Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XII, 2023
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE STATE AND BEHAVIOR OF SOME FORESTRY CULTURES INSTALLED ON DEGRADED LANDS IN THE FOREST-STEPPE SITE

Cristinel CONSTANDACHE, Ciprian TUDOR, Laurenţiu POPOVICI, Vlad RADU

"Marin Drăcea" National Institute for Research and Development in Forestry, Romania, 128 Eroilor Street, Voluntari, Ilfov County

Corresponding author email: cipriantudor210@gmail.com

Abstract

The research carried out aimed at capturing the structural and qualitative changes, the overall evolution of forest ecosystems on degraded lands and highlighting the types of effective cultures on different categories of degraded land. The researches were carried out in the period 2017-2018 in research plots located in perimeters for the improvement of degraded lands, in representative situations. In the paper are presented synthetically the data regarding on the characteristics of forestry cultures in the forest-steppe site, realized in different compositions on lands with various forms of degradation.

On very strongly eroded and ravenous lands, the forestry cultures made with black pine in intimate mixture with xerophytic species and shrubs, gave good results. On moderately to heavily eroded lands, mixed cultures with oak and different species, gave good results, in association them in biogroups or grouping at least 2 rows of oak interleaved with accessory species and shrubs. The obtained results offer particularly valuable information for the scientific substantiation of future afforestation compositions and of the silvotechnical works for the installation and tending of forestry cultures on degraded lands.

Key words: *afforestation, degraded lands, forest-steppe, forestry cultures.*

INTRODUCTION

In the current international circumstances, when more and more emphasis is placed on increasing the role of the forest in environmental protection and mitigating climate change, but also as a renewable natural resource, the management (tending and management) of stands becomes a primary concern of the forester.

On this line, the latest researches take into account the issues of stability, structure, regeneration, the dynamics of the development of stands on degraded lands (Vlad et al, 2019). Nowadays, the stands are affected by abiotic factors (drying, breaks, ruptures), following climate changes (Constandache et al., 2016; Dincă & Achim, 2019; Dinulică et al., 2015; Merlin et al., 2015; Silvestru-Grigore et al., 2016). Protective forestry cultures were installed on degraded lands in order to improve and exploit them (Constandache, 2003; Traci, 1985). The types of forestry cultures with an ameliorative role, the compositions and planting schemes, the techniques of land preparation and afforestation of degraded lands constituted an object of concern for a large number of researchers from the forestry and agricultural domains (Constandache et al., 2006; Ciortuz, 1981; Ciortuz, 2004; Nistor & Nistor, 2002). The afforestation actions carried out in the past, for the most part, had the expected improvement effects. It is estimated that in our country there are approximatively 300,000 hectares of degraded lands, mostly afforested with pine and locust (Enescu & Dănescu, 2015; Lukić et al., 2015; Untaru et al., 2012; Untaru et al., 2013). Many of these were damaged due to some abiotic factors (drought, wind, etc.), in the conditions of climate changes but also in situations where they were not covered in time or properly with tending works, being currently destructured (Constandache et al., 2020). Others have exceeded the age of 60 where silvotechnical measures are required for their regeneration and succession (Cenușa, 1992).

The evolution of cultures takes place in the most difficult pedo-climatic conditions, under the influence of a complex of abiotic (drought, wind, snow, etc.) and biotic (mushrooms, insects, etc.) disturbing factors whose action has intensified in the last time and which can generate strongly imbalances at certain moments, their behavior and evolution being unpredictable (Cenuşă, 2002; Constandache, 2003; Giurgiu, 1987; 2004). Very important, in the current conditions, are the state of health of the stands, given by the biological particularities of the species of trees and shrubs in the composition, in relation to the environmental conditions (Ganatsas, 2011; Chazdon, 2008; Onet et al, 2019).

The state and evolution of forestry cultures on degraded lands were monitored periodically (intervals of 5 years) starting from 1981, when permanent research plots were placed in perimeters for the improvement of afforested degraded lands (Traci & Untaru, 1986; Traci & Costin, 1966). In addition to the existing research plots, it was necessary to expand the network of permanent research plots and in forestry cultures installed on degraded lands after 1980 (especially in the forest-steppe site, where the effect of climate change is more obvious- PN 305, 2016). The monitoring of these cultures is important in the current conditions, the surface of the stands affected by drying or other harmful factors, being in a continuous increase. Assessing the state and their evolution are important for ensuring an adaptive management of forest ecosystems on degraded lands (Badea, 1998; Badea et al., 2004; Badea, 2008; Mînza & Mamai, 2010). Thus, in order to be able to create the conditions for maintaining ecological functionality and stability in forestry cultures on degraded lands, it will be necessary to take into account the effect of harmful factors, in addition to monitoring the structural parameters (consistency, thickness and so on) both directly influence stability (biotic, abiotic) and indirectly influence individual and group stability, in the context of climate change (Martín-Benito et al., 2013; Mérian & Lebourgeois, 2011; Zang et al., 2012; Vlad & Constandache, 2014). In the conditions of climate change, the increase in average annual temperatures by more than 1-2ºC will have as a first consequence, the aridification of the southern and south-eastern, plain, but also hilly areas, causing major changes in environmental conditions and the emergence of limiting conditions for vegetation forestry, according to the specifications published in the *"Guidelines on adaptation to the effects of climate change"* (Stocker et al., 2013).

The effects of forestry cultures consist in the improvement, stabilization and valorization of inefficient lands for other uses (Constandache et al., 2010) but also in mitigating the effects of global warming through the high storage capacity of atmospheric CO_2 (Dincă et al., 2015), stopping land degradation due to the ability to fix and improve soils (Nicolescu et al., 2018), reducing anthropogenic pressure on natural forestry ecosystems and using them as an alternative for obtaining fossil fuels (Spîrchez & Lunguleasa, 2016).

The research carried out was aimed at analyzing the current state of forest crops and structural characteristics in specific environmental conditions.

MATERIALS AND METHODS

The researches were carried out in 27 research plots, located in 7 improvement perimeters (PA) from Romania, afforested in the period 2002-2006, located in the east and south-east of the country, in representative situations (compositions and environmental conditions of degraded lands). At the establishment of the research plots there was in view of tracking the main species and formulas used in afforestation in relation to the intensity of degradation. After the establishment of the research plots, the measurements and observations in forestry cultures from forest-steppe site were made (Figure 1), on lands affected by complex degradation, respectively: moderate to very strongly erosion in the surface associated with excessive dryness, in the following improvement perimeters (PA):

- A. Buznea, Iloaiei Bridge Forest District-Iaşi County, (*47°11'29.41" N; 27°02'11.69" E*);
- B. Gropana and Hulubăţ, Epureni Forest District-Vaslui County (*46°19'52.22" N, 28°02'28.72" E*);
- C. Lozoviţa, Hanu Conachi Forest District, Galaţi County (*45°37'7.03" N, 27°53'12.12" E*);
- D. Agighiol I and Agighiol III, Babadag Forest District-Tulcea County (*45°7'30.82" N, 28°50'36.70" E; 45°8'39.74" N, 28°52'2.92" E*);
- E. Releu-Vâlceaua-Negureni, Baneasa Forest District Constanța County (*44˚03'46.2” N, 27˚44'32.1” E*).

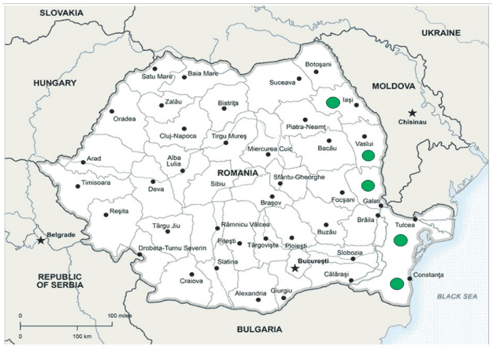

Figure 1. Location of improvement perimeters (PA) on the geographical map of Romania

The current state, biometric characteristics (average diameter-Dm; average height-hm), structural and diversity parameters of the stands in different environmenal conditions were analyzed and highlighted (Giurgiu et al, 2004; Giurgiu & Drăghiciu, 2004). To evaluate the structural diversity, a series of indexes were calculated: the basal surface (G), the average diameter (Dm) and its coefficient of variation (cv%-), the Hart-Becking (s%), Camino (H) and Gini (G). The Hart-Becking index (s%) expresses the density state of the stand. It was calculated according to the following formula:

$$s\% = \frac{a}{hdom} \cdot 100 \qquad (1)$$

where: *a* - distance between trees; *hdom* - dominant height of the stand. The Camino (H) index were calculated in ratio with the basal surface, with the following formula:

$$H = \frac{\sum_{i=1}^{n-1} SN\%}{\sum_{i=1}^{n-1} SN\% - SG\%} \qquad (2)$$

where: *SN%* - the cumulative number of trees until the i category; *SG%* - the cumulative basal surface until i category; n- maximum category of diameters in which SN% = 1.

According to Camino (1976), the homogeneity of stands can be expressed as a percentage ratio between the number of trees and the basal surface by category of diameters, expressed by a certain Lorenz curve. The degree of structural homogeneity is defined as a deviation of the Lorentz curve from the diagonal, in the sense that the value 10 indicates a high homogeneity, and the value 2 shows the lack of homogeneity. The Gini index (G) determined according to the basal surface is calculated as the ratio between the area determined by the Lorentz curve and the reference line. On the other hand, the area of the triangle is formed by the reference line with the abscissa and parallel to the ordinate through the point of intersection between the Lorentz curve and the right landmark. The values of the Gini coefficient are between 0 and 1, meaning maximum homogeneity and maximum heterogeneity. The more homogeneous a population is, the closer the value of the Gini index will be to 0.

The general calculation formula is:

$$G = 1 - 2 \cdot \int_0^1 f(x)dx \qquad (3)$$

where *f(x)* - the function of the Lorentz curve in relation to the considered variable.

The comparative analysis of afforestation compositions and cultures establishment techniques used on lands affected by various forms of degradation provides valuable information regarding the viability of various forestry species in certain enviromental conditions, as well as regarding the planting scheme, the type of mixture, the silvotechnical works applied. Thus, the forestry species capable of enhancing different categories of degraded land were highlighted, as well as the most suitable techniques for the installation of forestry cultures.

Thus, on moderately eroded lands, research areas were installed in plantations with greyish oak (Stb) or common oak (St) in an intimate, grouped mixture or strips with different mixed deciduous species (linden-Te, ash-Fr, sweet cherry- Ci, maple-Ml, elm-Ul, sycamore-Pa, wild pear-Pă, mahaleb cherry-Vit, oleaster-Sl) and with locust (Sc). On strongly eroded lands, research plots were installed in plantations of: locust (pure or mixed); of greyish/common oak, mixed with Siberian elm or elm, ash, oleaster, honey locust or mahaleb cherry (50-67%) mixed with oleaster. On highly eroded lands, mixed crops of different deciduous species were identified (oleaster, manna ash-Mj, wild pear, cherry plum-Cd, sycamore or black pine mixed with wild pear, oleaster, mahaleb cherry, manna ash with shrubs; on slippery lands with excess moisture- Pennsylvania ash and those without moisture- locust). The analyzed forestry cultures are between 10 and (15) years old and offer particularly valuable information for the scientific substantiation of afforestation compositions, mixing schemes, silvotechnical works (tending and management) of future forestry cultures on degraded lands.

RESULTS AND DISCUSSIONS

The afforestation works on the degraded lands were carried out by applying special techniques for the installation of forestry vegetation, different from those used in forestry lands, due to the harsh environmental conditions and the lack of shelter provided by the neighboring stands. As a result, the saplings were exposed to intense stress conditions (insolation and increased evapotranspiration, weed competition, limited access to nutrients, determined in particular by the accentuated shortage of water in the soil), requiring special measures for the establishment of the plantation, as well as for the maintenance of the cultures. Added to this is the fact that the soils in the degraded lands are beaten up by grazing and strongly sodded. The results obtained by afforestation of degraded lands are good, the forestry vegetation covering the entire area on which plantations were made (Figure 2).

Figure 2. Agighiol III improvement perimeter (Tulcea County Forest Administration, Babadag Forest District)

On moderately to heavily eroded land (E_1 - E_2), the forest crops have oak and acacia as the base species, being made through plantations both on simple terraces or on land prepared by strip plowing and on unprepared land (in pits etc.). In the compositions with oak (in a proportion of 10-30%, sometimes 70%), mixed species (linden, elm, cherry, palin, ash) were introduced as well as helpful xerophytic species: Turkish cherry, willow, Turkestan elm.

On moderately to heavily eroded lands (E_1 - E_2), the forestry cultures have common oak and locust as the base species, being made through plantations both on simple terraces or on land prepared by strip plowing and on unprepared land (in pits, hearths). In the compositions with common oak (in a proportion of 10-30%, sometimes 70%), mixed species (linden, elm, sweet cherry, sycamore, ash) were introduced as well as helpful xerophytic species: Mahaleb cherry, oleaster, Siberian elm.

The low proportion of common oak in the composition (<20%) and the intimate mixture with the other species are not favorable, especially on lands with more difficult conditions (sun exposure, higher slope, stronger erosion), where the common oak is overwhelmed and has reduced growths and the mixture/accessory species register an almost double increase in the number of exemplars compared to the normal number extracted from the production tables, a phenomenon that calls for the urgent application of silvicultural interventions to regulate thinning and especially to open some access roads in some places. It can be observed a large growth in the height of the greyish oak in the grouped mixture (Figure 3).

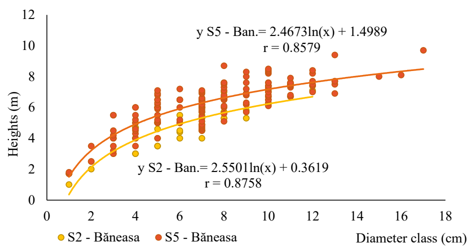

Figure 3. Height distribution on diameter classes at greyish oak (S2, S5-PA Releu-Vâlceaua-Negureni)

Regarding on the biometric characteristics of the stands analyzed: for common oaks, aged between 10-13 years, the average diameter (Dm) is between 2.88 cm (S1, PA Lozovița) and 6.47 cm (S3, PA Agighiol I), and the average height (hm), between 3.53 m (S1, PA Lozovița) and 5.04 m (S3, PA Agighiol I). These results lead to the conclusion that the oaks maintain their development growth even in the case of strongly eroded lands, but it is still distinguishable from this phase, the highlighting and the larger growths of the arborescent species of the III size and with xerophytic character: the Siberian elm, mahaleb cherry, tartarian maple, oleaster and so on (Figure 4).

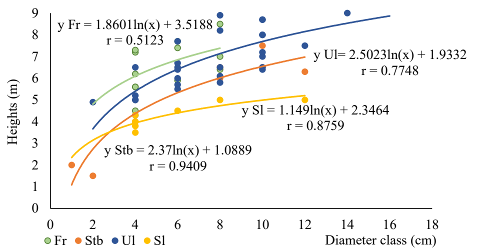

Figure 4. The distribution of the heights on diameter classes and on stand elements (S3, PA Agighiol I)

The oak is maintained and develops very well if the mixture is grouped or in rows grouped at least 2-3 and is surrounded, having lateral protection created by accessory and shrub species. Locust in pure cultures behaves very well achieving growths comparable to the higher production classes (II). The number of high trees is concentrated in the middle diameter classes and the curve of experimental frequencies follows the normal law of even-aged stands (Figure 5).

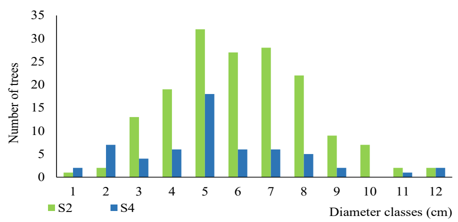

Figure 5. The structure of the stands in ratio with the diameter class at locust species

Locust cultures show different characteristics in different environmental conditions.

On lands with shaded and semi-shaded exposures, inferior slopes with a slight slope, without carbonates (S2, PA Lozovița), the locust cultures achieve values of the biometric characteristics (Dm, hm) significantly higher compared to the plantations of the lands with sunny exposures, with kneaded soils, with carbonates (S4, PA Lozovița) (Figure 6).

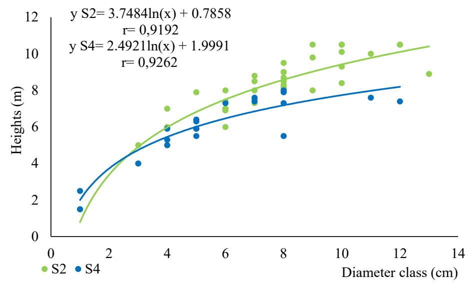

Figure 6. The relashionship between height and diameter at the stands constituted by locust species (S2, S4-PA Lozovița)

The biometric characteristics (number of trees, average diameter, average height) of the locust at the age of 10-12 years are superior to those of the common oak and the other species, both on moderately eroded and heavily eroded lands (Figure 7). The maximum number of trees belonging to the locust species falls into diameter class 6 (64 trees)-S2 PA Agighiol.

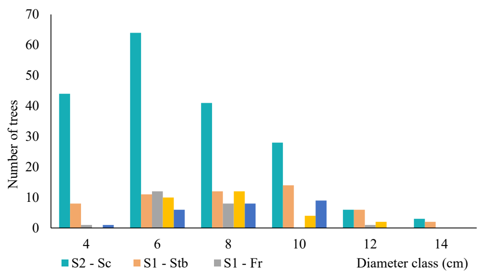

Figure 7. The distribution of the number of trees by diameter classes in pure cultures of locust and in mixed cultures of greyish oak and ash

On such lands, plantations of black pine (Pin) and/or Scots pine (Pi), (25%, in an intimate mixture with auxiliary species (manna ash, cherry plum, wild pear, mahaleb cherry) and xerophytic shrubs (blackthorn, dog rose, hawthorn and oleaster) at the age of 10 years, have both a state of vegetation and growth active, achieving average diameters between

8.84 and 9.78 cm and average heights between 4.61 and 5.06 m (Figure 8).
Such culture consisting of pines mixed with the mentioned auxiliary and shrub species, makes optimal use of environmental conditions and achieves higher biomass accumulations (in relation to the average basal area per stand) which represents 75% of the total.

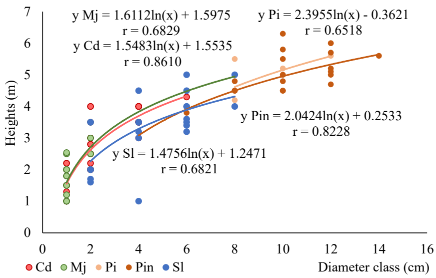

Figure 8. The distribution of heights on diameter classes for component species of forestry cultures from S4- PA Hulubăț (Vaslui) on very highly eroded lands (E_3)

Structural and diversity parameters of forestry cultures on degraded lands

When analyzing the structural diversity of forestry cultures, the grouping of individuals in space, their functional relationships and size variability were taken into account, highlighting the stability and ability to adapt to enviromental conditions, of forestry cultures with different compositions.
In the forestry cultures aged between 10-13 years from the 7 improvement perimeters investigated in the forest-steppe site, the dimensional variability of the exemplars is directly influenced both by the environmenal conditions specific to each improvement perimeter and by the nature of the species and their adaptability to the existing conditions. In addition, there are determining factors resulting from the constructive elements of the plantation, especially from the shape and dimensions of the planting device, the development space of each exemplar being often strongly influenced by the degree of development, especially in horizontal structure, of the neighboring exemplar of the adjacent species from device.

On heavily eroded lands, in the case of the mixture of xerophytic deciduous species (e.g., mahaleb cherry, oleaster, S1, PA Buznea), high variability was recorded both for diameters 35.36% and for heights (55.1%) due to the specificity of these species to form several stems on the same stump (bushes), with large diameters, which overwhelm each other, but which cover and stabilize the ground very well.
An optimal variability was registered by the pine cultures made on very strongly eroded lands, where the pine growths are distinguishable from the rest of the mixed species (S4, PA Hulubăt). The variability of the heights follows the distribution corresponding to the diameters.
Also on very strongly eroded land, but also with sliding phenomena, with excess water on the surface (S4, PA Buznea), the Pennsylvania ash culture proved to be a viable solution in such situations, registering a normal variability of diameters (31.2%), but a low variability of heights (11.9%).
On moderately to strongly eroded lands, common oak and greyish oak cultures in intimate mixture with different deciduous species (ash, S3, PA Gropana; S3, PA Agighiol I); Siberian elm, oleaster, S1, PA Lozovița) shows a higher variability of diameters (42.1-54.2%) and a low variability of heights (<30%), determined by the intimate mixture of some species with different bioecological parcularities.
On moderately to strongly eroded lands, in common oak cultures mixed with deciduous species, the variability of diameters (37.7%) and heights (31.6%) are high (S5, PA Hulubăț), as a result of the diversification of species still forming the structure from the planting, an optimal balance between all the component elements, the main species: common oak, ash with the mixed species: linden, sweet cherry and Siberian elm and the accessory and xerophytic shrubs: cheery-plum, hawthorn, mahaleb cherry and so on. It is considered to be the most appropriate compositional formula among the cultures analyzed (Figure 9).

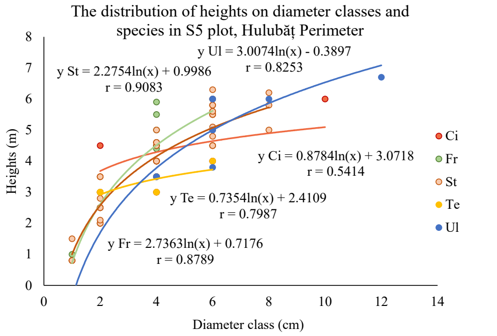

Figure 9. The relationship between quantitative variables (diameter class and height)

In the case of locust or honey locust cultures on heavily eroded land, the coefficients of variation for heights and diameters indicate normal distributions and variability, highlighting that the adopted solutions were appropriate to environmental conditions. The thickness (I_N) and density (I_G) indexex in some cases exceed the value of 1, due to the competitiveness and the very high number of trees (Table 1). The Hart-Becking spacing factor (s%) expresses in minimum percentages the connection that exists between the arrangement in the horizontal structure and the height of the trees, the maximum being reached in PA Releu-Vâlceaua-Negureni (S1).

Table 1. The indexes of thickness and spacing of the stands from analyzed improvement perimeters

PA	DEG	S	I_N	I_G	h_{dom}	s% $_{Hart-Becking}$
Buznea	E_1	2A	2.07	1.82	10.01	14.84
	E_2	1	1.66	0.75	5.09	26.49
	E_2+Al	2B	1.99	2.07	8.94	16.28
		3	1.27	0.86	7.12	19.23
Gropana	E_1	1	1.51	1.34	8.65	15.53
	E_1-E_2	2	1.01	0.89	9.41	18.88
Hulubăț	E_1-E_2	5	1.07	0.56	5.67	25.82
		6	2.26	1.53	8.65	15.54
	E_3+R	4	1.02	1.06	5.43	28.18
Lozovița	E_1	2	1.36	1.27	9.75	17.80
	E_2	4	0.96	0.70	7.28	28.28
	E_1-E_2	1	1.42	0.45	5.16	27.91
Releu-Vâlceaua-Negureni	E_1	1	0.78	0.33	5.44	34.37
		2	0.63	0.69	6.46	29.41
		5	0.98	1.23	7.66	23.91
Agighiol I	E_1	2	1.70	1.36	10.69	15.34
	E_1-E_2	1	0.88	1.30	9.17	21.64
	E_2	3	0.96	0.79	7.95	20.25
		10	0.89	1.08	7.53	24.49

Note: DEG- degradation form; S-permanent experimental plot; I_N-density index by the number of trees; I_G-density index by the basal area; s%$_{Hart-Becking}$- spatial index; R-ravenous land; Al-landslide.

The Gini (G) and Camino (H) indexes indicate a moderate to high degree of diversity for most of the analyzed mixed stands, which shows that these stands tend to evolve towards diversified structures on structural elements (classes of diameters, heights, number of trees, spacing index and so on) and tend to form relatively even-aged and relatively plurien structures from a juvenile stage of development. In relation to the Camino index (H), the structure of the stands varies from relatively even-aged (H between 3.25 and 4.71), to relatively plurien (H between 2.12 and 3.49), due to the diversified complexity of the species, competition ratios and dependence on ecological factors (Table 2). The homogeneity is represented by values of the Gini index close to the maximum homogeneity value (G = 0), which indicates that the frequency of the cumulative base areas (SG%) is distributed according to a Lorentz curve very close to the line of equality.

Table 2. Indexex of structural diversity and population variability

PA	DEG	S	cv% -D_m	H	G
Buznea	E_1	2A	35.70	4.02	0.37
	E_2	1	35.36	4.23	0.35
	E_2+Al	2B	34.80	4.32	0.35
		3	31.20	4.75	0.31
Gropana	E_1	1	46.30	3.49	0.47
	E_1-E_2	2	35.60	3.30	0.47
Hulubăț	E_1-E_2	5	44.32	5.86	0.44
		6	38.61	4.71	0.38
	E_3+R	4	26.86	2.33	0.59
Lozovița	E_1	2	35.30	4.52	0.36
	E_2	4	46.50	2.91	0.45
	E_1-E_2	1	56.10	3.23	0.52
Releu-Vâlceaua-Negureni	E_1	1	86.50	2.12	0.61
		2	56.20	3.25	0.36
		5	41.90	4.53	0.38
Agighiol I	E_1	2	34.50	4.36	0.36
	E_1-E_2	1	33.60	3.50	0.35
	E_2	3	45.10	3.95	0.45
		10	26.94	4.45	0.29

Note: cv%-D_m-coefficient of variation; H-Camino index; G-Gini index.

CONCLUSIONS

The forestry cultures made on degraded lands in the forest-steppe site for the most part, have achieved the purpose for which they were made and their follow-up over time will provide new scientific information particularly useful for the appropriate substantiation of the afforestation compositions of degraded lands from the forest-steppe site.

The results obtained from the research carried out are particularly useful in the management of stands on degraded lands, in establishing the type of silvotechnical interventions starting with the implementation of appropriate afforestation technologies and continuing with the application of tending and management works.

Diversification of afforestation compositions can sometimes present a disadvantage for valuable species (oaks), which in intimate mix with other species, can be embarrassed due to the high frequency of competition ratios.

This phenomenon calls for the urgent application of silvicultural interventions to regulate the thickness and density of cultures to optimize the multimodal structures.

For the best possible development, it is recommended that the xerophytic species of oaks to be introduced in grouped mixtures or in at least 2-3 grouped rows and ensure the planting of auxiliary species around them, to confer lateral protection.

The association of common oak mixed with deciduous species (linden, sweet cherry and Siberian elm) and with xerophytic accesory species and shrubs (cherry-plum, hawthorn, mahaleb cherry) proved to be the most appropriate compositional formula adapted to heavily eroded lands.

The behavior of locust proves to be beneficial in pure cultures, where it registers superior production classes (II).

Pine cultures, mixed with accesory species and shrubs species, make optimal use of environmental conditions and achieve superior biomass accumulations.

The installation of pines by association with a varied range of xerophytic species leads to obtaining multi-storey and multimodal structures, with higher resistance over time and with high anti-erosional efficiency.

In relation to Camino and Gini structural diversity indexed, most cultures show relatively even-aged to relatively plurien structures, homogeneous from the point of view of the Gini index.

In the future, resistant forms of the species used in afforestation or even other species that respond to the new complex challenges must be sought, respectively efficient ecological methods of management of the destabilizing factors.

ACKNOWLEDGEMENTS

This research work was carried out with the support of INCDS "Marin Drăcea", within the studies required for the assurance of sustainable management of the stands located on degraded lands in forest-steppe site (PN 16330305, 2016). The present work represents a starting point towards new directions and visions regarding the long-term research of the particularities of forestry cultures located on degraded lands from internal and external forest-steppe (PN 23090203, 2023).

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