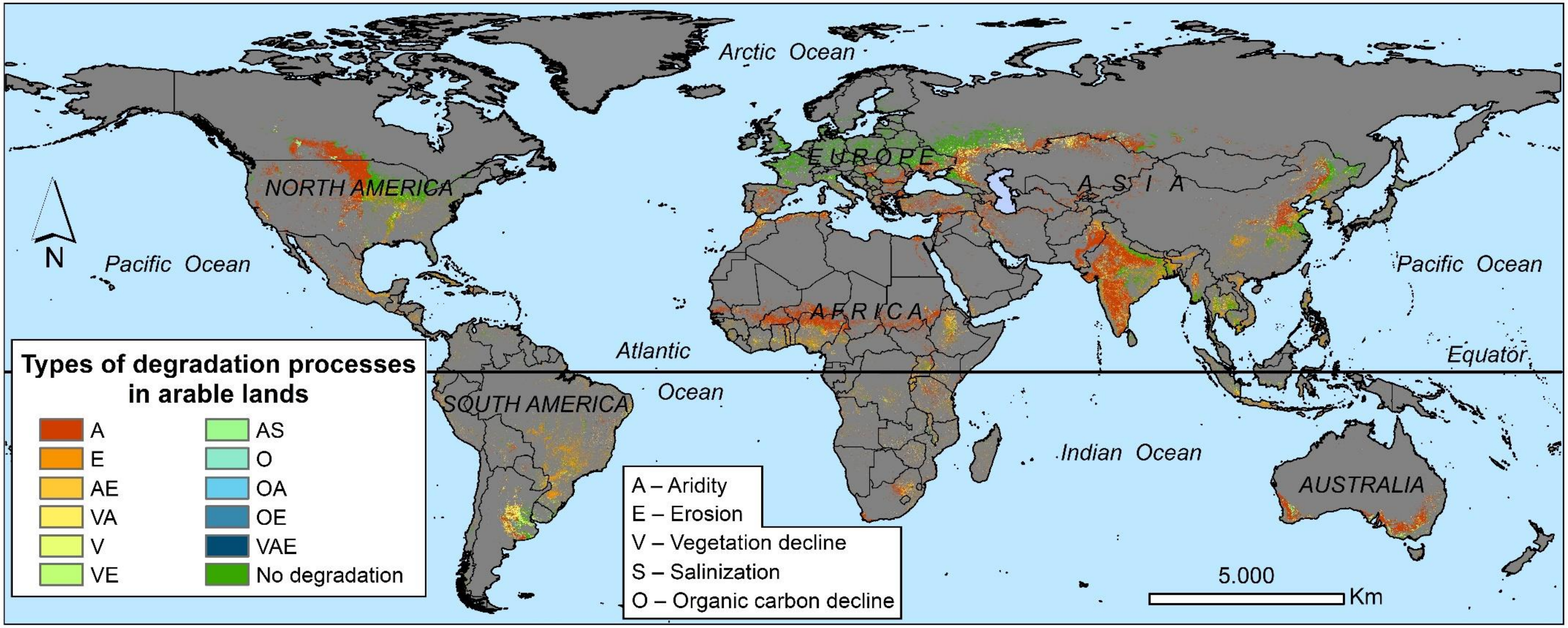

Fig. 11. *Global spatial representation of the types of land degradation processes in arable systems (after Prăvălie et al., 2021a).*

❑ *Towards an in-depth continental assessment of land multi-degradation:*

❖ *these global results are important for some key policies in the field of land degradation:*

▪ *Land Degradation Neutrality (Cowie et al., 2018);*

▪ *the 2030 Agenda for Sustainable Development (Wunder et al., 2018);*

▪ *Paris Agreement (Rumpel et al., 2018);*

❖ *more research details can be found in the published paper (upper right);*

❖ *our results were noted by* ***the United Nations*** *(middle right) and* ***the European Commission*** *(bottom right);*

❖ *this policy feedback – the reason for starting a detailed research on land multi-degradation on a continental (European) scale.*


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Arable lands under the pressure of multiple land degradation processes. A global perspective

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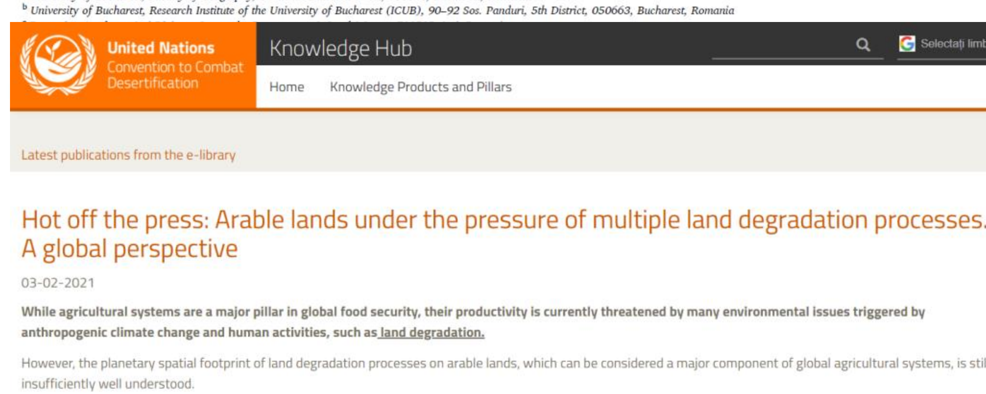
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Hot off the press: Arable lands under the pressure of multiple land degradation processes. A global perspective

03-02-2021

While agricultural systems are a major pillar in global food security, their productivity is currently threatened by many environmental issues triggered by anthropogenic climate change and human activities, such as land degradation.

However, the planetary spatial footprint of land degradation processes on arable lands, which can be considered a major component of global agricultural systems, is still insufficiently well understood.


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Land degradation in global arable lands

Analysis of the spatial footprint of the multiple forms of land degradation in global arable lands. This includes 5 land degradation processes: aridity, soil erosion, vegetation decline, soil salinization and soil organic carbon decline. Data are at global scale.

Resource Type: Datasets, Soil Threats Data
Registration is requested: Yes
Year: 2021
Language: en

Description | Request Form

Metadata

Title: Land degradation in global arable lands
Description: Land degradation is a global environmental issue that affects the world's arable lands on a large scale, thus threatening global food production systems. This study analyzes the land degradation footprint on global arable lands, using complex geospatial data on certain major degradation processes, i.e. aridity, soil erosion, vegetation decline, soil salinization and soil organic carbon decline. By applying geostatistical techniques that are representative for identifying the incidence of the five land degradation processes in global arable lands, results showed that aridity is by far the largest singular pressure for these agricultural systems, affecting ~40% of the arable lands' area, which cover approximately 14 million km^2 globally. Therefore, the world's arable lands are particularly vulnerable to uni-degradation (the incidence of a single degradation process), through large-scale aridity conditions. Also, it was found that soil erosion is another major degradation process, the unilateral impact of which affects ~20% of global arable systems.
Resolution: 1km
Time Reference: 2012
Format: GeoTIFF
Projection: Equal-area Mollweide
Input data: Aridity, soil erosion, vegetation decline, soil salinization and soil organic carbon decline.

Reference of source (Citations) :

Prăvălie, R., Patriche, C., Borrelli, P., Panagos, P., Roşca, B., Dumitraşcu, M., Nita, I.A., Săvulescu, I., Birsan, M.V. and Bandoc, G. 2021. Arable lands under the pressure of multiple land degradation processes. A global perspective. *Environmental Research*, **194**, art no .110697.

❑ *The methodological approach of land multi-degradation in Europe:*

- *this continental analysis focuses on modelling 12 processes in Europe – **water erosion, wind erosion, soil organic carbon loss, soil salinization, soil acidification, soil compaction, soil nutrient imbalances, soil pollution via pesticides, soil pollution via heavy metals, vegetation degradation, groundwater decline** and **aridity**) (Table 1);*

- *these land degradation processes are highly relevant for highlighting the agricultural land degradation in Europe and worldwide (Table 1);*

Table 1. *The 12 processes selected for this continental analysis, considering the general negative ecological effects for agricultural land productivity (after Prăvălie et al., 2023).*

No.	Land degradation processes	Examples of negative effects on agricultural land productivity
1	Water erosion	*Degrading soil structure, reducing soil depth or decreasing / losing the soil nutrient content*
2	Wind erosion	*Accelerating dust emission, damaging crops by abrasion or reducing the organic matter content*
3	Soil organic carbon loss	*Disrupting structural stability and water holding capacity of soils or decreasing soil fertility*
4	Soil salinization	*Limiting plant growth due to phytotoxicity, water uptake difficulty or soil organic carbon losses*
5	Soil acidification	*Threatening soil bacterial diversity, increasing toxicity for plants or limiting soil nutrient availability*
6	Soil compaction	*Reducing soil porosity, shrinking oxygen and water supply to plants or restricting root penetration*
7	Soil nutrient imbalances	*Amplifying acidity and micronutrient deficiencies in soils, due to N or P excess, or inhibiting plant growth, due to N or P deficit*
8	Soil pollution via pesticides	*Exerting stress on soil health via toxicity and decline in microbial community or earthworm activity*
9	Soil pollution via heavy metals	*Poisoning the soil, injuring plants via chlorosis and necrosis or hindering root growth and crop yields*
10	Vegetation degradation	*Decreasing soil productivity via soil organic carbon losses or through increased land exposure to water and wind erosion*
11	Groundwater decline	*Depleting groundwater resources, inducing soil water stress or inhibiting plant development*
12	Aridity	*Generating surface low water availability and constant soil water deficit or triggering desertification*

- *6 databases available internationally were directly used – water erosion (Borrelli et al., 2017), soil organic carbon (SOC) loss (Prăvălie et al., 2021b), soil salinization (Toth et al., 2008), soil acidification (Ballabio et al., 2019), soil compaction (EC, 2008) and soil pollution via pesticides (Tang et al., 2021) (Fig. 13);*
- *for the other layers (wind erosion, soil nutrient imbalances, soil pollution via heavy metals, vegetation degradation, groundwater decline and aridity), various pre-existent data from other sources were collected, in order to model the geospatial data for the remaining 6 processes (Prăvălie et al., 2023) (Table 2, Fig. 13);*
- *the 12 rasters, with various features (Table 2), were structured into **2 classes – Critical** and Non-critical (Fig. 13);*
- *by intersecting the Critical classes of the 12 datasets, a **Land Multi-degradation Index (LMI)** was obtained.*

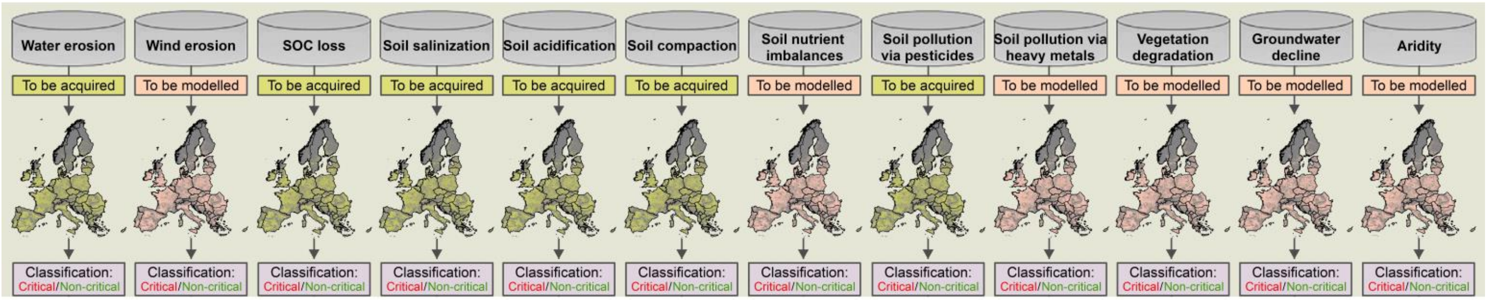

***Fig. 13.** Schematic approach to geospatial database processing in Europe.*

***Table 2.** Characteristics of land degradation data that were used in this continental approach (after Prăvălie et al., 2023).*

No.	LD data	Original resolution [a]	Time period	Metric
1	Water erosion	250 × 250 m	2012	t ha^{-1} yr^{-1}
2	Wind erosion	500 × 500 m	2001–2021	t ha^{-1} yr^{-1}
3	SOC loss	1 × 1 km	2001–2015	t C km^2 yr^{-1}
4	Soil salinization	1 × 1 km	2008	%
5	Soil acidification	500 × 500 m	2019	pH units
6	Soil compaction	1 × 1 km	2008	Susceptibility
7	Soil nutrient imbalances	1 × 1 km (N) 100 ×100 m (P)	2010–2019	kg/ha (N) mg/kg (P)
8	Soil pollution via pesticides	10 × 10 km	2015	Risk score
9	Soil pollution via heavy metals	1 × 1 km (As, Cd, Cr, Co, Pb, Sb, Ni) 500 × 500 m (Cu) 250 × 250 m (Hg)	2009	mg/kg
10	Vegetation degradation	500 × 500 m	2000–2015	NDVI units
11	Groundwater decline	1 × 1 km	2004–2013	GTD (m yr^{-1})
12	Aridity	1 × 1 km	1981–2018	AI (mm/mm)

Notes: m – meter, km – kilometer, ha – hectare, t – ton, C – carbon, N – Nitrogen, P – Phosphorous; NDVI – Normalized Difference Vegetation Index; GTD – Groundwater Table Depth; AI – Aridity Index; As – Arsenic; Cd – Cadmium; Cr – Chrome; Co – Cobalt; Pb – Lead; Sb – Antimony; Ni – Nickel; Cu – Copper; Hg – Mercury; a – spatial resolution of the originally collected data, which were processed at an intermediate resolution of 500 × 500 m.

❑ *The geospatial results of multiple land degradation processes in Europe:*

- *different spatial patterns of land (uni-) degradation processes across Europe (Figs. 14, 15);*
- *each driver of degradation – examined according to some specific critical thresholds (red class) (Figs. 14, 15);*

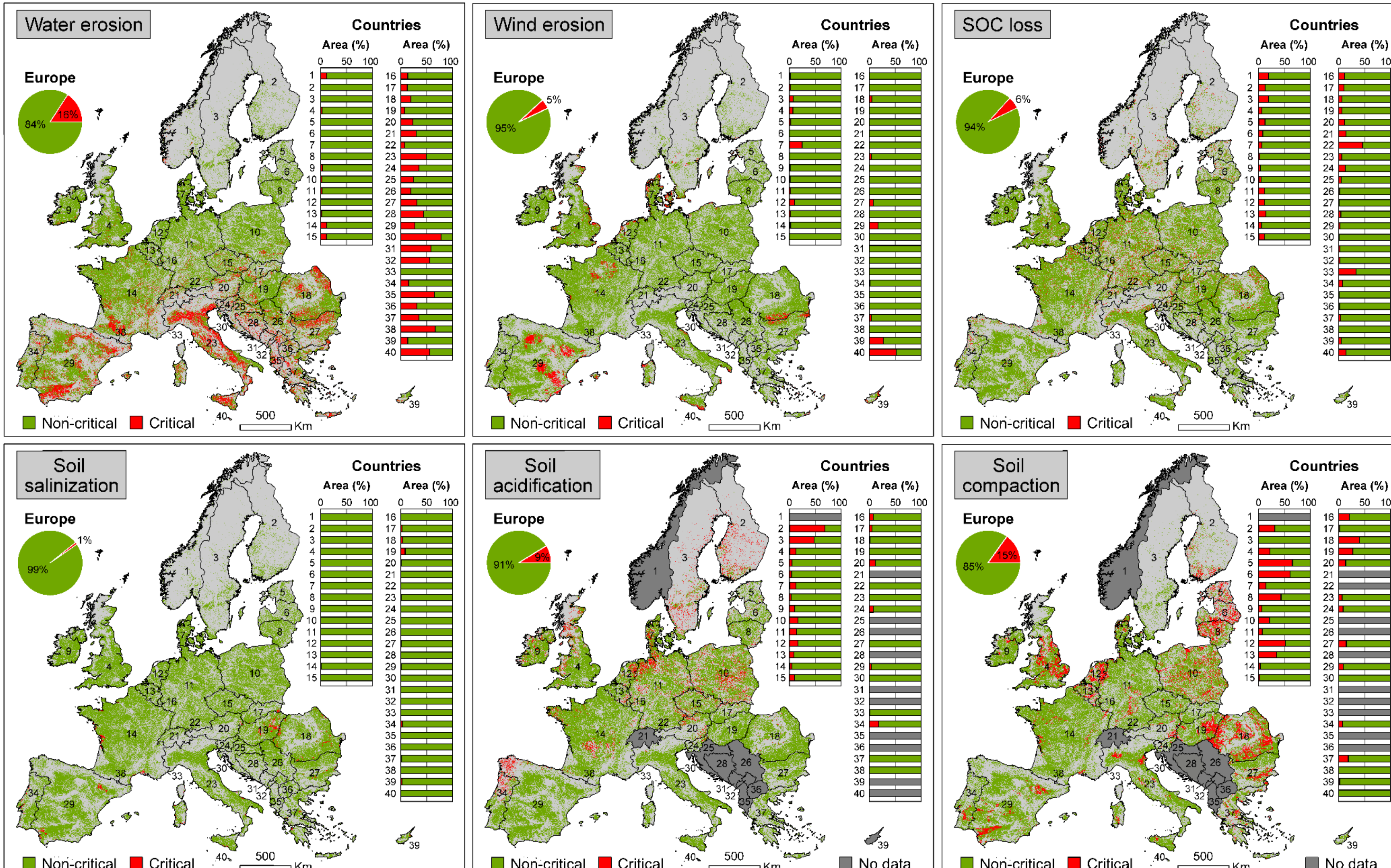

Fig. 14. *Mapping of water erosion, wind erosion, SOC loss, soil salinization, soil acidification and soil compaction in European agricultural areas.*

- *soil pollution via pesticides – the largest spatial footprint at continental level (52% of the cumulated agricultural area of the 40 investigated countries) (Fig. 15);*
- *followed by soil nutrient imbalances (39%), soil pollution via heavy metals (31%) and aridity (26%) (Fig. 15);*

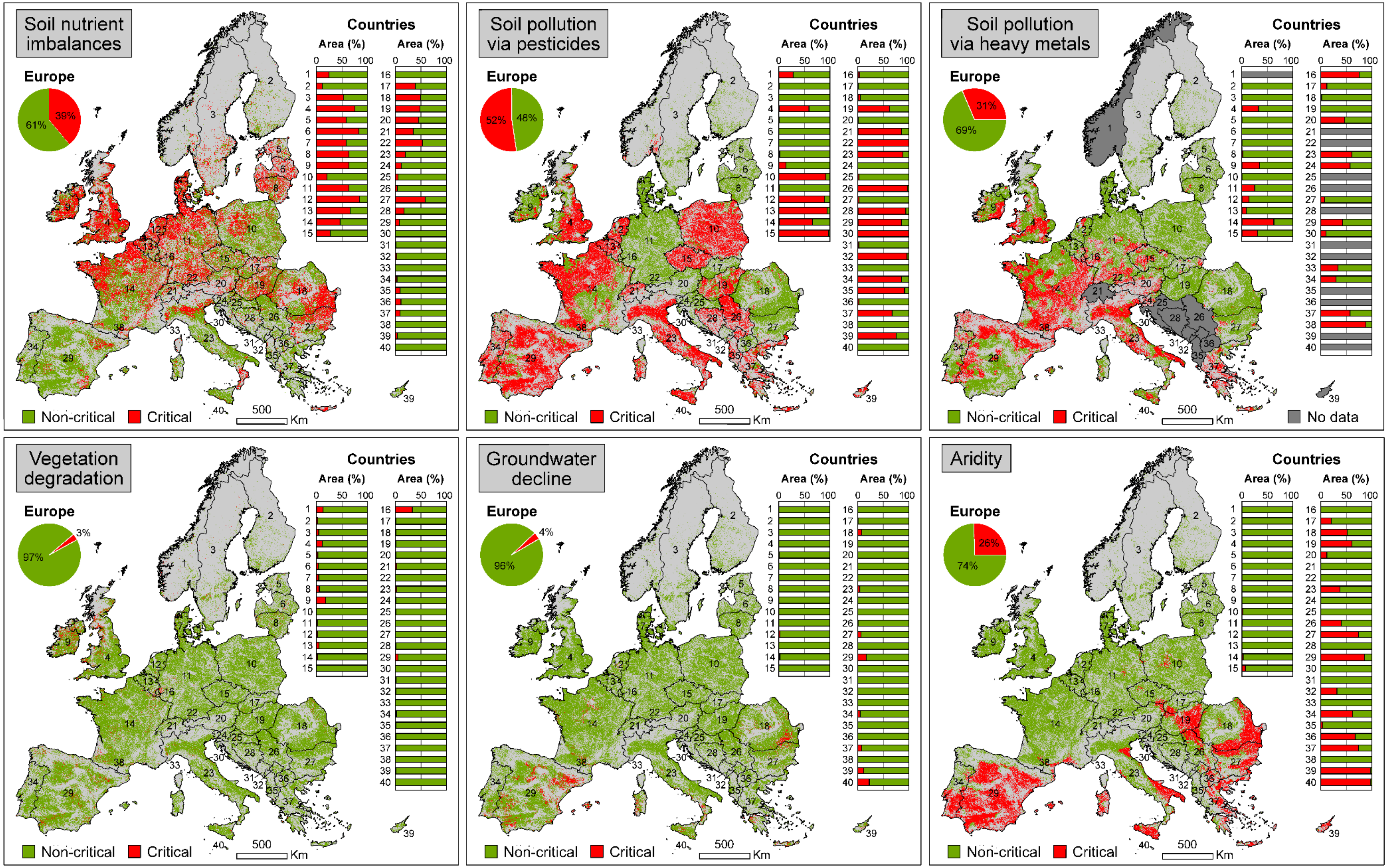

Fig. 15. Mapping of soil nutrient imbalances, soil pollution via pesticides, soil pollution via heavy metals, vegetation degradation, groundwater decline and aridity in European agricultural areas.

- ***Land Multi-degradation Index (LMI)*** *– obtained by fusing the 12 land degradation databases (Fig. 16);*
- *LMI revealed between one and ten converging (co-occurring) processes in Europe (Fig. 16);*
- *~10% of agricultural/arable lands are cumulatively affected by 4 and ≥ 5 concurrent processes (Table 3).*

Table 3. *Spatial extent (in km² and %) of LMI classes in agricultural/arable environments of Europe (after Prăvălie et al., 2023).*

No.	LMI classes (number of co-occurring processes)	Agricultural lands		Arable lands	
		km²	%	km²	%
1	No degradation (0)	143,626	6.84	71,196	6.23
2	Very low degradation (1)	577,279	27.50	304,105	26.60
3	Low degradation (2)	727,147	34.65	395,940	34.64
4	Medium degradation (3)	451,213	21.50	249,178	21.80
5	High degradation (4)	156,170	7.44	95,169	8.33
6	Very high degradation (≥ 5)	43,473	2.07	27,562	2.40

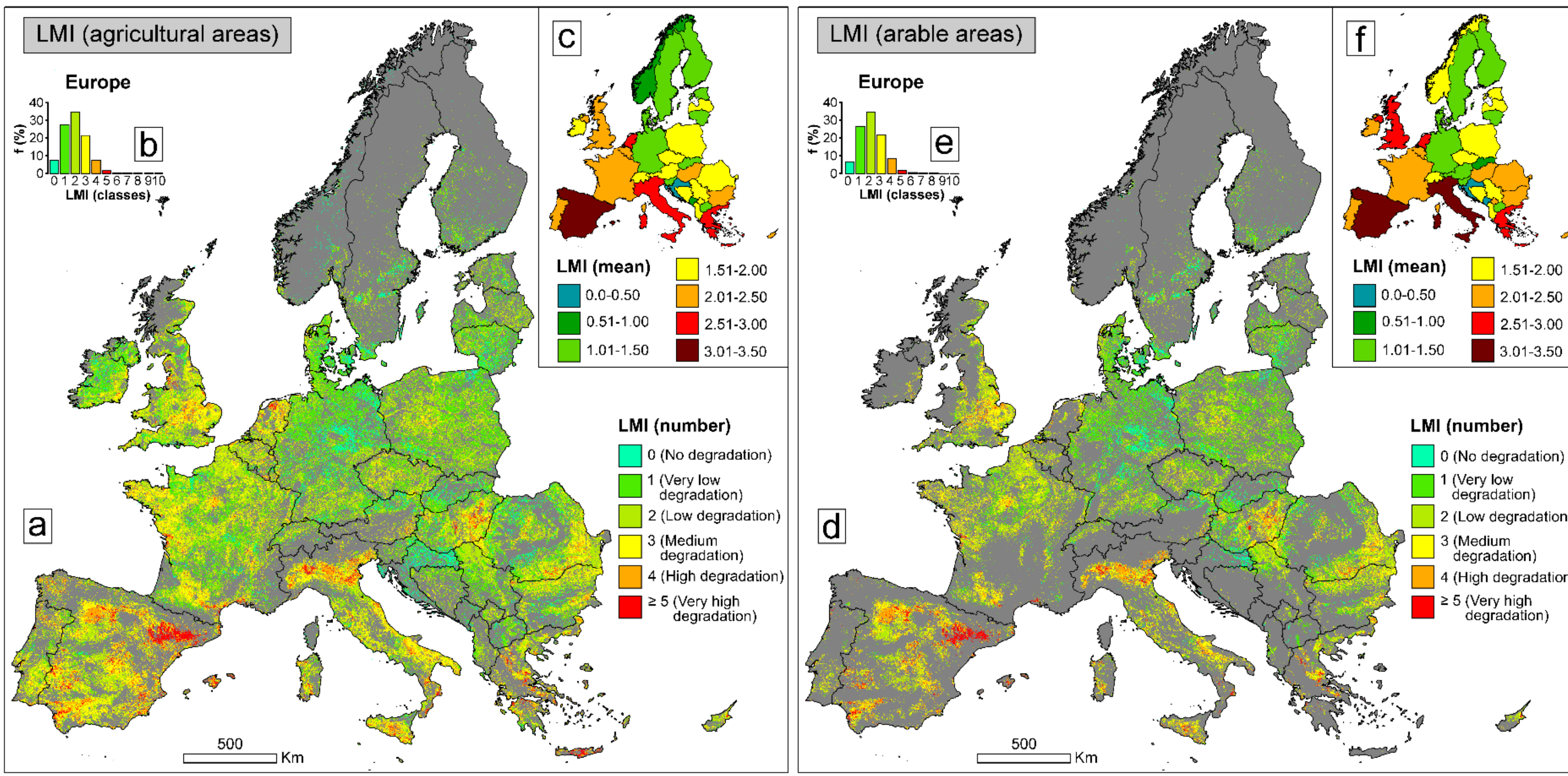

Fig. 16. *Land multi-degradation (LMI) in Europe.* ***a,d*** *Spatial distribution of LMI values in agricultural / arable landscapes.* ***b,e*** *Histogram of LMI values for European agricultural /arable lands.* ***c,f*** *Average number of co-occurring processes in agricultural / arable environments of Europe.*

❑ *Conclusions:*

- ✓ *global and European arable systems – under the pressure of various land degradative conditions;*

- ✓ *the convergent analysis of major degradation processes – addressed globally and continentally in this studies, using large-scale geospatial data and complex methods;*

- ✓ *the geospatial results obtained are important for some key land degradation policies, like Land Degradation Neutrality, the 2030 Agenda for Sustainable Development or Paris Agreement;*

- ✓ *essentially, our findings will enable policy makers to develop knowledge-based strategies for land degradation mitigation and other critical global and European sustainable development goals;*

- ✓ *these scientific results were obtained through an international research project financed by the European Commission via PNRR.*

Finanțat de Uniunea Europeană NextGenerationEU

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Acknowledgements

This work was funded by the EU's NextGenerationEU instrument through the National Recovery and Resilience Plan of Romania – Pillar III-C9-2022-I8, managed by the Ministry of Research, Innovation and Digitalization, within the project entitled "Complex modelling of multiple land degradation processes in Europe. Towards an integrative scientific framework for sustainable land management across the continent", contract no. 760051/23.05.2023, code CF 216/29.11.2022.

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