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ASPECTS RELATED TO VEGETATION SUCCESSION, ON AGRICULTURAL LANDS, IMPROPERLY EXPLOITED AND ABANDONED, AFFECTED BY DROUGHT, IN NON-COLLECTIVIZED AREAS

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Abstract

The paper aims to study and analyze the succession process of arboreal and shrub vegetation on a series of agricultural lands, which have not been administered and exploited in accordance with their use category, in a non-collectivized hill area, in the Vîrfurile locality, Arad county. The study was carried out for the period 1990-2025, with observations, inventories, comparisons, simulations, and magnetic recordings of relevant images related to the studied lands. Also, the records from the agricultural register and the parcel plan that was drawn up by the Cadastre and Real Estate Advertising Office of Arad county were analyzed, on the occasion of the systematic registration works of the real estates in the rural areas, for this location. The results obtained confirm that on the studied lands, a succession of arborescent and shrub vegetation was triggered, with a relatively active dynamic. Consequently, a series of pioneer, invasive tree species were highlighted, as well as forest tree species of the genus Quercus, which settled on areas ranging between 10-100% of the mentioned location.

Key words*: agricultural lands, improper exploitation, non-collectivized areas, shrub species, tree species use category, vegetation succession.*

INTRODUCTION

The Earth's vegetation cover is characterized by continuous changes in the composition and distribution of its component species, which unfold with differentiated dynamics and particularities, determined by a series of conditions and factors that trigger, influence, and sustain them.

These processes may consist of local or seasonal changes, known as symphenological processes, characterized by a recurrent rhythm influenced by climate, up to secular or millennial developments on a large spatial and very long temporal scale - namely synchronological processes, which are in fact determined by major climate changes and, implicitly, by changes in vegetation conditions, such as the development of vegetation in the post-glacial period (Fickert & Richter, 2025).

Consequently, regeneration processes, which are considered cyclical, and succession processes, which have a strongly directional character, represent indicators of temporal changes in species populations, communities, and even entire ecosystems (Fickert & Richter, 2025).

Vegetation succession represents the modification or replacement, over a period of time, of the phytocoenosis composition on a given land surface, as a direct consequence of changes in vegetation conditions and, implicitly, in interspecific relationships. As a result, species and species associations are eliminated and replaced by others (Florescu & Nicolescu, 1996). According to the theory proposed by Clements (Florescu & Nicolescu, 1996; Fickert & Richter, 2025), the vegetation succession process goes through a series of successive stages: denudation of the territory, species

migration, colonization, competition, reaction, stabilization, and regression.

Denudation, or exposure of the substrate through disturbance, may result from natural phenomena such as landslides, avalanches, vegetation fires (De Giuli et al., 2024), active erosion, the formation of river islands, volcanic eruptions (Moreno-Gonzalez et al., 2025), or climate changes. This stage may also be significantly influenced by anthropogenic activities such as pollution, excessive exploitation or abandonment of agricultural lands (Cioflan, 2025), irrational forest exploitation, improper conservation or abandonment of mining sites (Garate-Quispe et al., 2023; 2024), construction works, hydrotechnical developments, etc.

Migration (immigration) of herbaceous and woody species and the occupation of vacant ecological niches or newly denuded habitats generally occur through seed dispersal, depending on their morphological and physiological characteristics. Thus, this stage unfolds differently depending on the dispersal mechanism, with vector agents including wind, water, animals, and humans (Fickert & Richter, 2025).

Colonization, or establishment of species in the new habitat, involves the installation and development of immigrant species, directly influenced by their ecological requirements and vegetation conditions. In some cases, this stage results in the emergence and spread of valuable natural species (Szirmai et al., 2022). Consequently, this stage includes successive processes: seed germination, seedling emergence, growth, development, maturation, and finally sexual reproduction of mature individuals.

Competition in the newly colonized location occurs both interspecifically and intraspecifically, through competition among new species and between immigrant species and the former inhabitants of the territory, for both underground and aboveground space. As a result, species or groups of species that regenerate easily under the new conditions and do not have high trophic requirements-namely pioneer and invasive species-become dominant, with biodiversity playing an important role in this stage (Pérez-Hernández & Gavilán, 2021).

Reaction represents the habitat's response to the impact of the new phytocoenosis. Consequently, a new ecological niche is shaped, with specific characteristics that may significantly influence all bioecological processes of the emerging ecosystem, as well as its stability and persistence. The new landscape that forms will reflect the interaction between the habitat and the new phytocoenosis (Fickert & Richter, 2025).

Stabilization represents the stage of consolidation of the new phytocoenosis. A dynamic equilibrium is established, characterized by consolidated ecosystem stability, also known as the climax stage. Reaching an advanced climax stage marks the completion of succession.

Regression represents the initial stage of degradation of the advanced climax state, resulting from reduced resistance of the phytocoenosis to competitive pressure from potential immigrant species, which may trigger a new succession (Florescu & Nicolescu, 1996).

In some situations, depending on vegetation conditions and land-use practices, certain stages of vegetation succession may be absent, with migration, competition, reaction, stabilization, and regression being the most commonly observed.

The rate at which successions occur may be rapid or slow. If species replacement occurs within a relatively short time-years or decades-the succession is considered rapid. When species replacement occurs over more than a century, the succession is considered slow and can be analyzed using the chronosequence method (Nasibullina et al., 2024) and pollen analyses (O'Connell & Wolters, 2025), based on the study and analysis of vegetation maps (Fickert & Richter, 2025) prepared over time for the respective region.

Improper exploitation and abandonment of agricultural lands in non-collectivized areas, gradually after 1989, in the medium and high hill regions of western Romania, created the premises for the initiation of vegetation succession processes. The abandonment of agricultural lands resulted directly from depopulation of these areas, lack of modern equipment, absence of adequate agricultural strategies and policies for local farmers, excessive land fragmentation in non-

collectivized areas, and the effects of climate change.

Considering the aspects presented, vegetation succession represents a fundamental concept of great importance for agro-forestry activities, as it indicates how species populations, communities, and ecosystems change over time in a new habitat or after a disturbance (Poorter et al., 2023) that affects their previous ecosystem stability.

The objectives of this study are to analyze the climatic conditions that favored and sustained the succession of arboreal and shrub vegetation, as well as the dynamics and particularities of this process, on a series of agricultural lands in a non-collectivized area that were abandoned or not exploited according to their land-use category.

MATERIALS AND METHODS

The case study was conducted in the locality of Vârfurile, which is the seat of the Vârfurile commune in Arad county, which was a non-collectivized area. It is located in the east of Arad county, in the Hălmagiu Depression in the Apuseni Mountains. The depression is crossed by the Crișul Alb River and is located on its upper course. Vârfurile village is located in the northwest of the Hălmagiu Depression and is bordered by the Bihor Mountains to the northeast, the Codru-Moma Mountains to the northwest and the Zarandului Mountains to the south and southwest (by the Gorgana Massif, more precisely). Vârfurile Commune consists of 8 localities and has an average altitude of 231 m (Pop, 2005; https://primariavirfurile.ro/despre-noi/prezentare/).

Vârfurile Commune has a temperate-continental, moderate climate, with slight Mediterranean influences, the summers not being excessively warm, and the winters being generally mild. The depression area in which the locality is situated communicates to the west with the Zarandului Depression, which has a wide opening to the west, towards the Crișurilor Plain. That favors the easy penetration of western air masses (of Atlantic or Mediterranean origin), rich in moisture, which makes precipitation abundant. During certain periods of the year, hot and dry continental-tropical air masses from northern Africa can also penetrate, generating heatwaves and drought. The thermal inversions are frequent in the cold season, specific to the intermontane depression areas, generating dense fogs. The shelter provided by the surrounding mountains reduces wind speed and protects the village from strong winds. The moderate thermal climate with abundant rainfall makes the region well forested (Pop, 2005; https://primariahalmagiu.ro/download/urvqbaO3Rf0Eh7w9f690f8ugJ6lAzB8W4JBO4a7g.pdf).

The studies and research fall within the scope of doctoral studies regarding the category of agricultural land use in the mentioned location. To achieve the established objectives, appropriate bibliographic documentation was created (Duduman, 2023).

Data from the Gurahonț meteorological station were used for the climatic characterization of the studied area, being the closest to the Vârfurile locality. The station is located at an altitude of 177 m, has the code 15182 and the geographical coordinates 46°27' N latitude, 22°33' E longitude (www.meteomanz.com).

Meteorological data regarding the monthly and annual average air temperature and the monthly and annual precipitation amount were used in the paper. The analyzed period was 1990-2025 (36 years). The temporal variability, frequency and linear trend of the average annual values of temperature and precipitation, as well as the polynomial trend of annual precipitation amounts, were analyzed. The average annual values of air temperature and precipitation were compared with the multiannual average of the period 1966-2025 (60 years), to better highlight the climate trends of recent years. The variation during the year of the multiannual monthly average values of air temperature and precipitation (1990-2025) was also analyzed.

The meteorological data used in the paper came from the database of the National Meteorological Administration (N.M.A.) of Romania and from the Meteomanz.com (www.meteomanz.com) and rp5.ru (https://rp5.ru/) websites.

For the purpose of conducting the study and analyzing the dynamics and particularities of the vegetation succession process in the established location, route-based and stationary observations were carried out, along with inventories on experimental surfaces, simulations, comparisons, and analyses.

As a result, the study and analysis of the dynamics of the vegetation succession process were performed on 100 agricultural parcels that had been improperly exploited or abandoned.

The parcels were identified on the parcel plan corresponding to cadastral sector no. 15 (provided by OCPI Arad), which was superimposed on the orthophotomap using the mapSys 10.1 software. Also, the category and subcategory of use were identified from the agricultural register of the Vârfurile locality, with the agreement and collaboration of the owners.

Field identification of the studied parcels and delimitation of the areas where vegetation succession had been triggered and was ongoing were performed using GNSS technology, with TRIMBLE R10I receivers, through the real-time kinematic (RTK) method, using the permanent GNSS station Gurahonț, Arad County.

In this context, the parcels were physically surveyed, allowing direct observation of the stages of succession, identification of the arboreal and shrub species that had established, and the manner in which these areas were being exploited. The field data were recorded in tabular field sheets, prepared to streamline the data collection and processing procedure. These sheets included the following fields: Nrp - number of the analyzed parcel, Sp - surface area of the analyzed parcel, Sc - surface colonized by the identified species, Pc - percentage of colonization of the studied lands where vegetation succession is occurring, land-use category and subcategory, and installed arboreal and shrub species.

Additionally, for the study and analysis of the structural characteristics defining the arboreal and shrub vegetation that had established, inventories were carried out in five representative and relatively accessible parcels. On the surfaces where arboreal vegetation had established, complete inventories were performed, recording all individuals within the identified biogroups. A biogroup of trees represents a cluster of 7-10 trees, either of the same species or of different species, which mutually influence each other and exhibit evident intra- or interspecific competition, both underground and aboveground. These can occupy different areas, depending on a series of factors and vegetation conditions, and if the area occupied exceeds 0.5 hectares, the height of the component trees is greater than 5 m, and the consistency index k > 0.4, they can be considered as a forest (Law no. 331/2024).

Tree diameter was measured with a forest caliper at a height of 1.30 m above ground (diameter at breast height - d1.30), at 2 cm intervals, starting from a minimum diameter of 4 cm. Tree height up to 8.0 m was measured with a special rod graduated in millimeters, while heights above 8.0 m were determined using the VERTEX 5 device. On surfaces covered with shrubs, inventories were carried out on rectangular experimental plots, with areas ranging between 1 m² and 5 m², depending on their distribution and accessibility. Shrub diameter was measured with a caliper or measuring tape (with millimeter divisions), depending on accessibility and biogroup density. Their height was measured with a special rod graduated in millimeters.

For the analysis of the structural characteristics of the inventoried tree biogroups, a series of structural indices representative for forest stands were used by similarity. Consequently, the following were determined: the number of trees (N_{exp}), diameter at breast height (d1.30), cumulative basal area (G_{exp}), composition by number of trees and by basal area, the density index (I_N) and the density coefficient (I_G); the slenderness coefficient (Z%) and the Hart-Beking spacing factor in the square ($S_{4\%}$) and hexagonal ($S_{6\%}$) The indicators were calculated using the formulas established by Florescu & Nicolescu (1996) and Crainic et al. (2024). The values obtained are presented below:

$$I_N = \frac{N_{exp}}{N_{th}} \quad (1)$$

$$I_G = \frac{G_{exp}}{G_{th}} \quad (2)$$

$$Z_{(\%)} = \frac{h}{d} \quad (3)$$

$$S_{(\%)} = \frac{a}{h_{dom}} \times 100 \quad (4)$$

$$S_{4(\%)} = \frac{a_4}{h_{dom}} \times 100 \quad (5)$$

$$S_{6(\%)} = \frac{a_6}{h_{dom}} \times 100 \quad (6)$$

$$h_{dom} = h + 0.15\,h = 1.15\,h \quad (7)$$

$$a_4 = \sqrt{\frac{10000}{N}} \quad (8)$$

$$a_6 = \sqrt{\frac{10000}{N\sqrt{\frac{3}{2}}}} \quad (9)$$

The elements of formulas (1) - (8) have the following meaning:
I_N - density index determined according to the number of trees;
I_G - density index determined according to the cumulative basal area;
N_{exp} - number of trees per hectare, determined experimentally through inventories;
N_{th} - theoretical values of the number of trees from general yield tables, for the same species, yield class, and age;
G_{exp} - cumulative basal area per hectare, determined experimentally through inventories;
G_{th} - theoretical values of the cumulative basal area from general yield tables, for the same species, yield class, and age;
$Z_{(\%)}$ - slenderness coefficient of the stand;
h - mean height of the stand;
d - mean diameter of the stand;
$S_{(\%)}$ - Hart-Beking spacing index;
h_{dom} - dominant height of the stand;
a - theoretical spacing between trees
S_4 - spacing index for the square arrangement;
a_4 - theoretical spacing between trees in a square layout;
S_6 - spacing index for the hexagonal arrangement;
a_6 - theoretical spacing between trees in a hexagonal layout.

Additionally, for comparing the experimental values with the theoretical ones corresponding to forest arboreal vegetation, it was necessary to extrapolate the experimental values to one hectare. The theoretical values of the structural characteristics used were those provided by Biometrics of trees and stands in Romania (Giurgiu et al., 1972).

RESULTS AND DISCUSSIONS

The multiannual average air temperature was 10.9°C for the period 1990-2025, at the Gurahonț meteorological station. It was 0.4°C higher than the multiannual average of the period 1966-2025 (10.5°C) and 1.0°C higher than that of the period 1966-1990 (9.9°C).
The average annual air temperature ranged between 9.5°C (in the years 1991 and 1997) and 12.8°C (in 2024), during the period 1990-2025 (Figure 1). The coldest years were 1991, 1997, 2005, 1996, 1993, 1998 and the warmest years were 2024, 2019, 2023, 2014, 2018, 2025. So, the coldest years were recorded at the beginning of the analyzed period, and the warmest towards its end. Five years had an annual average value above 9°C, 11 years above 10°C, 16 years above 11°C, and 4 years above 12°C, during the analyzed period. 24 years out of the 36 analyzed (2/3 of the years) had an annual average value above the multiannual average of the period 1966-2025 (of 10.5°C).
Since 1994, an increase in air temperature has been observed in Gurahonț. Moreover, the linear trend of the average annual values of air temperature is strongly upward. It is due to the very high values of recent years, which have been exceptionally warm. The 2007-2025 interval was the warmest, being characterized by annual average values above the multiannual average of the 1966-2025 period (Figure 1).

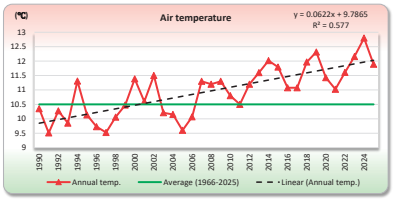


Figure 1. Average annual air temperature, its linear trend (1990-2025) and multiannual average (1966-2025), at the Gurahonț meteorological station

The multiannual average amount of precipitation was 747.5 mm for the period 1990-2025, at the Gurahonț weather station. It was only 4.5 mm lower than the multiannual average of the period 1966-2025 (752.0 mm) and only 3.2 mm lower than that of the period 1966-1990 (750.7 mm).
The annual amount of precipitation varied between 438.4 mm (in 2025) and 996.2 mm (in 2005), during the period 1990-2025 (Figure 2). The rainiest years were 2005, 2001, 2004, 2016, 1999, 2023 (with a rainfall surplus between 125 and 245 mm), and the driest were 2025, 2024, 2000, 2011, 1990, 1992, 1993 (with a rainfall deficit between 130 and 314 mm). There were 15 years with over 800 mm of precipitation and 14 years with under 700 mm of precipitation, during the mentioned period.

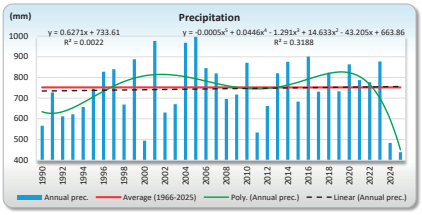


Figure 2. Annual precipitation amounts and their linear and polynomial trend, at the Gurahonț meteorological station (1990-2025)

The linear trend of the annual precipitation amounts is slightly upward.
The polynomial trend, rendered based on the 5th order polynomial, shows that after the dry period 1990-1994, there is a rainy period 1995-2007 (of 13 years), followed by a short dry period 2008-2012, then by a rainy one 2013-2023 (of 11 years) and two extremely dry years 2024-2025. It is noted that the drought of 2024-2025 exceeded the great drought of 2000. Also, these years followed the very rainy year 2023 and a longer period of precipitation excess.
During the year, the air temperature increases from January (the multiannual monthly average: 0.0°C) to July (21.3°C), when it reaches a maximum, after which it decreases until December (1.4°C) (Figure 3).

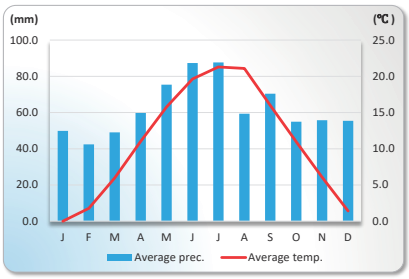


Figure 3. Multiannual monthly average values of air temperature and atmospheric precipitation, at the Gurahonț meteorological station (1990-2025)

Precipitation follows a somewhat similar pattern, being higher in summer (except August) and lower in winter and early spring. The most rain falls between May and July (75.4-87.7 mm), and the least between January and March (42.4-49.9 mm). It is noted that the rainfall maximum was not recorded in June (87.3 mm), but in July (87.7 mm), in the period 1990-2025. This is due to the large amounts of precipitation that fell in July, amid the severe heatwaves of recent years, in this month, when the land surface strongly heats up and generates intense thermal convection. August is a very hot and dry month, because the anticyclonic baric formations prevail, which generate clear and warm, even scorching weather.
Comparing the multiannual monthly average of the months of the period 1990-2025 with the multiannual average of the period 1966-2025, it can be said that the months of June, August, May and January recorded lower amounts of precipitation during the period 1990-2025, compared to the period 1966-2025. So, they were drier. All months of the year were warmer during the period 1990-2025 than during the period 1966-2025. The warmest months were August, June, July, January and November.
From the analysis of the results obtained after processing the data recorded during the study of the particularities of the vegetation succession process on the 100 parcels, presented in Table 1, it is observed that the process of colonization and establishment of arboreal and shrub vegetation on a series of agricultural lands occurred with differentiated dynamics, depending on the land-use categories and subcategories, as well as on the manner in which these lands had been exploited.
Consequently, the land-use subcategory most affected by the succession process was wooded pasture, with 76% of its analyzed surface undergoing succession, followed by wooded hayfield with 53%, hayfield with trees with 46%, arable land with shrubs and isolated trees with 38%, traditional orchard with 27%, pasture with trees with 25%, and finally clean hayfield and hayfield with shrub patches, each with 19%.
Overall, it is found that 55% of the total surface of the 100 analyzed parcels was colonized by arboreal and shrub vegetation (Table 1), as a result of the vegetation succession process, which occurred due to improper exploitation and the abandonment of agricultural land.
The initiation and development of the vegetation succession process on the 100 studied parcels took place without a specific denudation stage of the habitat, the premises for triggering this process being represented by improper land use and the abandonment of considerable areas of agricultural land.
The arboreal species that have established in the studied location are represented by forest species that form the fundamental natural forest types of the surrounding areas, in relatively high proportions - *Quercus cerris*, *Quercus robur*, *Fagus sylvatica*, *Carpinus betulus*, *Prunus avium*, *Tilia tomentosa* - followed by pioneer species such as *Betula pendula*, *Populus tremula*, *Salix caprea*, *Salix alba*, and a single invasive species, *Robinia pseudacacia*.

Table 1. Synthetic record of the surface areas of agricultural land-use categories and subcategories on which arboreal and shrub vegetation has established, following the onset of the vegetation succession process

Nr. crt.	Nrp	Sp (ha)	Land use Category	Land use Subcategory	Sc (ha)	Pc (%)	Inatalled species Forest trees	Inatalled species Shrubs
1	11	4.58	Arable	Arable land with shrubs and isolated trees	1.73	38	*Qr, Qc, Cb, Bp, Tt, Pt, Rp*	*Ps, Cm, Rc, Rh,*
2	2	1.50	Orchard	Traditional orchard	0.40	27	*Qr, Qc, Cb, Pt, Sc, Ms, Pp*	*Ps, Ca, Cm, Rc, Rh,*
3	45	27.36	Pasture	Wooded pasture	20.74	76	*Qr, Qc, Fs, Cb, Bp, Tt, Pt, Sc, Ms, Pp*	*Ps, Jc, Ca, Cm, Rc, Rh,*
4	4	3.76	Pasture	Pasture with trees	0.93	25	*Qr, Qc, Cb, Pt, Sc, Ms, Pp*	*Ps, Ca, Cm, Rc, Rh,*
5	2	0.79	Hayfield	Hayfield with shrub patches	0.15	19	*Qr, Qc, Cb, Bp, Pt, Sc, Ms, Pp*	*Ps, Cm, Rc, Rh,*
6	12	6.06	Hayfield	Wooded hayfield	3.21	53	*Qr, Qc, Fs, Cb, Bp, Tt, Pt, Sc, Sa, Ms, Pp*	*Ps, Cm, Rc, Rh,*
7	13	7.08	Hayfield	Clean hayfield	1.34	19	*Qr, Qc, Cb, Pt, Sc, Sa, Ms, Pp*	*Ps, Rc, Rh,*
8	11	4.82	Hayfield	Hayfield with trees	2.23	46	*Qr, Qc, Cb, Bp, Tt, Pt, Sc, Ms, Pp*	*Ps, Ca, Cm, Rc, Rh*
Total	100	55.94	/	/	30.74	55	/	/

Nrp - number of analyzed parcels, Sp - surface area of the analyzed parcels, Sc - surface area colonized by the identified species, Pc - percentage of colonization of the studied lands on which vegetation succession occurred, *Qr-Quercus robur* L., *Qc-Quercus cerris* L., *Pt-Populus tremula* L., *Rp-Robinia pseudacaccia* L., *Bp-Betula pendula* Roth, *Tt-Tilia tomentosa* Monech., *Sc-Salix caprea* L., *Sa-Salix alba* L., *Fs-Fagus sylvatica* L., *Cb-Carpinus betulus* L., *Ms-Malus sylvestris* (L.) Mill., *Pp-Pyrus pyraster* (L.) Burgsd., *Ps-Prunus spinosa* L., *Jc-Juniperus communis* L., *Rh-Rubus hirtus* W. et. K., *Ca-Corylus avellana* L., *Crataegus momogyna* Jacq., *Rosa canina* L. (Stănescu, et al., 1997).

Consequently, the migration of oak species, which have relatively large seeds, occurred exclusively through zoochorous dispersal, with vector agents represented by birds and certain rodents (Yang & Yi, 2022). Moreover, the zoochorous dispersal of acorns immediately after abundant fructification events led to their germination under optimal conditions, a phenomenon identified especially in several traditional orchards and agro-silvopastoral systems (Crainic et al., 2023a), located at distances of over 1500-2000 m from mature oak trees.

These processes result from the dispersal of acorns, which do not enter dormancy, thus ensuring a high efficiency of germination and seedling emergence (Yang & Yi, 2022). Fruit trees and certain shrub biogroups or pioneer species also play an important role in supporting and enhancing these bioecological processes, as they partially fulfill the role of nurse species (Fodor et al., 2018), by providing protection for young oak individuals.

Recent studies have highlighted a clear trend of expansion of some native oak species in western Romania, as a result of abundant fruiting (Crainic et al., 2023b), on a series of lands with forestry and agricultural use, as a direct consequence of climate change and easy vegetation conditions.

A similar pattern is characteristic of the establishment of *Fagus sylvatica*, but only on small areas and at shorter distances from an existing forest (a stand) or from larger biogroups of trees. This is due to the species' shade-tolerant temperament and its difficulty in regenerating in open terrain without protection.

Mixed species and pioneer species establish relatively more easily due to their more efficient dispersal mechanisms, determined by seed size and the greater diversity of vector agents. Their germination characteristics also positively influence their ability to germinate and emerge under favorable conditions.

The *Robinia pseudacaia* species, which is considered invasive, was identified in a location bordering an area from which nine years ago all the biogroups formed by mature trees of this species were extracted and exploited. These trees had produced abundant seed crops in the year prior to harvesting, and the seeds were easily dispersed onto the neighbouring land (which had not been exploited during that period), where they germinated and emerged under optimal conditions. They now show a tendency to form a closed forest stand within 9-10 years, without any anthropogenic intervention.

Recent research has highlighted that excessive fragmentation of agricultural landscapes causes changes in the composition of plant associations and implicitly reduces the size of plant populations and genetic diversity, with direct implications for biodiversity (Hurajová et al., 2024).

Consequently, conservation and restoration efforts for grasslands, pastures, and other agricultural lands must take into account the information provided by fine-scale monitoring of vegetation matrix organization (Bartha et al., 2025), as part of the sustainable use of plant resources, considering the trend of climate change and society's need for high-quality agricultural products and integrated ecosystem services.

The values of the structural characteristics of the arboreal and shrub forest biogroups, determined after processing the field data, are presented synthetically in Table 2 for each parcela.

Table 2. Synthetic values of structural indices related to biogroups of inventoried trees from the studied plots

Parcela	Cps(N_{exp}) Cps(G_{exp})	dg_M (cm)	H_{dgM} (m)	T (ani)	CLP	N_{exp} (buc./ha)	N_{th} (buc./ha)	G_{exp} (m^2/ha)	G_{th} (m^2/ha)	I_N, I_G	Z (%)	$S_{4\%}$(%), $S_{6\%}$(%)
1771	2Qc2Ms1Qr1Pt1B p1Sc1Sa1Pp / 2Qc2Qr2Pt1Bp1Sc 1Sa1Ms dis.Pp	Qc = 18	17.2	40	III	242	1099	3.918	21.500	0.7 0.9	93	16 17
		Qr = 18	18.4	40	III	169	1305	2.785	21.800			
		Pt = 19	19.6	30	III	177	614	2.855	28.900			
		Bp = 17	18.3	40	II	103	1210	2.161	22.500			
		Sc = 15	17.8	30	IV	110	594	1.387	30.600			
		Sa = 19	17.7	30	IV	95	594	1.941	30.600			
		Ms = 11	7.5	15	III	317	3929	2.401	11.000			
		Pp = 12	6.8	15	III	155	3929	1.188	11.000			
	Total values	/	/	/	/	1368	/	18.636	/			
	Wav	16	14.80	30	III	/	1830	/	21.040			
1774	*5Qr 5Qc*	Qc = 29	21.5	60	III	290	765	13.008	27.000	0.8 0.9	74	17 18
	5Qr 5Qc	Qr = 29	21.3	60	III	303	657	13.686	29.700			
	Total values	/	/	/	/	593	/	26.694	/			
	Wav	29	21.4	60	III	/	711	/	28.350			
1776	*4Qr3Qc3Cb*	Qr = 39	22.6	60	III	268	657	8.974	29.700	0.5 0.7	70	18 19
	5Qr3Qc2Cb	Qc = 22	21.4	60	III	240	765	5.479	27.000			
		Cb = 16	10.3	20	III	188	3087	2.837	14.200			
	Total values	/	/	/	/	696	/	17.290	/			
	Wav	27	18.55	48	III	/	1418	/	24.240			
1835	*8Tt1Qr1Pa*	Tt =16	14.9	40	III	994	1290	16.657	26.600	0.9 0.9	89	17 18
	7Tt3Qr disPa	Qr =30	21.8	55	III	114	729	6.527	28.200			
		Pa =17	14.2	35	III	83	1818	1.791	23.400			
	Total values	/	/	/	/	1191	/	24.976	/			
	Wav	17	15.21	41	III	/	1288	/	26.520			
1930	*9Rp1Pa*	Rp = 10	8.64	10	III	1831	2200	9.189	11.000	0.8 0.9	86	23 25
	9Rp1Pa	Pa = 11	8.52	10	III	114	3890	1.091	15.400			
	Total values	/	/	/	/	1945	/	10.280	/			
	Wav	10	8.63	10	III	/	2369	/	11.440			

Wav-Weighted average value, Cps (N_{exp})-composition according to the number of trees determined experimentally, Cps (G_{exp})-composition based on experimentally determined base area, dg_M-median diameter of the base surface determined experimentally, H_{dgM}-the corresponding height dg_M, T-average age, CLP-production class

In parcel 1771, over an area of 1350 m², a total of 185 trees were inventoried, belonging to seven species: 33 trees of *Quercus cerris*, 23 trees of *Quercus robur*, 24 trees of *Populus tremula*, 14 trees of *Betula pendula*, 15 trees of *Salix caprea*, 13 trees of *Salix alba*, 43 trees of *Malus sylvestris*, and 21 trees of *Pyrus pyraster* (Figure 4).



Figure 4. Biogroups with trees from plot 1771, Cadastral Sector 15, Vârfurile ATU, Arad County

Additionally, 8 specimens of *Corylus avellana* were identified, along with a cumulative area of 200 m² occupied by shrub biogroups of *Prunus spinosa* L., which exhibit an average density of 12 individuals/m² and an average height of 2.25 m (Figure 5).



Figure 5. Biogroups with shrubs of the *Prunus spinosa* species in plot 1771, Cadastral Sector 15, Vârfurile ATU, Arad County

The total number of inventoried trees extrapolated per hectare is N_{exp} = 1368 trees/ha, with a mean diameter dg_M = 16 cm, a total basal area G_{exp} = 18.636 m²/ha, a mean height H_{dgM} = 14.800 m, a mean age T = 30 years, and a relative yield class of III.
The composition of the inventoried forest vegetation is:
Cps(N_{exp}):2Qc2Ms1Qr1Pt1Bp1Sc1Sa1Pp, and
Cps(G_{exp}):2Qc2Qr2Pt1Bp1Sc1Sa1Ms dis.Pp.
From the analysis of the diagrams presented in Figure 6, it is observed that the distribution of the number of trees by diameter classes is plurimodal, due to the particularities of establishment, growth, and development of the species that have colonized this location, as well as the manner in which the land has been exploited.

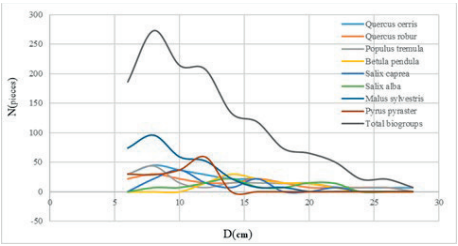


Figure 6. Distribution of the number of trees by diameter classes, extrapolated per hectare, in the fully inventoried biogroup from parcel 1771

The theoretical values for the weighted number of trees are N_{th} = 1830, and the weighted total basal area is G_{th} = 21.040 m²/ha. Consequently, the density index is I_N = 0.7, the density coefficient I_G = 0.9, the slenderness coefficient Z = 93%, and the spacing indices are $s_{4\%}$ = 16% and $s_{6\%}$ = 17% (Table 2).
The biogroups of installed trees present a varied composition, bringing together seven tree species with different ecological behavior, their density is moderate to normal, satisfactory stability to the action of the dominant wind, and they are also moderately spaced. Consequently, a state outlined by climax is highlighted.
In parcel 1774, the inventory of tree biogroups was carried out over an area of 1214 m². As a result, a total of 72 trees were inventoried, of which 37 belonged to *Quercus cerris* and 35 to *Quercus robur* - Figure 7. The total number of inventoried trees extrapolated per hectare is N_{exp} = 593 trees/ha, with a mean diameter dg_M = 29 cm, a total basal area G_{exp} = 26.694 m²/ha, a mean height H_{dgM} = 21.40 m, a mean age T = 60 years, and a relative yield class of III.
The composition of the inventoried forest vegetation, based on both characteristics, is: 5Qr5Qc.
From the analysis of the diagrams presented in Figure 8, it is observed that the distribution of the number of trees by diameter classes is plurimodal, due to the particularities of establishment, growth, and development of the species that have colonized this location.



Figure 7. Biogroups with trees from plot 1774, Cadastral Sector 15, Vârfurile ATU, Arad County

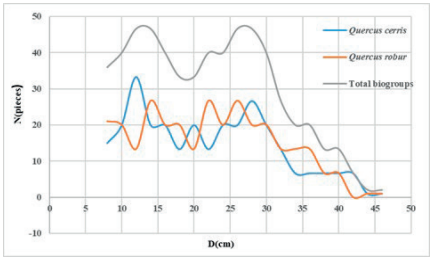


Figure 8. Distribution of the number of trees by diameter classes, extrapolated per hectare, in the fully inventoried biogroup from parcel 1774

The theoretical values for the weighted number of trees are N_{th} = 711 trees/ha, and the weighted total basal area is G_{th} = 26.250 m²/ha. Consequently, the density index is I_N = 0.8, the density coefficient I_G = 0.9, the slenderness coefficient Z = 74%, and the spacing indices are $s_{4\%}$ = 17% and $s_{6\%}$ = 18% (Table 2).
The tree biogroups are characterized by a moderate to normal density and thickness, a high stability to the dominant wind action and a moderate spacing, respectively. These aspects thus confirm a stable climax state, the succession process being completed on the analyzed surface.

In parcel 1776, over an area of 2529 m², a total of 176 trees were inventoried. The arboreal species recorded include *Carpinus betulus* with 48 individuals, *Quercus cerris* with 61 individuals, and *Quercus robur* with 68 individuals, totaling 176 individuals (Figure 9).



Figure 9. Biogroups with trees from plot 1776, Cadastral Sector 15, Vârfurile ATU, Arad County

Additionally, 6 *Quercus robur* trees with diameters between 52-68 cm were affected by extreme meteorological events on 17 September 2017 (Sicoe et al., 2023), and were subsequently removed and utilized by the landowners. The total number of inventoried trees extrapolated per hectare is N_{exp} = 696 trees/ha, with a mean diameter d_{gM} = 27 cm, a total basal area G_{exp} = 17.290 m²/ha, a mean height H_{dgM} = 18.55 m, a mean age T = 60 years, and a relative yield class of III.

The composition of the inventoried forest vegetation is: Cps(N_{exp}): 4Qr3Qc3Cb, and respectively Cps(G_{exp}): 5Qr3Qc2Cb.

From the analysis of the distribution of the number of trees extrapolated per hectare, by diameter classes and species, in the inventoried biogroups from parcel 1776, presented in Figure 10, it is observed that the distribution has a plurimodal pattern.

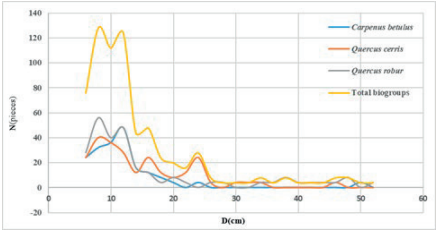


Figure 10. Distribution of the number of trees extrapolated per hectare, by diameter classes and species, in the inventoried biogroups from parcel 1776

This pattern is the consequence of the differentiated ages of the trees, the number of trees within each diameter class, the particularities of the natural regeneration process, and the manner in which the land has been exploited.

The theoretical values for the number of trees are N_{th} = 1418 trees/ha, and the total basal area is G_{th} = 24.240 m²/ha. Consequently, the density index is IN = 0.5, the density coefficient IG = 0.7, the slenderness coefficient Z = 70%, and the spacing indices are $s_{4\%}$ = 18% and $s_{6\%}$ = 19% (Table 2).

As a result, the tree biogroups present a low to moderate density, a high stability to the dominant wind action and a moderate spacing respectively. In this context, a stable climax state is reached, and the process of forest vegetation succession on the studied area can be considered completed.

In parcel 1853, over an area of 600 m², the inventoried arboreal species are represented by *Quercus robur* with 7 individuals, *Tilia tomentosa* with 58 individuals, and *Prunus avium* with 5 individuals, totaling 70 individuals. Also, a number of 5 specimens of pedunculated oak were identified, which were felled by the storm of 17 September 2017 (Figure 11).

The total number of inventoried trees extrapolated per hectare is N_{exp} = 1191 trees/ha, with a mean diameter d_{gM} = 17 cm, a total basal area G_{exp} = 24.976 m²/ha, a mean height H_{dgM} = 15.21 m, a mean age T = 41 years, and a relative yield class of III.

The composition of the inventoried forest vegetation is: Cps(N_{exp}): 8Tt1Qr1Pa, and respectively Cps(G_{exp}): 7Tt3Qr dis.Pa.



Figure 11. Biogroups with trees from plot 1853, Cadastral Sector 15, Vârfurile ATU, Arad County

From the analysis of the diagrams in Figure 12, it can be seen that the distribution of the number of trees by diameter categories is multimodal, due to the particularities of vegetation conditions, the ecological demands of the installed woody species and extreme weather phenomena (Sicoe et al., 2023).

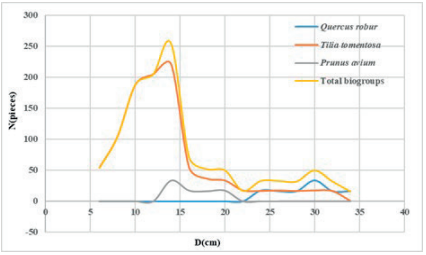


Figure 12. Distribution of the number of trees by diameter classes and species, extrapolated per hectare, for the tree biogroups in parcel 1853

The theoretical values for the number of trees are N_{th} = 1288 trees/ha, and the total basal area is G_{th} = 26.250 m²/ha. Consequently, the density index is IN = 0.9, the density coefficient IG = 0.9, the slenderness coefficient Z = 90%, and the spacing indices are $s_{4\%}$ = 17% and $s_{6\%}$ = 18% (Table 2).

In this case, the analyzed biogroups are characterized by a relatively normal density and thickness, a satisfactory stability to the action of the dominant wind and a moderate spacing. Although the process of succession of forest vegetation on the studied surface was affected by extreme weather phenomena (Sicoe et al., 2023), the tree biogroups are in a relative state of equilibrium, and on the surfaces where the trees were affected, the process of natural regeneration from seed, is carried out with a relatively active dynamic. As a result, the climax state can be identified for this location as well.

In parcel 1930, over an area of 437 m², a total of 80 individuals of *Robinia pseudacacia* and 10 individuals of *Prunus avium* were identified and inventoried (Figure 13). The total number of inventoried trees extrapolated per hectare is N_{exp} = 1945 trees/ha, with a mean diameter d1.30 = 10 cm, a total basal area G_{exp} = 10.280 m²/ha, a mean height H = 8.63 m, a mean age T = 10 years, and a relative yield class of III. The composition of the inventoried biogroups, based on both structural characteristics, is 9Rp + 1Pa.



Figure 13. Biogroups with trees from plot 1930, Cadastral Sector 15, Vârfurile ATU, Arad County

The distribution of the number of trees by diameter classes for the biogroups of *Robinia pseudacacia* and *Prunus avium* appears as a normal distribution with a slight right-side asymmetry (Figure 14), because vegetation establishment on the analyzed surface occurred over a relatively short period of time, without disturbances. The successional process unfolded with active dynamics and high efficiency.

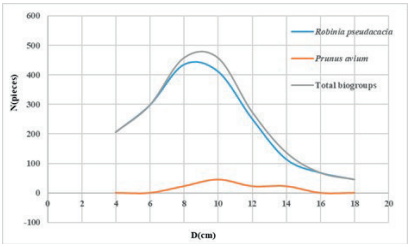


Figure 14. Distribution of the number of trees by diameter classes in the tree biogroups from parcel 1930

The theoretical value for the weighted number of trees is N_{th} = 2369 trees/ha, and the weighted total basal area is G_{th} =11.440 m²/ha. Consequently, the density index is I_N = 0.8, the density coefficient I_G = 0.9, the slenderness coefficient Z = 86%, and the spacing indices are $s_{4\%}$ = 23% and $s_{6\%}$ = 25% (Table 2).

The biogroups of trees installed in a proportion of 90% belong to the species Robinia pseudacacia, which is an allochthonous species, and is considered invasive, successfully colonizing agricultural lands that are improperly exploited or abandoned. They are characterized by a moderate to normal density and thickness, presenting a satisfactory stability to the action of the dominant wind and a very good spacing. Consequently, the biogroups in this plot are in an obvious state of climax.

Although the development of successional processes on various agricultural lands results in excessive fragmentation of the agricultural landscape, with a series of negative effects, the abundance of certain species can be increased and consequently the resistance of the phytocenosis to the effects of climate change can be optimized (Hurajová et al., 2024).

The climatological analysis carried out in the paper shows that the period 1990-2025 was very warm, the linear trend of the average annual values of air temperature being strongly upward. Annual rainy periods were longer than dry periods between 1990 and 2025, but the rainfall extremes were very clearly highlighted. There have been very rainy years, with large amounts of precipitation falling in a short time, interspersed with exceptionally dry years, in which droughts were long and intense. The recent years have been exceptionally hot and dry. The rainfall extremes facilitated the establishment of shrub and arboreal vegetation, both successively and in parallel. As a result, we showed that the climatic conditions favoured and supported the succession of arboreal and shrub vegetation, the first objective of the study being achieved.

The improper exploitation or abandonment of some agricultural use land in non-collectivized areas created the premises for the initiation and development of some succession processes between the grass species afferent to them and the shrub and arboreal species, native and exotic, in the areas bordering the case study location. As a result, the analyzed successions present an active dynamic and a series of specific particularities, due to the categories and subcategories of land use, the vegetation conditions and the size and excessive division of the plots, respectively. Also, anthropogenic impact conditions and influences the dynamics, specificity and particularities of these processes in the studied and analyzed plots.

From the analysis of the obtained results related to the structural particularities of the biogroups with arboreal vegetation, which were inventoried, it is highlighted that the areas on which they were installed meet the conditions to be introduced into the forest fund, according to the forestry code. As a result, the use category can be modified, these areas being considered as forestry use, at the proposal and with the agreement of the owners, obviously. Consequently, the second objective of the study was also achieved.

The results obtained in our study contributed to the advancement of scientific knowledge in the addressed field, by particularizing the succession process of the arboreal and shrub vegetation on agricultural use lands, highlighting the fact that successions of pioneer species and respectively successions between the pioneer species and fundamental ones related to the forest fundamental natural type, in the neighbouring areas, were simultaneously identified in the same plots, under similar climatic and pedo-stationary conditions.

The emergence of some successions between the shrub species and some oak species (*Quercus ceris* and *Quercus robur*) was also highlighted, that being a particularly important aspect for the development of some seed regeneration technologies, under shelter, of some oak species, in the context of climate change and the effect of extreme weather phenomena.

The extension of research to all agricultural use land that have been abandoned or improperly managed, in non-collectivized areas, is limited due to the fact that the exploitation of some areas was carried out with some intermittency (periodicity), an aspect that prevents a coherent analysis of successional aspects. Also, the access to some information from the agricultural register related to the lands that could be the subject of the study could be limited, due to the refusal or lack of a response from the owners.

Studies could be expanded in the future to plots in the mentioned location that are available or in locations with similar conditions, in the Vârfurile commune and/or in neighbouring communes that were not collectivized prior to 1989.

The continuation and expansion of this study in the future, in the presented location, can be achieved in two scenarios: a) if the improper exploitation of agricultural lands will continue or they will be abandoned; b) if the use category will be modified by assigning some lands to forestry use, where the conditions are met, in accordance with the Forestry Code (Low no. 331/2024).

Consequently, if the lands from the present case study will be exploited in the future in accordance with the current use categories and

subcategories, then further studies and research will be irrelevant.

CONCLUSIONS

The period 1990-2025 was relatively rich in precipitation, with many rainy years, even very rainy, interspersed with exceptionally dry years. Thus, the rainfall extremes in the studied area were highlighted. The period was also very warm. Of course, the amounts of precipitation were not distributed uniformly throughout the year, with frequent cases of very large amounts falling in a short time, but also very long droughts.

Consequently, the extremes of rainfall have favoured the establishment in optimal conditions of arboreal vegetation from the species of the fundamental natural type of forest bordering the study location, respectively of pioneer, invasive and shrub species in dry years.

The process of succession of arboreal and shrub vegetation on agricultural lands in non-collectivized areas presents a series of particularities, and has a specific dynamic, depending on the way these lands are exploited.

Consequently, the denudation stage of the habitat is practically substituted by their abandonment or improper exploitation.

The native oak species, represented by *Quercus cerris* and *Quercus robur*, present a high colonization rate of agricultural lands, which are abandoned, due to the vegetation conditions and respectively their ecological demands, the dissemination of seeds being carried out exclusively zoochorically, by birds and rodent mammals.

The pioneer species that settled in simultaneously colonized the same habitats with the other arboreal species, thus indicating a simultaneous succession of them.

The invasive species *Robinia pseudacaia* colonized 90% of the new habitat, thus forming practically pure biogroups.

The shrub species that colonized some areas, forming compact biogroups with variable extents, facilitate their installation and colonization by the native oak species.

The results obtained confirm that on agricultural areas that were improperly exploited or abandoned, the succession process of arboreal and shrub vegetation took place with a differentiated dynamic, with a series of biogroups identified with the climax stage achieved.

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