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ECOLOGICAL RECONSTRUCTION OF THE STANDS AFFECTED BY DROUGHT FROM MEADOWS OF INLAND RIVERS

Cristinel CONSTANDACHE[1], Ciprian TUDOR[1], Laurenţiu POPOVICI[1], Lucian DINCĂ[2]

[1]National Institute for Research and Development in Forestry "Marin Dracea", 7 Republicii Street, Focsani, Romania
[2]National Institute for Research and Development in Forestry "Marin Dracea", 13 Closca Street, Brasov, Romania

Corresponding author email: cipriantudor95@yahoo.com

Abstract

The surface of the stands affected by drying, located in the meadows of the inland rivers is in continuous growing due to the modification of the hydrological parameters under abiotic, biotic and anthropogenic factors. The forest species frequently used in the past (1970-1990) for afforestation were the hybrid black poplars or the selected willows. Currently, they are less used, due to the change of environmental conditions but also by including them in protected areas, for the detriment of native species. In the paper, are presented data regarding on the characteristics of the stands affected by drying located in research plots from Buzău and Lower Siret meadows. The results bring the environmental potential of the lands by restoration of the affected stands from forest-steppe areas using adequate species adapted to resist on different types of soils, being able to face the new ecotope conditions. The ecological reconstruction of these stands is an urgent need and is the only way to maintain the ecological balance, biodiversity and, at the same time, to capitalize on these categories of land unsuitable for other destinations.

Key words*: ecological reconstruction, meadow, restoration, riverside coppice, riparian forests.*

INTRODUCTION

The deregulators of forest ecosystems along rivers are those that can alter the water supply conditions of the forest by: channeling the course to limit floods with the risk of raising the minor riverbed and lowering the groundwater; groundwater pumping; road crossings; extraction of sand and stone from the course bed; dams built along the water; pollution with household waste and construction materials (Constandache et al., 2018).

Some forestry works are likely to alter the dendrological richness and structure of the stands, especially by: large area cuts that cause difficulties in regeneration; monospecific plantations or with few species without ensuring dendrological diversity (Untaru et al., 2012; Untaru et al., 2013). In Romania, year 2005, there were registered abundant precipitations that favored the accumulation of rainwater and therefore the flooding of the land, as well as the prolonged stagnation of the water, causing partial or even total drying of the stands (Dănescu et al., 2011).

In some areas, there has been fragmentation of forest massifs and various structures have been implanted (treatment of water plants, stone and sand mining quarries, pumping stations), necessary for local development. However, in all cases, the riparian forests are a landscape and functional element that structures the mountain, hilly or plain valleys and are particularly and mostly important for environmental protection. The vegetation corridors of inland rivers, regardless of their type of property or their role of production or protection, must be the subject of a rational management (Constandache et al., 2018; Fedorca et al., 2020, Fedorca et al., 2021).

Biodiversity of species or the soil coverage degree decrease the intensity of rainfall and the specific erosion of the soil, emphasizing their hydrological and anti-erosion efficiency (Constandache et al., 2018; Vlad et al., 2019).

The health state and stability of meadow forests riparian to inland rivers is threatened by various abiotic (climate change), biotic and anthropogenic factors. In general, lately, we are facing a decrease in the groundwater level and the number and duration of flood periods,

which has led to major seasonal changes in inland river meadows. To this is added the massive deforestation of riparian forests in the area of plains and low hills where the land was given for agricultural use (cereals crops, pastures, hayfields, rarely orchards).

In the large river meadows, in which was kept the forestry use, have been installed monocultures of poplars and willows with shorter cycles, highly productive (Filat et al., 2009), but which no longer corresponding to the requirements of maintaining and stabilizing protected natural areas wihich were located mainly in such areas.

The area of stands affected by drought, located in the inland river meadows, is constantly growing due to climate change but also to the worsening of the seasonal conditions of the meadows through the modification of the hydrological parameters under anthropogenic action.

Climatic factors were analyzed for the plain areas in Romania (Banat, Bărăgan, Oltenia) which accentuated the drying phenomena (drought) of the last 2 decades (Angearu et al., 2020).

The factors that caused the expansion of arid areas were: destruction and abandonment of irrigation systems; deforestation; excessive land fragmentation; inappropriate agricultural practices (Constandache et al., 2006).

In the Bărăgan Plain, the extreme drought affected significant areas of agricultural land. For example: 22.4%, in 2002 (June), respectively, 35.7%, in 2007 (July). The results indicate a high drought vulnerability of the Bărăgan Plain, due to the increased intensity and frequency of climatic characteristics recorded in this region.

In the context of climate change, the increase of the average annual temperatures by more than 1-2ºC will have as a first consequence, the aridization of the southern and plain areas, but also of the hilly areas, causing major changes in seasonal conditions and the emergence of limits for forest vegetation, according to the "Climate Change Adaptation Guidelines" (https://www.meteoromania.ro/anm/images/clima/SSCGhidASC.pdf).

In the future, we need to look for resilient forms of species from riverside coppice or even other species that respond to the new complex challenges, respectively environmentally efficient methods of managing destabilizing factors (Onet et al., 2019; Ducci et al., 2021; Kutnar et al., 2021). To eliminate the excess water, drainage works or hydrophilic forest plantations are frequently applied, which aim at the efficient use of excess moisture from the soil. Poplar and willow are most often planted. The banks of rivers exposed to lateral erosion are fixed by plantations of willow, alder and sea buckthorn species, after which, at an interval of 3-5 years, are planted the species that make up the permanent stands (poplar, oak, ash and so on), resulting in finally a compact orchard wall that runs parallel to the watercourse (Bojariu et al., 2021). As species from *Populus* Genus, white poplar (*Populus alba*) was used for the afforestation of torrential alluvial situations or in the alluvial cones from the downstream torrents (Constandache et al., 2020).

On lands with additional moisture input (valley bottoms, micro-depressions with "mosaic structure") and with at least moderately deep and humid soil, starting from the forest-steppe area to the forest area, it is recommended to plant seedlings of species such as walnut, cherry and hazelnut (Constandache et al., 2006).

Ecological reconstruction consists in replacing the current Poplar or another forest plantations installed to water meadows and which in the current conditions of modification of the original stations especially, by decreasing soil trophicity, do not have the capacity of maintaining and further develop viable stands and finding the compositions and technologies of suitable regeneration (Roșu & Dănescu 2013; Davidescu et al., 2020).

For this reason, it is recommended to extend the biomonitoring of air quality and nutritional status of the main natural species and initiating riparian forest research projects (Gavrilescu & Bolea, 2014; Dinca et al., 2018). The effects of meadow forest crops consist in the improvement, stabilization and capitalization of lands, inefficient 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 forest ecosystems and using them as an alternative to fossil fuel replacement (Spîrchez & Lunguleasa, 2016).
The restoration of riparian forest may be a valuable strategy having the potential for fast carbon sequestration, are vectors of biodiversity and provide precious ecosystem services (Dybala et al., 2019; Murariu et al., 2021; Tiwary et al., 2020; Tudor et al., 2020; Vechiu et al., 2021).
In the Northern China, Poplar plantations, due the fast growing which means high productivity, have an extended potential in carbon sequestration. To maintain their high growth rate, they require more water (Zhou et al., 2013). In Israel, the ecological restoration include mainly the improvement of vegetation coverage and reducing the desertification by accessing projects addressed to the management of water resources, enhancing the downstream water supply from main rivers (Yao et al., 2021). Benefits from restoration depending of the nature of the intervention, several of them may provide a rapid benefit, an example being the establishment of riparian forests (Smith et al., 2014).
The studies carried out in the current stage were case studies aimed at applying the results of previous research conducted under "Marin Drăcea" National Institute for Research and Development in Silviculture in 2018-2019 regarding on *"Revision of the systematic of the forest sites used in the meadow areas of the inland rivers, in order to adapt the management measures of the stands at the modification of the environmental conditions"* (National Project Report, code PN 19070503).

MATERIALS AND METHODS

The researches were carried out in 10 research areas, located in representative situations of lands placed in the lower meadows of the rivers Buzău and Siret with stands or forest crops affected by drought.
The current state of the stands in different environmental conditions were analyzed and highlighted. In order to highlight the limiting factors for forest species, the pedo-stationary conditions were analyzed, starting from the fact that the physical environment of the terrestrial ecosystems is the ecotope, and the soil is one of its most important components (Untaru, 1976).
For the characterization of the soil from the researched lands, the depth, the groundwater level, the thickness of the humus horizon (A), the depth at which horizon C appears, the texture and the $CaCO_3$ content in the horizons above the horizon C that limit the installation and development of forest species were taken into account (Dănescu et al., 2010).
The type of soil was determined by field work (description of soils on standard sheets) and with the help of laboratory analyzes of samples collected on diagnostic horizons from soil profiles.
In order to characterize the soils, main soil profiles and secondary profiles for control were carried out at distances of approximately 20-30 m, in order to ascertain the modification of the soil profile, being delimited the surfaces related to the main profile.
From the main profiles, soil samples were collected on diagnostic horizons. The soil samples collected were analyzed in the I.N.C.D.S "Marin Drăcea" laboratory, being determined the chemical properties (pH, humus content, carbonates, salts etc.) and physical (granulometry).
Territorially, the research was carried out in the lower meadows of the rivers Buzau and Siret. All the analyzed areas are located in the southeastern part of Romania, respectively in the south of the Moldavian Plateau (Lower Siret Meadow) and the North Bărăgan Plain (Lower Buzău Meadow). From the point of view of the bioclimatic zonality, the studied surfaces are framed in the forest-steppe zone (Ss).
The research consisted of collecting field data, processing and interpreting them. The processing of field data was done in a computer system by using specific statistical programs in forestry.
All the analyzed areas are located in the southeastern part of Romania, respectively in the south of the Moldavian Plateau (Lower Siret Meadow) and the North Bărăgan Plain (Lower Buzău Meadow). From the point of view of the bioclimatic zonality, the studied surfaces are framed in the forest-steppe zone (S_s).

RESULTS AND DISCUSSIONS

A. Pedo-stationary characteristics of lands with stands affected by drought in Buzău Meadow (Ianca Forest District)

Five situations of stands with white poplar and elm trees affected by drying were analyzed (Figure 1, Table 1), divided into three production units (U.P.).

Figure 1. White poplar stands affected by drying, Ianca Forest District

The analyzed soils were classified as *Aluviosol* soil type. They consist of fluvial parent material at least 50 centimeters thick, with a very high content of fine sand, for which reason they have been classified mainly in *the psamic subtype*, except in one case (u.a 16D, U.P III), where the subtype it is *molic* and *mesohyposaline*.

Table 1. Situation of areas with stands affected by drying (Ianca F.D.)

U.P	Total surface [hectares]	Surface affected by drying [hectares]	Affected stands [%]
II	460.47	27.50	6
III	538.61	8.21	2
V	1075.96	54.69	5

The texture of the soils is from coarse to medium between sand-loam to medium clay, except in u.a 16D, where the texture is fine, falling into the clay-clay class (Table 2).

There is an increase in the clay content per profile to the detriment of the percentage of sand, only in the case mentioned above.

The soils are weak to moderately humiferous in the first horizon between 15-25 centimeters, weak in the middle supplied with nitrogen, phosphorus and mobile potassium, they contained from weak to moderately carbonates and weak of salts with one exception (u.a 16D) where the number of salts increases, but below the threshold and at depths of more than 50 centimeters.

Table 2. The results of the physical analyzes of the soil in Lunca Buzaului (Ianca F.D)

Identification		Colloidal clay [%gr*]	Coarse sand [%gr*]	Fine sand [%gr*]	Silt [%gr*]
Profile	Depth [centimeters]				
P1	0-35	15.03	1.86	65.87	17.24
	35-60	15.33	0.38	52.42	31.87
	60-75	16.90	0.32	70.10	12.68
P2	0-35	29.6	0.46	45.94	24.54
	35-50	5.26	0.03	82.22	12.49
	50-90	16.63	0.01	48.08	35.28
P3	0-20	12.35	0.06	73.57	14.02
	20-47	7.07	0.17	81.56	11.20
	47-70	23.32	0.41	49.00	27.27
P4	0-25	34.88	1.33	35.44	28.35
	25-50	38.20	0.16	25.96	35.68
	50-75	32.71	0.39	34.65	32.25
P5	0-20	26.17	0.13	61.83	11.87
	20-40	17.31	0.10	59.00	23.59

Note: *) colloidal clay<0.002 milimeters; coarse sand=2.0-2 milimeters; fine sand=0.2-0.063 milimeters; silt=0.063-0.002 milimeters.

As limiting factors for the cultivation of forest species, we mention:

- lowering of groundwater levels to levels inaccessible to meadow-specific species: *Populus nigra* (Pl.n), *Populus alba* (Pl), *Salix* sp. (Sa);
- increasing the percentage of carbonates and salts per profile that limits the maintenance and development of certain forest species: *Robinia pseudacacia* (Sc), *Gleditsia triacanthos* (Gl), *Acer platanoides* (Pa), *Prunus avium* (Ci) (Enescu & Dănescu, 2015);
- low to very low amounts of mobile humus, nitrogen and potassium, concomitant with increasing alkalinity per profile;
- the increase in temperature and the sharp decrease in soil moisture per profile during the summer;

- infections with the Asian fungus *Ophiostoma novo-ulmi* which causes the mass drying of field elm (*Ulmus minor*).

As favorable factors, we mention:

- high clay content per profile, to the detriment of low amounts of fine and coarse sand, which makes it easier to catch, maintain and develop especially xerophytic oaks: *Quercus pedunculiflora* (St.b), *Quercus cerris* (Ce), to which are added the ashes: *Fraxinus excelsior* (Fr), *Fraxinus angustifolia* (Fr.î), *Fraxinus pennsylvanica* (Fr.b) and elms: *Ulmus pumila* (Ul.t), *Ulmus minor* (Ul.c);
- high percentages of nitrogen, phosphorus and mobile potassium in certain parts of the land, favorable to physiological processes for any species.

From the secondary surveys carried out, on certain parts of the land surface, especially near the course of the minor riverbed of the Buzău river, there is a load of soluble salts and carbonates, even from the upper horizons, which limits the development of forest species. Adaptable to these microstationary conditions are only the following forest species: *Eleagnus angustifolia* (Sl), *Pyrus piraster* (Pă), Acer tataricum (Ar), Prunus cerasifera (Cd), *Ulmus pumilla* (Ul.t). The total area is approximately 0.5 ha.

B. Lower Siret Meadow (Focșani Forest District)

In this area were analyzed five situations in which, the plantations with greyish oak (*Quercus pedunculiflora* K. Koch) carried out in the period 2017-2020, on agricultural lands, did not give results on certain portions of land, registering successive losses (over 50-60%). The plantations were made with greyish oak mixed with deciduous xerophytes species (20-30%), in prepared soil on the whole surface (ploughing, discing). The general pedo-stationary characteristics of the analyzed lands and soils are favorable to the greyish oak. However, insular, there are areas between 0.1-0.3 hectares, where the situation changes due to the great diversity of soil subtypes that are interspersed as a mosaic due to the existence of alluvial layers brought by the successive floods of the Siret River. The main parameters that most decisively change the fertility and favorability of these soils are the following: the varied content of clay, sand and dust on the profile, the contents of carbonates and salts and the process of stagnation or not of water from precipitation in the upper horizons and in the lower ones through ascent from the groundwater.

Therefore, the textural specificity presented in the description of each soil profile analyzed, differently influences the permeability and aeration regime of soils, stagnation and water retention mainly from precipitation (because floods are rare and at long intervals due to the damming of the area) with major impact r on the maintenance and development of forest seedlings.

Table 3. The results of physical analysis of the soil in the Lower Siret Meadow (Focșani Forest District)

Identification		Colloidal clay [%g*]	Coarse sand [%g*]	Fine sand [%g*]	Silt[%g*]
Profile	Depth [centimeters]				
P1	0-40	35.39	0.45	18.22	45.94
	41-60	50.02	0.34	1.23	48.41
	61-80	40.48	0.98	13.71	44.83
	81-110	54.89	2.10	36.45	6.56
P2	0-30	31.18	0.96	52.16	15.70
	31-60	23.39	11.15	60.26	5.20
	61-100	10.03	6.82	75.17	7.98
P3	0-18	35.48	0.20	33.41	30.91
	18-48	35.75	0.17	27.42	36.66
	48-68	40.30	0.02	16.84	42.85
	68-98	19.32	0.01	59.36	21.31
P4	0-30	24.21	0.12	43.61	32.06
	31-55	36.64	0.08	22.70	40.58
	56-90	41.62	0.08	26.20	32.10
	91-110	32.41	0.07	48.61	18.91
P5	0-17	44.84	1.87	26.95	26.34
	17-50	45.62	0.33	16.62	37.43
	50-80	35.03	0.12	23.05	41.80
	81-115	23.87	0.04	35.69	40.40

Analyzed in the order of decreasing clay content and changing texture from fine to coarse (Table 3), the analyzed soils are divided as follows:

- *soils with above average clay content (35-50%), in the first 60-70 centimeters.* Even if it has a high water storage capacity, the other physical and hydrophysical properties except for the aeration porosity which has very low values overall, become unfavorable: wilting coefficient - high, bulk density - high, total porosity - low, especially in the horizons where a maximum clay content is recorded, sometimes even from the surface. The low porosity of aeration can be explained by the long stagnation of water from rainfall, but also by the intensive grazing and pastures

fertilisation practiced previously, more in this area;

- *in the case of soil with medium texture (P2),* due to the maximum average clay content, the soil still has a high water retention capacity (useful water capacity has high values) and the wilting coefficient has medium to low values. The other physical and hydrophysical properties are generally favorable: bulk density - low, total porosity - large, aeration porosity - medium, but decrease with depth when they reach the sand layer (>50%).

The necessity for ecological reconstruction is to replace Poplar stands or forest crops from inland river meadows that do not have the capacity to maintain and develop viable stands under actual conditions of changing environmental conditions, especially by lowering groundwater levels and soil trophicity. In some places, the rise of carbonates and salts levels limit the development of species such as locust.

For lands in the Buzău meadow where the soil has a high sand content, the recommended species that can withstand the mentioned conditions are: honey locust, locust, mulberry, oleaster, cherry-plum. If the percentage of carbonates increases, the participation of locust decreases.

The technology of ecological reconstruction consists in the partial preparation of the soil in hearths, plantations in normal pits of 30x30x30 centimeters, with seedlings with bare roots, manually and maintenances for 5 years.

For soils with a higher percentage of clay, the soil preparation consists in removing stumps, scarifying, plowing and discing, and the maintenance's will be staggered over a period of 6-7 years (in the case of compositions with oak species).

In Siret meadow, the favorability of ecological factors and determinants for the main forest species in the area, recommends an optim of vegetation for the basic species: greyish oak, common oak, Turkey oak, pubescent oak and mixed species: Norway maple, European sweet cherry, European white lime, field maple, field elm, honey locus and oleaster.

It is recommended to introduce the following resistant forest species with a higher capacity to adapt to environmental conditions:

-in areas of land where the soil is clayey from the surface and which due to its high compactness in the summer season becomes a limitative factor for the main forest species, it is recommended to introduce the Turkey oak (*Quercus cerris*) from the oak family, assuming the risk that it may be dry if at very long intervals are produced floods followed by stagnant water exceeding 6 months;

-in the parts of the land where the soil has a medium texture, but in depth it becomes compact due to the higher content of migrated clay it is recommended the common oak (*Quercus robur*), which resist relatively good at compaction, but much better at stagnant waters or other biotic or abiotic factors with harmful effects on forest crops;

-in areas of land where the soil has a transitional texture in profile from medium to coarse, honey locust (*Gladitsia triacanthos*) is recommended, with ambivalent resistance both to clayey soils with compactness and water stagnation to sandy soils with low humidity and high temperatures, especially in the summer season.

Honey locust also led to good results on alluvial protisols, withstanding short-term floods well (Constandache et al., 2012).

-as a suitable oak species, pubescent oak (*Quercus pubescens*) or *Quercus virgiliana* is recommended, both of which being native species. The strong change of edapho-climatic factors determines the choice of alternative solutions regarding the structure of the stands from the inland river meadows using species, mostly exotic and the adoption of more extensive maintenance systems for viable forest crops.

CONCLUSIONS

The results of the study consisted in the analysis of the pedo-stationary conditions of the meadow lands with stands or forest crops affected by drying and the scientific substantiation of their restoration compositions.

The stability of riverside coppice (meadow forests, riparian inland rivers) is threatened by various abiotic factors (climate change), anthropogenic (qualitative and quantitative changes in surface water and groundwater) and

biotic (oomycetes, fungi and invasive plants, with great power destabilization of stands.

In order to highlight the limiting factors for forest species, the pedo-stationary conditions were analyzed, starting from the fact that the physical environment of the terrestrial ecosystems is the station (ecotope) and the soil is one of its most important components.

As limiting factors for forest species culture, the following have been identified:

-decreasing the groundwater level to levels inaccessible to species specific to riverside coppice of meadow: *Populus nigra* (Pl.n), *Populus alba* (Pl), *Salix* sp. (Sa);

-increasing the percentage of carbonates and salts per profile that limits the maintenance and development of certain forest species: *Robinia pseudacacia* (Sc), *Gleditsia triacanthos* (Gl),

-increase in temperature and high decrease in soil moisture per profile during the summer season;

-infections with the Asian fungus *Ophiostoma novo-ulmi* which causes the mass drying of the field elm (*Ulmus minor*).

As favorable factors, identified in certain situations are mentioned:

-increasing the clay content per profile, to the detriment of the fine and coarse sand, which facilitates the catching, maintenance and development especially of xerophytic oaks: *Quercus pedunculiflora* (St.b), *Quercus cerris* (Ce), to which are added the ashes: *Fraxinus excelsior* (Fr), *Fraxinus angustifolia* (Fr.î), *Fraxinus pennsylvanica* (Fr.b) and elms: *Ulmus pumila* (Ul.t), *Ulmus minor* (Ul.c);

-high content of nitrogen, phosphorus and mobile potassium in certain parts of the lands, favorable to physiological processes for any species. The research carried out allowed the appropriate environmental classification of the lands with stands affected by drying and the scientific substantiation of the solutions for ecological reconstruction of the affected stands by identifying the species corresponding to the identified environmental conditions.

The strong change of edapho-climatic factors determines the choice of alternative solutions regarding the regeneration composition of the stands of the inland river meadows using species, often exotic and the adoption of more extensive maintenance systems for the realization of viable forest crops.

Having the significant existing areas at national level with the stands affected by drought in the meadow areas, as well as the need for their improvement and sustainable use, ecological reconstruction by afforestation of these lands contributes, in addition to generating essential ecosystem services (soil and water protection) in areas exposed to desertification and to the realization of additional incomes from the capitalization of the resulting wood or non-wood products.

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