STUDY ON THE EVOLUTION AND DYNAMICS OF ANTI-EROSIONAL MANAGED AREAS AT NATIONAL LEVEL ACROSS DIVERSE LAND USE CATEGORIES

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Abstract

The present study analyzes the evolution of anti-erosion landscaped surfaces in Romania over a period of almost three decades (1997-2024). The data illustrate diverse trends, from sustained growth in arable land and natural hayfields to significant restructuring in the fruit and viticultural sectors, all culminating in a stabilization phase in recent years. The largest share within the anti-erosion area is held by arable land, with more than half of the total (53.59%). This underscores the crucial importance given to protecting cultivated soils, which are most exposed to erosion risk, with investments being essential for maintaining long-term soil fertility and ensuring productivity. The significant share of hayfields (pastures and natural hayfields, totaling 31.35%, with 22.57% pastures and 8.78% grasslands) reflects the recognized importance of grassy ecosystems in soil conservation, by stabilizing slopes and regulating the water regime on the slopes. The inclusion of non-agricultural areas (6.39%) underlines a holistic approach to erosion management, extending conservation efforts beyond strictly agricultural borders. Orchards and fruit nurseries arranged with anti-erosion works (5.09%) and vineyards and wine nurseries (3.59%) have lower shares, probably suggesting a restructuring of the fruit and wine sector. These dynamics reflect an adaptive and continuous commitment to soil protection, which is essential for the sustainability of national land resources. Studies on anti-erosional land management are crucial for promoting sustainable agriculture, addressing the conservation of water and soil resources, and mitigating the challenges generated by climate change.

Key words**: **landscaped land, anti-erosion works, sustainable management.

INTRODUCTION

The processes that influence soil quality and productivity represent a field of great complexity and importance in land resource management. To achieve sustainable agriculture, it is necessary to implement programs and initiatives aimed at minimizing environmental impact and improving benefits for farmers. Romania can leverage this sector by taking advantage of less degraded and polluted soils and suitable conditions for the development of this agricultural system (Soare et Micu, 2018).

Soil erosion, through its complex processes of physical, chemical, and biological degradation, represents a major challenge at both global and national levels for environmental and agricultural sustainability (Lal, 2003; Bălan, 2010; Bălan, 2017). The consequences range from the loss of soil fertility, reduced agricultural yields, and pollution of water sources to the destabilization of landscapes and increased flood risk (Pimentel et al., 1995; Niţu et al., 2024). This phenomenon, amplified by climate change (Bonea, 2018; Bonea, 2024; Niţu et al., 2023) and unsustainable agricultural practices (Bonea, 2013; Bonea, 2024a; Niţu et al., 2023; 2024), necessitates a proactive approach through the implementation of effective anti-erosion measures. In the case of Romania, both theoretical and applied studies dedicated to water erosion, as well as measures to combat it, acquire strategic relevance, considering the predominantly favorable

physical-geographical conditions for the manifestation of the process, along with the socio-economic dynamics that influence land management (Bălan, 2020). Historically, the evolution of anti-erosion interventions in Romania illustrates a gradual developmental process, with early beginnings in the 1950s when the area treated with erosion control measures (ECM) was limited to approximately 2,000 hectares. In the subsequent decades, this figure experienced accelerated growth; thus, by 1960, the treated area had reached around 100,000 hectares, and by 1970, it was projected to be about 435,000 hectares, highlighting an exponential increase in mitigation efforts. In the 1980s, the treated area was approximately 1,600 hectares, while by 1989, it had risen to around 2,200 hectares (Campeanu & Bucur, 2009).

However, after 1990, the processes of land fragmentation and the deinstitutionalization of land management, resulting from the application of Law No. 18/1991 concerning land restitution, led to a significant deterioration in the maintenance status of erosion control works. This fragmentation of properties resulted in a loss of continuity in the implementation of protective measures, which manifested as land abandonment, consequently causing physical and chemical degradation of the soil layer and, in many instances, the complete destruction of existing works (Bălan & Popescu, 2024). As a result, this phenomenon has intensified the erosion process, exacerbating the soil's vulnerability and undermining previous efforts to strengthen and conserve the pedological resources. In the current context, there is a pressing need to reassess and adapt intervention strategies, as well as to implement integrated, multidisciplinary measures aimed at reducing the impact of erosion and ensuring both ecological and economic sustainability of agricultural and natural lands in Romania (Mușat et al., 2024; Nițu et al., 2010).

The concept of anti-erosion managed area encompasses the entirety of hydrotechnical and agropedological interventions, systematically integrated, designed to mitigate or prevent the morphological degradation of the soil layer induced by erosional processes (Ioniță, 2000; Popescu et al., 2024).

Anti-erosion measures involve two main categories: preventive measures and combat measures, which must be designed and implemented in full interdependence and complementarity. One of the essential preventive interventions involves organizing arable land on slopes according to the degree of inclination and the intensity of erosional processes, through the appropriate allocation of land use types (Iancu & Soare, 2017) (field crops, vineyards or orchards, pastures, and meadows). Regardless of the land use type, the most effective tools for the prevention and control of erosion are agrotechnical measures and specialized hydrotechnical works. These include: soil work (plowing, deep tillage, re-tilling), crop structure and rotation, crop placement on slopes (compact systems, strips, grassed bands), furrowing, decompacting, and re-decompacting, bundling, mulching, planting systems, intercropping annual species between rows of trees or vines, grassed strips, protective hedges, overseeding, and reseeding.

Anti-erosion hydrotechnical works, which deliberately modify the microrelief to intercept and regulate surface runoff, are differentiated according to their use as follows: on sloped arable lands: works for intercepting and retaining surface runoff (earth mounds, agro-terraces); in vineyards with slopes greater than 15%: leveling and shaping works, terraces, coastal channels, and outlets; in fruit orchards: continuous and individual terraces, coastal channels, and outlets; on pastures and meadows: earth mounds and coastal channels. The integrated implementation of these interventions, correlated with the specific topographic and pedoclimatic

characteristics, maximizes the effectiveness of erosion control, reducing soil losses, enhancing water infiltration, and stabilizing slopes. Long-term effectiveness depends on the accurate sizing of the works, periodic maintenance (de-silting of channels, restoration of mounds, reseeding grassed bands), monitoring of erosion, and continuous adaptation of practices in accordance with the dynamics of pedoclimatic conditions and land use (Soare et al., 2020; Soare et al., 2024; Vrînceanu et al., 2009). The development of Romanian agriculture is necessary because it represents an important branch for the Romanian economy, and as a result, there is a need for infrastructure development, improvement of the irrigation system, research and innovation (Leoveanu-Soare et al., 2020).

MATERIALS AND METHODS

To study the current situation of anti-erosion managed lands in Romania, statistical data provided by the National Institute of Statistics (INS) of Romania were utilized, and the percentage method was applied, taking into account the various categories of land At the national level, it is proposed to highlight the proportion for each land use type (land category). Additionally, data from the National Agency for Land Improvement (ANIF) were used to analyze the dynamics of soil erosion control works at the national level, employing data from the years 1997 and from the INS for the year 2007, as well as the average for the years 2020-2024, resulting in a statistical analysis over a period of 28 years.

RESULTS AND DISCUSSIONS

According to Table 1 and Figure 1, which present the average situation of anti-erosion managed areas at the national level for the period 2020-2024, the total managed area is 2,284,670.2 hectares. Of this, a staggering majority, namely 2,138,666.2 hectares (93.61%), represents agricultural land. The non-agricultural managed area constitutes 146,004 hectares (6.39%). Within the anti-erosion managed agricultural area, the distribution by land use categories is as follows:

- Arable land holds the largest share, with 1,224,249.6 hectares, representing 53.59% of the total managed area. This underscores the critical importance placed on the protection of cultivated soils, which are most exposed to the risk of erosion.
- Natural pastures cover 515,615.8 hectares (22.57%), while natural meadows account for 200,496.2 hectares (8.78%). Together, these form a significant portion (31.35%) of the managed lands, highlighting the role of grassland ecosystems in soil conservation and hydrological regulation.
- Orchards and fruit nurseries total 116,372.8 hectares (5.09%).
- Vineyards and vine nurseries represent the smallest share, with 81,931.8 hectares (3.59%)

Table 1. Situation of anti-erosion managed lands at the national level (Average 2020-2024)

Item No.	Land category	Area * -ha-	% of total managed **
1	Total landscape area	2284670,2	100
2	Landscaped agricultural area	2138666,2	93,61
3	Arable land	1224249,6	53,59
4	Natural pastures	515615,8	22,57
5	Natural graslands	200496,2	8,78
6	Vineyards and nurseries	81931,8	3,59
7	Orchards and fruit nurseries	116372,8	5,09
8	Landscaped non-agricultural area	146004	6,39

* http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table (29.10.2025)
** own calculations

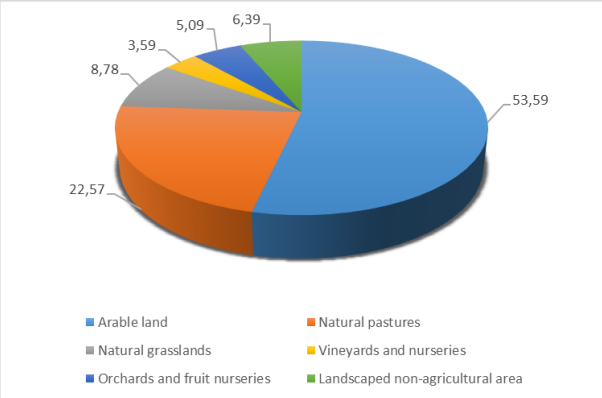

Fig. 1. Structura suprafețelor amenajate cu lucrări antierozionale

Regarding the dynamics of anti-erosion managed lands, Table 2 provides an overview of the evolution of managed areas, comparing the years 1997, 2007, and the average for the period 2020-2024. The following main trends are observed from this table:

Table 2. Dynamics of anti-erosion managed lands at the national level (hectares)

Item No.	Land category	Years				
		1997*	2007*		2020-2024**Average	
		Effective	Effective	±Δ1997 vs 2007**	Effective	±Δ1997 vs Media 2020-2024
1	Total landscape area	2276492	2278619	+2127	2284670,2	+8178,2
2	Landscaped agricultural area	2131524	2134250	+2726	2138666,2	+7142,2
3	Arable land	1203684	1221525	+17841	1224249,6	+20565,6
4	Natural pastures	513954	514829	+875	515615,8	+1661,8
5	Natural grasslands	197113	197764	+651	200496,2	+3383,2
6	Vineyards and nurseries	94029	83356	-10673	81931,8	-12097,2
7	Orchards and fruit nurseries	122744	116776	-5968	116372,8	-6371,2
8	Landscaped non-agricultural area	144968	144369	-599	146004	+1036

* http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table (29.10.2025)
** own calculations

The total managed area experienced a slight increase, from 2,276,492 hectares in 1997 to 2,284,670.2 hectares in the average for 2020-2024 (+8,178.2 hectares). This growth is primarily attributed to the expansion of the managed agricultural area.

The managed agricultural area has consistently increased from 2,131,524 hectares in 1997 to 2,138,666.2 hectares in 2020-2024 (+7,142.2 hectares), maintaining its dominant share.

Arable land recorded the most significant absolute increase, rising from 1,203,684 hectares in 1997 to 1,224,249.6 hectares in 2020-2024 (+20,565.6 hectares). This demonstrates a sustained effort to protect essential agricultural lands.

Natural pastures and meadows also experienced increases during 2020-2024 (+7,142.2 hectares), maintaining their dominant share.

Natural pastures and meadows also showed positive evolution, with their anti-erosion managed areas increasing from 513,954 hectares to 515,615.8 hectares (pastures) and from 197,113 hectares to 200,496.2 hectares (meadows) during the analyzed periods.

In contrast, vineyards and vine nurseries experienced a decline, from 94,029 hectares in 1997 to 81,931.8 hectares in 2020-2024 (-12,097.2 hectares). Similarly, orchards and fruit nurseries decreased from 122,744 hectares to 116,372.8 hectares (-6,371.2 hectares). These declines may indicate restructuring or a

shift in these sectors, potentially influenced by profitability or climate change.

The non-agricultural managed area has seen a slight long-term increase, rising from 144,968 hectares in 1997 to 146,004 hectares in 2020-2024 (+1,036 hectares), following a slight decrease in 2007.

Between 1997 and 2024, the dynamics of anti-erosion managed areas highlight differentiated developments across land use categories (Figures 2–9), generally characterized by moderate variations, slow growth trends, and subsequent stabilization phases. The total anti-erosion managed area (Figure 2) experienced a gradual increase from 2,276,492 hectares in 1997 to a peak of 2,291,107 hectares in 2020 and 2021. This expansion (+0.55% between 2007 and 2020) reflects an increased commitment to erosion management at the national level. The subsequent decrease to 2,280,188 hectares in 2022 (-0.47% compared to 2021) and stabilization at 2,280,475 hectares in 2023-2024 indicate a readjustment and the attainment of a new equilibrium in soil protection strategies.

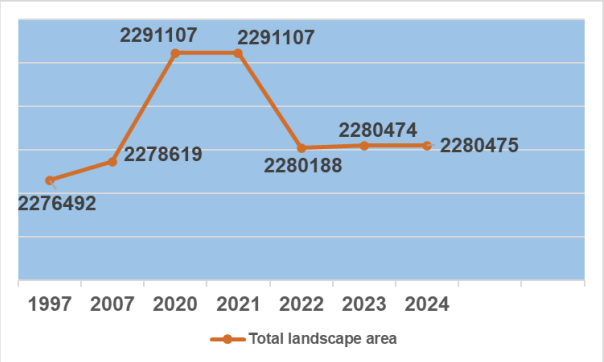

Fig. 2 Total anti-erosion managed area (1997-2024)

The anti-erosion managed agricultural area (Figure 3) has followed an upward trajectory, increasing from 2,131,524 hectares in 1997 to a peak of 2,145,426 hectares in 2020, stabilizing at 2,134,078 hectares in 2024. The substantial growth up to 2020-2021 (+0.52% compared to 2007) indicates a prioritization of the protection of agricultural lands, which are crucial for food security, often supported by the Common Agricultural Policy (CAP) and other national mechanisms. The decline post-2021 and subsequent stabilization reflect a possible rationalization or optimization of interventions.

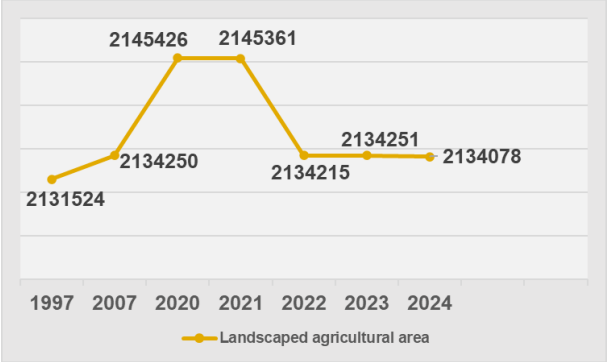

Fig. 3 Evolution of the anti-erosion managed agricultural area

The anti-erosion managed arable land (Figure 4) has demonstrated a consistent and sustained increase, from 1,203,684 hectares in 1997 to a peak of 1,227,407 hectares in 2020. The substantial growth (+1.48% between 1997-2007 and +0.48% between 2007-2020) highlights the significant emphasis placed on the conservation of arable soil, which is essential for maintaining agricultural productivity. A slight downward adjustment post-2020 and stabilization at 1,222,093 hectares in 2024 suggest a continuous optimization of management practices.

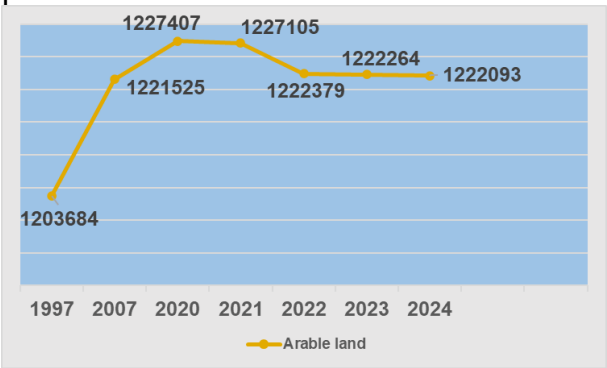

Fig. 4 Evolution of the anti-erosion managed arable area

Natural pastures managed against erosion (Figure 5) recorded an increase from 513,954 hectares in 1997 to a peak of 518,128 hectares in 2021 (+0.64%

compared to 2007), followed by a decline to approximately 514,012 hectares in 2024. This dynamic suggests a period of consolidation and expansion, likely supported by pasture conservation programs.

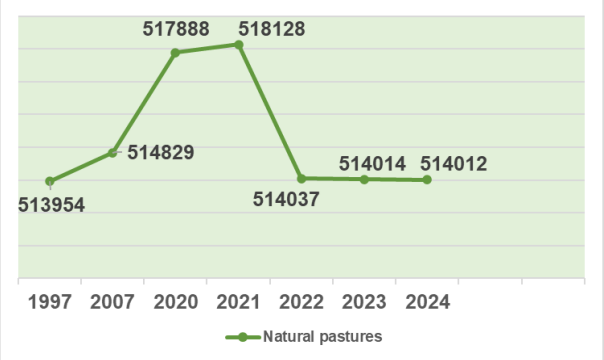

Fig.5 Evolution of the total anti-erosion managed pastures

The abrupt decline of approximately 0.79% between 2021 and 2022, followed by subsequent stabilization, can be attributed to reassessments, changes in classification, or anthropogenic pressures that led to the conversion or degradation of certain areas.

Natural grasslands managed against erosion (Figure 6) showed a positive trend, increasing from 197,113 hectares in 1997 to 200,716 hectares in 2024. A significant increase was observed between 2007 and 2020 (+1.47%), reaching a peak and subsequently stabilizing at this elevated level. This evolution underscores the ongoing commitment to the conservation of these ecosystems, which are essential for biodiversity and hydrological cycle management, reflecting the success of environmental and agroecological policies.

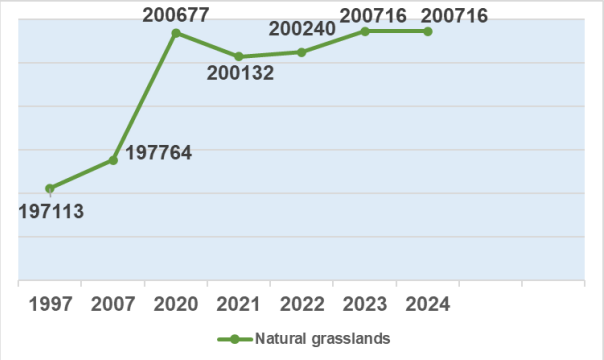

Fig.6 Evolution of the anti-erosion managed grasslands

The area of vineyards and vine nurseries managed against erosion (Figure 7) has experienced a continuous and marked decline, from 94,029 hectares in 1997 to a minimum of 81,019 hectares in 2023-2024 (-11.35% between 1997 and 2007).

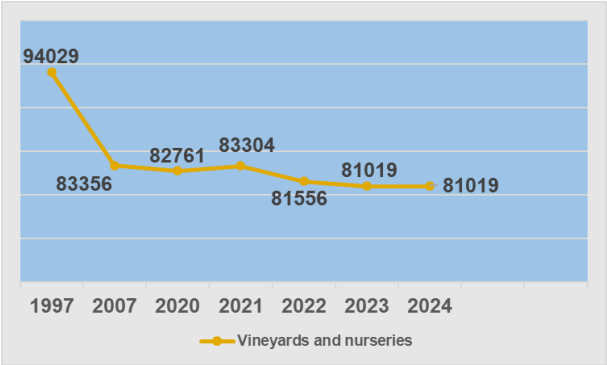

Fig.7 Evolution of the anti-erosion managed vineyards and vine nurseries

This drastic contraction indicates a profound restructuring of the viticulture sector, likely under pressure from profitability and market demand, culminating in the attainment of a new equilibrium at a reduced level of area.

Similarly, the area of orchards and fruit nurseries managed against erosion (Figure 8) experienced a significant decline, from 122,744 hectares in 1997 to 116,776 hectares in 2007 (-4.86%). This dramatic reduction suggests a major restructuring of the fruit sector, possibly through the removal of old or inefficient plantations. Subsequently, stabilization was observed at a lower level, around 116,238 hectares in 2023-2024, indicating an adaptation to market conditions and optimization of productive areas.

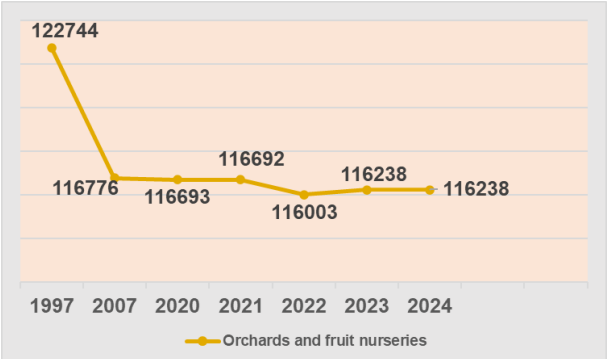

Fig.8 Evolution of the anti-erosion managed orchards and fruit nurseries

The evolution of the non-agricultural anti-erosion managed area (Figure 9) indicates an initial stability, followed by a constant increase. From 144,968 hectares in 1997, it slightly decreased to 144,369 hectares in 2007 (-0.41%), and then progressively increased, reaching 146,397 hectares in 2024. This recent upward trend emphasizes an expansion of soil conservation strategies in non-agricultural areas, which are essential for protecting infrastructure and landscapes in the context of anthropogenic pressures.

The inclusion of non-agricultural areas in this total underscores a holistic approach to erosion management, extending conservation efforts beyond strictly agricultural boundaries. The current distribution serves as an indicator of resource allocation and priorities in land management policies, reflecting a balance between the imperative of agricultural productivity and ecological sustainability.

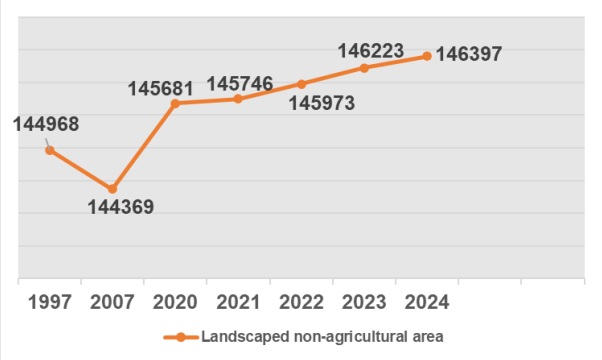

Fig.9 Evolution of the anti-erosion managed non-agricultural area

CONCLUSIONS

The longitudinal analysis of anti-erosion managed areas in Romania over the period from 1997 to 2024 reveals a complex and multifunctional dynamic of land management strategies in the face of environmental and socio-economic challenges.

The study highlights a landscape of soil conservation interventions that is not linear, but marked by periods of expansion, adjustment, and stabilization, specific to each land use category. The overall trend indicates an increase in awareness and investment in anti-erosion measures for essential agricultural land categories, such as arable land and natural meadows. This positive dynamic underscores Romania's commitment to soil conservation and the promotion of sustainable agricultural practices, likely stimulated by European agricultural policies and national rural development and environmental programs. The predominant role of arable land within the total managed areas emphasizes the prioritization of protecting soils at the highest risk of degradation, which have a direct impact on food production.

On the other hand, the fruit and viticulture sectors have undergone significant restructuring periods, marked by a reduction in managed areas. This evolution does not necessarily indicate a decrease in conservation efforts, but rather an optimization and adaptation to market demands and economic pressures. Natural pastures, although they reached a peak in recent years, have experienced a slight downward adjustment, indicating a reevaluation of management strategies or conversion pressures.

In contrast, the non-agricultural anti-erosion managed area has demonstrated progressive growth, reflecting an expansion of soil conservation strategies beyond strictly agricultural zones, aimed at protecting infrastructure and landscapes.

Overall, the study reveals a continuous adaptation of land management in Romania, aligning with sustainability objectives and addressing soil degradation. The observed fluctuations reflect the complexity of the challenges and the associated political and practical responses, underscoring the necessity for ongoing monitoring and interventions tailored to the specifics of each land use category. This multidirectional approach is crucial for ensuring the long-term sustainability of soil resources and for strengthening the resilience of Romanian landscapes in the face of climate change.

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