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THE BIOPRODUCTIVE POTENTIAL OF FAST-GROWING FOREST SPECIES ON DEGRADED LANDS

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Abstract

Afforestation represents a viable solution for the ecological reconstruction of degraded lands, creating medium and long-term premises for using and sustainably developing these lands. The usage of fast-growing woody species in the afforestation of degraded lands include many advantages. The present paper presents data regarding the actual state, biometrics and auxological characteristics, as well as the productive potential of stands from fast-growing species (locust, alders, poplars and willows) from different conditions of degraded lands. Locust (Robinia pseudacacia L.) is one of the fast-growing forest species utilised on degraded lands in Romania. In addition, the species has a recognized importance at a high international level both through its bioproductive potential as well as through its ecological plasticity. All the species that were analysed had a good behviour in relation with the environmental conditions of degraded lands, both from a growing perspective and a health state one. However, this situation is present up to the age of 25-30 years. After this age, stand dryness, thinning, and a decrease of tree growth and quality are affecting the stand's natural regeneration capacity and ecological diversity.

Key words*: bioproductive potential, degraded lands, fast-growing species.*

INTRODUCTION

In the context of climate changes that generate a worldwide increase of temperatures (Badea et al., 2013) with values estimated between 0.3 and 4.8ºC in this century (IPCC AR5, 2013), the United Nations Convention for Combating Drought (UNCCD) has proposed the concept of Land Degradation Neutrality (NDT). This concept intends to encourage measures for stopping land degradation, combined with measures for diminishing/reversing the already existent processes in order to prevent the negative effects generated by net losses for lands and productive soils.

According to recent estimations (ICPA, 2002), the surface of degraded agricultural lands from Romania ammounts to approximately 6.3 million hectares from which 2.5 million hecatres are strongly degraded. Previous or recent investigations (Untaru et al., 2013) have shownt that afforestation represents a medium and long-term viable solution for the ecological reconstruction of these lands, as it creates the premises for their usage and long-lasting management. With this purpose in mind, the National Strategy and Program of Actions for Combating Drought (2008) as well as the new Forest Code have identified and proposed for afforestation approximately 2 million hectares of nationally degraded lands.

In this context, the usage of fast-growing wood species for improving degraded lands presents numerous advantages among which the most important ones are: diminishing the effects of global warming through their high capacity of stocking atmospheric CO_2 (Dinca et al., 2015), fighting against desertification by stopping land degradation (Constandache et al., 2010) due to their soil fixing and improvement capacity (Nicolescu et al., 2018; Onet et al., 2019), supplying renewable energy as alternative for fosile fuels (Spirchez and Lunguleasa, 2016) and reducing the anthropic pressure on natural forest ecosystems.

The fast-growing species used in Romania on degraded lands with pedo-ameliorative purposes include poplars, locust, alders and willow. Amongst them, locust *(Robinia pseudoacacia* L.*)* is renowned at an

international level for its bioproductive potential (growth speed, wood quality, lack of harmful agents, an almost unlimited range of usages etc.) and ecologic plasticity. In Romania, locust occupies approximately 250.000 hectares (approximately 4% of the forests' surface) (Nicolescu et al., 2018), and is used in the afforestation of lands affected by different degradation processes (Constandache et al., 2006; Untaru et al., 2008; Enescu and Dănescu, 2013) or in creating protection forest belts (Constandache and Nistor, 2012; Constandache, 2006).

Even though fast-growing species were the subject of previous studies (Radu, 1972), there is a national need for updated data regarding the productivity of these species in different vegetation conditions and in the context of climatic changes.

The studies carried out in the present stage wanted to continue the research in order to know the state, structure and growth of forest cultures composed of fast-growing species (with a short production cicle) from degraded lands.

MATERIALS AND METHODS

The investigations were carried out on 32 long-term experimental surfaces (S), in representative stand and degraded lands situations. Locust, poplar, willow and alder forest cultures were investigated.

In addition, representative situations regarding the stand's characteristics were also analysed with a focus on: current state, biometric and auxologic characteristics, productive protential in different stational conditions;

Measurements and observations were carried out in forest cultures composed of fast-growinf species from improvement perimeters of degraded lands in which there are or were located (long-term) research surfaces. From a territorial point of view, the investigation were realized in the silvosteppe area (Agighiol - OS. Tulcea perimeter; Releu-Valceaua Negureni - OS Baneasa, Constanta; Hulubat - OS Epureni, Vaslui; Livada - O.S. Ramnicu Sarat; Lozovita - OS Hanu Conachi), oaks subarea (Murgeşti - OS Ramnicu Sarat perimeter; Valea Caselor - OS Vaslui, Buznea - OS Podu Iloaiei, Iasi perimeter), holm subarea (Caciu-BE Vidra perimeter), and common beech subarea (Rosoiu-Andreiasu - OS Focsani perimeter). The investigations were represented by collecting land data as well as operating and interpreting them. Their processing was done in an informatic system by using specific forestry statistical softwares.

RESULTS AND DISCUSSIONS

The investigations led to the identification of the main fast-growing species and categories of afforested degraded lands, namely:

-locust: clough lands, lands affected by surface erosion (with diversely eroded lands); mobile sands, puddled landslide lands without water excess and detachment ravines, ranging from the silvosteppe area up to the oaks subarea (and even the holm one);

-white and black alder - puddled landslide lands with an ensured humidity, clough lands (on the bottom of cloughs), alluvial lands;

-white and black poplar, white willow - puddled landslide lands and alluvial lands with water excess.

Land preparation works were realized before planting in order to ensure vegetation conditions, namely: landslides have undergone land modeling/leveling, the drainage of microdepressions with water excess etc. (Constandache et al., 2019; Dinca and Achim, 2019); strongly eroded lands (slopes) and cloughs from the silvosteppe area were managed/consolidated with simple terraces; clough bottoms were consolidated with grating or thresholds from local materials (Constandache et al., 2010).

The adopted afforestation compositions have included fast-growing forest species, differentiated based on the degradation form.

Locust cultures (*Robinia pseudacacia*) were realized on different categories of degraded lands, namely: on moderately to very strongly eroded lands, on clough lands (R) represented by clough ramps with molassic substratum formed of weakly consolidated sedimentary rocks (loess), on landslides with strongly fragmented soil mass (with light, deranged soils without water excess) and on the landslide dislocation ravine with surface rock.

The plantations included a number of seedlings between 5,000 and 10,000 per hectare,

depending on the degradation's form and intensity.

Locust is a thermophile fast-growing species, domesticated in our country during the last two centuries. The results were good in steppe and silvosteppe areas as well as in the inferior part of the forest area (oak and hol subareas), on degraded lands with light and loose soils. Satisfactory results were obtained on lands with a mellow rock substratum without a soil layer, especially on loess, sands and gravel with a lot of sand; the restrictive factors for the development of locusts are: the presence of calcium carbonates in the soil's first 100 cm, clay content, the soil's compaction degree, the lithological substratum (clay, shale, hard rocks, especially chalcky ones), superficial soils or early frosts. Locust is the most suitable species for lands eroded by water due to its fast growth rhythm (soil consolidation and coverage in 3-5 years). The species develops well on in depth erosion forms due to its exceptional biological particularities.

The investigations have shown that the locust stands show different biometric and auxologic characteristics in regard with the stational conditions (Murariu et al., 2018). In Romania, according to the domestic yield tables (Giurgiu and Draghiciu, 2004), the volume of the standing crop ranges between 81 and 365 m^3 ha^{-1}, depending on yield class.

In the case of young stands (aged 7-15), the consistency is high (0.8-1.0), while the number of trees is relatively high, of 4,000-5,000 samples per hectare (Figure 1).

The accumulated wood mass volume is correlated with the stand's age and stational conditions, being of: 32.5 m^3/ha, at 10 years and 80 m^3/ha, at 13 years on strongly eroded lands; 60 m^3/ha, at 10 years and 128 m^3/ha at 12 years on moderately eroded lands. The annual average growths in the case of pure stands are ranging between 3.225 m^3/year/ha at 10 years on strongly eroded lands and 9.652 m^3/year/ha at 11 years (first sprout generation) on moderately fragmented landslide lands (Table 1). The comparative analysis fo the locust's biometric characteristics at young ages (7-15 years) on different categories of degraded lands (Figure 2), emphasizes the effect of stational conditions on their growth. The largest diameters were obtained on moderately eroded and landslides , while the largest heights were on moderately eroded and clough lands. Weaker results (growts, number of trees/ha) were recorded in locust cultures from strongly eroded and clough lands (Table 1).

Figure 1. Locust aged 10-12 (sprout regeneration) on clough land (S3 - Murgesti)

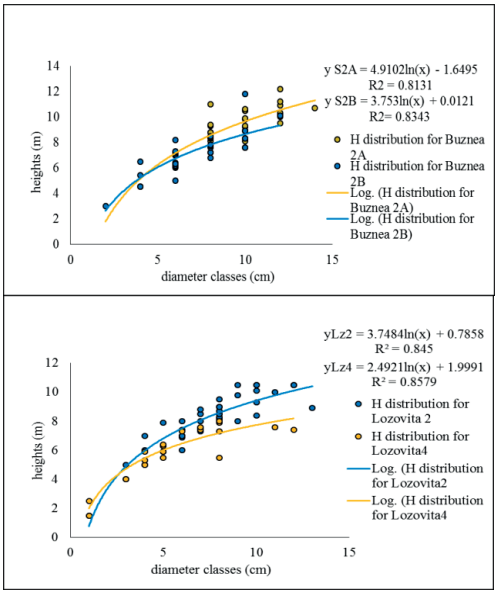

Figure 2. Distribution of heights on diameter species for the locust species in comparative situations on moderately to strongly eroded lands

Certain young locust stands originating from the natural regeneration of sprouts or suckers, have resulted after regeneration cuttings realized after the age of 30-35 years, an age when tree vitality is strongly weakened.

Table 1. Average growths (m^3/year/ha) for different fast-growing specices on degraded lands

Experimental plot	Phytoclimatic area-form of degradation	% species	Age	Mean growth (m^3/year/ha)
Livada S2/R	Ssd/R	20 locust	30*	2.103
		80 locust	64	4.415
Hulubat S6	SSd/E1	100 locust	10	6.727
Lobovita S2	Ss/E2	100 locust	10	5.987
Lobovita S4	Ss/E4	100 locust	10	3.255
Agighiol S2	Ss/E1	100 locust	13	6.646
Baneasa S4	Ss/E1	89 locust	10	9.366
		11 hardwood sp.	10	0.807
Murgesti S3	FD1/R	80 locust	12*	6.573
		20 ash		1.375
Murgesti S4	FD1/E2	92 locust	9*	5.218
		8 ash		0.461
Murgesti S5	FD1/A1	100 locust	11*	9.652
Murgesti S7	FD1/A1	100 white poplar	11*	15.61
Murgesti S13	FD1/A1	97 white poplar	43	10.188
		3 black poplar	43	0.105
Murgesti S14	FD1/A1	98 black poplar	43	4.383
		2 hardwood sp.	15	0.233
Vl. Caselor S1	FD1/A1	100 locust	15*	6.319
Vl. Caselor S2	FD1/R	100 locust	7*	6.731
Vl. Caselor S11	FD1/A1	83 white willow	40	4.740
		17 hardwood sp.	15	6.979
Buznea S2A	FD1/E1	100 locust	13	7.818
Buznea S2B	FD1/E2	100 locust	13	6.175
Caciu S1	FD3/A1+R	79 grey alder	38	2.702
		21 white willow		0.656
Caciu S2	FD3/A1+R	100 black alder	38	5.469
Rosoiu S5	FD3/ R	56 grey alder	45	2.224
		44 hardwood sp.		1.759
Rosoiu S6	FD3/ R	68 grey alder	45	2.566
		32 hardwood sp.		1.396

Legend: Ssd - hill forest steppe; Ss - forest steppe; FD1 - hill level with oaks and mixed harwood stands; FD3 - holm, common beech and holm-common beech hill level; R-ravines; Al - landslide; E 1…3 - moderately (1), strongly (2), very strongly (3) eroded lands; *second generation originating from sprouts.

The sprouts have reduced growths and are more inclined to damages in comparison with samples originating from suckers that are more vigorous and resistant to the action of harmful agents.

In the case of cultures with advanced ages (46-64 years), the consistency is reduced (0.5-0.7), while the number of trees per hectare is also diminished (729-1010 samples, including the naturally installed mixture species); locust is affected by drought in a percentage of 30-50% of the number of trees, while the annual average growths are of approximately 4.5 m^3/year/ha; the majority of locust samples present deformities (saber butts, twisted trunks, etc) or are inclined, a fact that compromises regeneration.

The distribution of the number of trees on diameter ccategories in the case of locusts older than 40 years emphasizes the fact that locust stands are relatively even-aged (Figure 3).

This situation as well as the fact that the stand's composition includes, besides the main species (locust), naturally regnerated species (American alder, elm, cherry tree) of different ages in small diameter categories (6-16 cm) determines high values for the variation coefficient (45.7%). This data emphasizes an increased stand variability and non-uniformity.

In the majority of situations, the average diameter and average height increase with aging. The growth tendency is differentiated based on the degradation form. Lower values are recorded for heights at an advanced age, a fact that is explained by the number of trees and the stand's thickness.

Forest poplar cultures were generally realized on landslide lands with a moderately to strongly fragmented soil mass, with a shifting mass, without water excecss (black poplar - S11 Murgesti) and on landslide lands with strongly fragmented soil mass, with derranged soils and without water excess: white poplar/black poplar (pure cultures or mxied with different species: white seabuckthorn or alder and willow).

White poplar was frequently used for the afforestation of torrential alluvial situations, especially downstream of transversal hydrotechnical works and in the alluvial cones of torrents. This specie prefers predominantly fine deposits, with accessible phreatic water from the silvosteppe area up to the common beech area. The investigations have

emphasized a good behaviour of white poplar on landslides with a fragmented soil mass, with soils mixed with rock and with a loamy to loamy-clay texture.

The average annual growths for poplars were of up to 15.6 m^3/year/ha at the age of 11 years old (sprout regeneration, first generation) and between 4.4 (black poplar) and 10.2 m^3/year/ha (white poplar) when exceeding 40 years old (Table 1). Black poplar has recorded weaker results in comparison with the white poplar.

The willow species used for the afforestation of degraded lands were white willow (*Salix alba* L.) and crack willow (*Salix fragilis* L.). Their results were good on deposits, especially on torrential alluvial ones, fine or coarse, mixed with fine material and accesible phreatic water, as well as on landslides with water excess.

After the age of 30-35, poplar and willow stands were affected by droughts (in a percentage of over 60%), a fact that has reduced their vitality, growth and consistency. The state of these stands indicates the effect of not realizing on time regeneration cuts, a fact that has led to a significant depreciation of their structure and a weakening of tree vitality and natural regeneration capacities. According to the approved technical regulations, the maximum age at which regeneration cuts must be done is of 33-35 years old.

The stand's structure degradation has allowed the regeneration of other species present nearby (locust, ash, sycamore, cherry and sometimes even holm or common beech) that ensure land coverage and protection functions.

Black alder (*Alnus glutinosa*) and **white alder** (*Alnus incana*) are species with a high adaptability to climate and soil conditions. However, they do not support drought and have requests regarding soil water and vegetate actively on humid soils from meadows (Blaga et al., 2019). Black alder had good results in capitalizing lands with ensured humidity (clough bottoms, plastic streams, landslides, alluvial deposits ş.a.) from low areas (plain, hill), while white alder has covered the same structures but on higher areas. Alders have recorded growths between 2.2-5.5 m^3/year/ha (Table 1) at ages of 38-45 years on clough lands and landslides from holm and common beech sub-areas (FD3).

In fast-growing forest cultures from the investigated improvement perimeters, the samples' dimensional variability is directly influenced by the stational conditions specific for each perimeter as well as by the species nature and their adaptability to present conditions.

In addition, expanded factors resulted from the plantation's characteristics also appear, especially from the plantation's scheme, distance or composition. Each sample's development space is many times strongly influenced by the development degree (especially horizontal) of nearby samples.

The comparative analysis of the real number of tree indicates a larger number of trees than the one from the tables in the case of 15 year old stands (locust, white poplar) originating from thick plantation schemes (1.5 x 1.0 m) with a large number of seedlings (6700/ha, S6 - Hulubat) or regenerated from sprouts and suckers. This aspects emphasizes the necessity of cultural operations (cleanings), especially in situations with more samples on the stump (resulted as cutting back after plantation).

CONCLUSIONS

From the current perspective of stand evolution on degraded lands, the following elements were highlighted:

-good results were recorded by forest cultures with locust and black poplar on landslides with reduced mobility, in stations with sandy-loamy up to loamy soils;

-pure locust cultures were realized on strongly up to very strongly fragmented landslides, in stations with regosols or erodisols with a sandy-loamy up to loamy texture; white poplar, alder and white willow cultures were realized in stations with ensures or excess soil humidity;

-relatively good results were obtained by locust cultures on clough lands, on landslide detachment surfaces and on strongly eroded lands with loamy-sandy up to loamy erodisols and a reduced content of calcium carbonates.

The majority of fast-growing forest cultures are presently pure stands; on degraded lands with more difficult conditions, forest cultures were realized from a reduced number of species (locust, alder) that had a good behaviour in regard with present conditions up to the age of

25-30. After this age, the stand became dry and thin, with a reduced quality, a fact that has affected its natural regeneration capacity.

Amongst the fast-growing species, locust was the most used one for the afforestation of degraded lands. The species capitalizes very well moderately up to strongly eroded lands with loamy or sandy soils and without or with a reduced content of carbonates, situated on slopes or ridges. The species has a good behaviour in pure cultures, realizing growths specific to average up to superior production classes. In these conditions, locust cultures have recorded annual average growths between 3.25 and 9.65 m^3/year/ha in report with stational conditions; the structural diversity degree is reduced, affecting the culture's stability and resistance towards abiotic factors (climatic stress).

White poplar was frequently used in the afforestation of strongly up to very fragmented landslides where it has generated annual average growths between 10.2 and 15.6 m^3/year/ha. Black poplar has recorded weaker results than the white poplar.

Alder (black and white) has realized growths between 2.2-5.5 m^3/year/ha, on different categories of degraded lands.

A good behaviour and growth can be observed for locust and white poplar, as well as a higher regeneration capacity and adaptability on degraded lands with different stational conditions in comparison with other species such as pines for example (Silvestru-Grigore et al., 2018; Vlad et al., 2019).

The age up to which the growths are active and stands can be led by these species is of 25-35 years for locst, 25-30 for willow, 30-35 for white and black poplar and 45-50 years for alder. Stands older than that were affected by drying, recording reduced values for growths, tree quality, regeneration capacity and protection functions.

Taking into account the significant number of degraded lands at a national level as well the nececssity of properly managing them on long-term, the usage of fast-growing species for ecological reconstruction works generates vital ecosystem services in areas with a deficit of forests.

In addition, they contribute to the diminishing of negative effects brought by climatic changes.

Choosing fast-growing species in the afforestation of degraded lands requires an optimum correlation between their biological characteristics and the stational conditions in order to avoid negative effects at the biotop level.

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