

RESEARCH REGARDING THE LANDSHAFT RECONSTRUCTION IN THE FORMER BAUXITE QUARRIES FROM PĂDUREA CRAIULUI MOUNTAIN

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Abstract

The reconstruction of the landschaft in the former bauxite quarries is a complex problem and the paper presents the results carried out during 2005-2013 in the research field placed in a former bauxite quarry from Zece Hotare, Bihor county. The former quarry is situated in the Pădurea Craiului Mountain. The exploitation of the bauxite ended in 1998 and in 2004 and 2005 the complex work (levelling, mattresses on the hillside, planting) were carried out.

Physical properties (bulk density, total porosity, penetration resistance, hydraulic conductivity) chemical parameters (pH, humus, mobile phosphorus, mobile potassium) enzymatic activity (actual and potential dehydrogenase activity, acid and potential phosphatase activity, catalase activity, non-enzymatic catalytic activity, urease activity) are studied in 3 profiles situated in the high leveled area, low leveled area and on the hillside. The parameters of the land from former bauxite quarry compared with the parameters of the soil from beech tree forest situated in adjacent area have the values less favourable. The installing of the planting vegetation was studied, too and the results of the research emphasize the positive influence of the fertilizers on the growth rhythm of the Robinia pseudocacia planted on the plateau area.

The mattresses on the hillside determined a better growth rhythm of the Pinus silvestris. The following spontaneous species were installed in the former bauxite quarry: Tusilago farfara, Cirsium arvense, Poa pratensis, Rubus caesius, Calamagrostis epigeios, Hypericum perforatum, Equisetum arvense, Polygonum persicaria, Juncus inflexus. The installing evolution was studied, too. The degree of the covering with the natural vegetation decreases altogether with the increase of the slope. Soil losses are in direct link with hillside slope. The mattresses execution determinate a very important decrease of the soil losses, 3.6 t/ha vs. 97.8 t/ha in 2013; in these condition the covering vegetation degree was of 96.67 the hillside with slope of 10% and mattresses in comparison with 21.2%.

Key words: quarry, bauxite, soil, vegetation, mattresses, landschaft

INTRODUCTION

The research on restoration of degraded landschaft by the bauxite industry were initiated in 2005, at the Pădurea Craiului mountains, in the former bauxite quarry at Zece Hotare, he has placed research on differentiation of physical, chemical and biological soil parameters of different areas of the quarry in comparison with adjacent beech forest, the influence of fertilization on the planted vegetation, on spontaneous vegetation, the soil erosion on slopes, the dynamics of grassy vegetation installation. (Brejea, 2005)

The landschaft is an area with its own properties, with a homogenous aspect; it is a result of an interaction between relief, climate, hydrography, soils, vegetation and human activity which makes it different from other neighboring areas.

Based on the research results obtained at Zece Hotare, the following project was elaborated "*Rehabilitation and maintenance of the former bauxite quarry from Șuncuiuș and promoting the environmental protection*", by Brejea R. This project was proposed

under the program "Together for everyone 2010" organized by Rompetrol. Also, the research at Zece Hotare were an integrated part of the CEEX 35/2006 project „Study of the risk factors, quantifying their impact on agricultural systems, creation of new genotypes and the development of sustainable technology” project manager Ciobanu Gh, scientific director of the project C. Domuta. (Domuta (coord.), 2012)

The paper presents a short synthesis of the research carried out during 2005-2013 regarding the physical, chemical and enzymatical parameters of the land from former bauxite quarry, the influence of the chemical and organic fertilizers on planting vegetation, natural vegetation installing and the influence of the slope and mattresses in this process, the erosion of the hillside.

MATERIAL AND METHOD

The research field was set in 2005 in a former bauxite quarry in Zece Hotare, Pădurea Craiului Mountains. The area of the quarry is 10 ha. The exploitation of bauxite ceased in 1998, and in 2004 and 2005 were carried out extensive development work: leveling, mattresses on the slopes, planting acacia trees in the leveled area and spruce in the higher zones. (fig.1., fig.2)



Fig.1. Reclamation view of the former bauxite quarry from Zece Hotare, Bihor



Fig. 2. The levelled bauxite quarry from Zece Hotare, Bihor

Acacia and spruce seedlings were planted at distance of 1 m in a row and with 2 m between rows. The holes had dimensions of 40 x 40 x 40 cm, and at every hole there were used 6.0 kg of manure. To ensure a high success rate for the saplings, immediately after planting, they were wet with 16 liters of water each. Mattresses were made of oak poles (diameter of 6-8 cm and a length of 1-1.2 m) and beech twigs placed at distances of 2.0 m. (fig.3)



Fig. 3 Mattresse made of beech, after execution (2004), at the former bauxite quarry at Zece Hotare, Bihor

The study on slope erosion was done by measuring the size of runoffs and furrows on target surfaces followed by calculating the volumes, transforming them into tons knowing that $1 \text{ m}^3 = 1.5 \text{ tons}$ of earth. Climatic data were taken from the National Institute of Meteorology and Hydrology.

Study of the influence of fertilization on the growth of the acacia tree was done in an experiment located in the upper third of the former bauxite quarry in a leveled area. The experiment consists of the following:

V_1 = Control, without fertilizer

$V_2 = N_{120}P_{120}K_{120}$ (24 g of complex fertilizers /hole)

V_3 = Manure 30t/ha (6 kg/hole)

V_4 = Manure 30 t/ha (6 kg/ hole) + $N_{120}P_{120}K_{120}$ /24 g/ hole

The saplings were planted at a distance of 2 m distance between rows and 1 m between the line. The experiment was placed after the block method in 4 replications.

The number of plants per plot was 20. The influence of Mattresse on spruce growth was studied on two versants with a slope of 10% in the following:

V_1 = without antierosion works on slopes,

V_2 = erosion control works on slopes with Mattresse.

While planting the spruce saplings, they applied 6kg manure (30t/ha hole) and 24 g of complex fertilizers ($N_{120}P_{120}K_{120}$).

Both acacia and spruce, were watered immediately after planting with 16 liters of water each, ensuring a percentage of saplings success rate of 95%. Annual growth was determined from 40 plants of each embodiment (10 x 4 repetitions, in the experiment with fertilizers)

In order to determine the physical and chemical characteristics of the land of the former bauxite quarry at Zece Hotare and of the soil from the neighboring beech forest, there were placed 4 soil profiles, in the high leveled area, in the depression leveled are, on a versant with a slope of 10% planted with spruce and without Mattresse works and finally

in the beech forest 50 m inside from the edge. The soil samples for the enzymatic analysis were collected with the agrochemical probe from 10 to 10 cm in the same area.

Determination of the physical parameters (texture, bulk density, porosity, hydraulic conductivity, penetration resistance), chemical (pH, humus, mobile phosphorus, mobile potassium) and biological (acid and alkaline phosphatase activity, catalase activity, non-enzymatic catalase activity, urease activity) were made in the laboratory of Agricultural Research and Development Station Oradea, using the usual method. (Brejea, 2010, 2011)

RESULTS AND DISSCUSIONS

Physical parameters of the land in different parts of the former bauxite quarry at Zece Hotare

In August 2007 they conducted 4 soil profiles, they studied the depths of 0-17 cm, 17-30 cm, 30-40 cm and 40-60 cm. Three of the profiles were carried out in the former bauxite quarry and one in the beech forest in the immediate vicinity.

Laboratory determinations allowed the following conclusions:

Granulometry of the three soil profiles from the former bauxite quarry differs substantially from the soil of the beech forest in terms of particle size. The largest difference occurred in the colloidal clay content ($\Phi < 0,002$), On average on the soil profile, compared to beech forest soil, the soil on the versant slope from the bauxite quarry had a difference of 89.1% and for the profiles located in the high-leveled zone and respectively in the depression area was 71.1%, and 67.7%.

The highest values of bulk density were recorded on the slope of the former bauxite quarry, the average value of profile is 1.62 g/cm³. Levelling determined the apparent density values to be lower than the values recorded in the beech forest in the vicinity. (table 1.)

Table 1

Physical parameters of the land from the former bauxite quarry at Zece Hotare, Bihor (average values on 0-60cm depth), 2013

Parameter	Profile 1		Profile 2		Profile 3		Profile 4	
	Vol	%	Vol	%	Vol	%	Vol	%
Bulk density g/cm ³	1.29	100	1.16	90	1.09	84	1.62	125
Total porosity %	53.5	100	56.75	106	59.5	111	39.25	73
Penetration rezistance	46.78	100	38.0	81	37.7	80	59.0	126
Hydraulic conductivity	3.63	100	4.38	121	6.8	187	2.33	64

Profile 1, beech forest, adjacent area;

Profile 2 acacia tree - the high leveled area,

Profile 3 acacia tree - depressionary leveled area;

Profile 4 fir tree, versant.

As a result of bulk density values, the lowest values of total porosity were recorded in the profile located on the slope of the former bauxite quarry, the average being 39.25% for a profile. At all depths, and on the average soil profile, the highest values of total porosity (and therefore the most favorable) were recorded in the leveled area, the values were higher than those recorded in the beech forest soil.

Resistance to penetration had the highest values on the profile located on the slope at the former bauxite quarry. On the profiles situated on the leveled area from the former bauxite quarry, the values for the penetration resistance were close to the values determined in the beech forest soil but slightly larger.

The most unfavorable values of hydraulic conductivity were determined on the slope of the former bauxite mining site: 4.5 mm / h, to 0.17 cm, 2.1 mm / h at 17 to 30 cm, 1.3 mm / h at 30-40 cm and 1.4 mm / h at 40-60 cm, on the profile of the leveled area, the hydraulic conductivity values were higher than the values determined from the slope of the former quarry, and than the values of the profile from the beech forests nearby.

Chemical parameters of soil in different parts of the former bauxite quarry at Zece Hotare

The determination of the chemical characteristics of the profiles have been conducted on the same profiles where the physical properties were determined, here are the following conclusions:

The humus content in the soil from the former bauxite quarry, is much lower than that of the soil from the neighboring beech forest and was discovered only till the depth of 30 cm. The lowest values of humus content were recorded on the slope of the former bauxite quarry: 0.93% for 0-17 cm and 0.00% on 17-30 cm compared to 3.7% in the 0-17 cm and 2.9% in the 17 to 30 cm in the soil from the beech forest, also there were determined humus content of 1.1% in the 30-40 cm and 0.4% in the 40-60 cm.

PH values determined in soil profiles from the former bauxite quarry are lower than the values determined in the soil profile in the beech forest, the lowest values occurring in the soil profile of the beech forest (6.0 to 0 -17cm, 5.6 in 17-30, 5.5 per 30-40cm and 5.2 in 40-60), the lowest values occurring in the soil profile are located on the soil profile situated on the slope.

The mobile phosphorus content is very low in all 4 soil profiles, the lowest values recorded are in the profile located on the slope of the former bauxite quarry, and the largest in the soil profile in the beech forest. On average on the depth of 0-60 cm the differences from the value recorded in the beech forest soil (5.75 ppm), were -74% on the slope, -65% in the high leveled area, of -57% in the leveled depressionary area. (table 2.)

Table 2

Chemical parameters of the land from the former bauxite quarry from Zece Hotare, Bihor (average values on 0-60cm depth), 2013

Parameter	Profile 1		Profile 2		Profile 3		Profile 4	
	Vol	%	Vol	%	Vol	%	Vol	%
pH	5.58	100	5.4	91.6	5.42	97.1	5.21	92.4
Humus %	2.02	100	0.16	7.9	0.19	9.3	0.03	0.9
Mobile phosphorus, ppm	5.75	100	2.00	35	2.5	43	1.5	26
Mobile potassium, ppm	82.5	100	32.5	39	42.5	51.5	23.8	28.8

Profile 1, beech forest, adjacent area;

Profile 2 acacia tree - the high leveled area,

Profile 3 acacia tree - depressionary leveled area;

Profile 4 fir tree, versant.

Mobile potassium content in the soil from the former bauxite quarry is less than the content determined at all depths in the soil from the beech forest.

The average soil profile, differences from the value determined in the beech forest soil (82.5 ppm), 71.2% for the profile on the slope from the former bauxite quarry, 61.0% of for the profile situated on the high leveled area and 48.5% for the profile located in the depressionary leveled area.

Parameters of enzymatical activity in different areas of the former bauxite quarry at Zece Hotare

For the enzymatic determinations in September 2007 there were taken soil samples from a depth of 40 cm from 10 to 10 cm, and the research findings are:

Actual dehydrogenase activity had the lowest values in the soil profile located on the slope of the former bauxite quarry. On average for the depth of 0-40 cm, the differences from the value determined in the beech forest soil (8.5 mg triphenylformazan / 10g soil in 24 hours) were 39, 5% in the profile on the slope , 27.9% in the profile located in the high leveled area and 13.7% in the profile located in the flattened depression. Regarding the potential dehydrogenase activity (12.38 mg g triphenylformazan/10 g soil in 24 hours, at the depth of 0-40 cm) the differences are even larger: 60.1%, 47.1% and 24.8%.

The phosphatase activity, both the acid and the alkaline value is lower in the field from the former bauxite quarry compared to the beech forest soil. On average at the depth of 0-40 cm the acid phosphatase activity in the beech forest soil, compared to the other profiles the differences are 57, 8% in the slope profile, 40% for the profile located in the high leveled area and 16.1% for the profile located in the leveled depression. On average at the depth of 0-40 cm the acid phosphatase activity in the beech forest soil, compared to the other profiles, the differences are 57, 8% in the slope profile, 40% for the profile located in the high leveled area and 16.1% for the profile located in the leveled depression.

Catalase activity has lower values in the profiles from the former bauxite quarry compared to the catalase activity in the neighboring beech forest soil (11.65 mg H₂O₂ / 1 g soil), the average difference in the soil profiles are of 22.5% for the profile located on the slope, 19.4% in the profile located in the high level leveled area and the value of 15.2% in the profile located in the flattened depression. The same sense of difference was recorded in the non-enzymatic catalytic activity (13.65 mg H₂O₂ / 1 g soil in the beech forest soil), but the differences have smaller values.

The urease activity values are very different in the soil of the former bauxite quarry, compared to the average of the beech forest soil profile, 10.03 mg NH₄/100 g soil, the differences are 56.6% in the slope profile, 44.5 % profile located in the high leveled area and of 24.1% in profile located in the flattened depression. (table 3)

Table 3

Enzymatic parameters of the soil of from the former bauxite quarry at Zece Hotare, Bihor (depth of 0-40cm), 2013

Parameter	Profile ₁		Profile ₂		Profile ₃		Profile ₄	
Actual dehydrogenase activity mg sol/24 h	8.50	100	6.13	72.1	7.37	86.7	5.14	60.5
Potential dehydrogenase activity, mg Triphenylformazann 110g sol/24h	12.38	100	6.54	52.9	9.31	75.2	4.95	39.9
Acid phosphatase activity, mg phenol/g soil	0.263	100	0.158	60.0	0.221	83.9	0.111	42.2
Potential phosphatase activity, mg phenol/g soil	0 157	100	0.103	65.4	0.113	71.9	0.092	58.6
Catalase activityă mg H ₂ O/1g soil	11.65	100	9.38	80.4	9.88	84.8	8.33	77.5
Non-enzymatic catalytic activity, mg H ₂ O/1g soil	13.65	100	12.53	92.0	13.42	98.4	11.58	84.7
Urease activity, mg NH ₄ /100g soil	10.03	100	5.57	55.5	7.62	75.9	4.36	43.4

Installing of the planting vegetation in the former bauxite quarry

The fertilizing used at planting the acacia tree in the leveled area of the former bauxite quarry is important, the organo-mineral fertilization consists of manure 30t/ha +N₁₂₀ P₁₂₀ K₁₂₀ determined the highest annual growth of plants. The organic fertilization (manure 30 t/ha), respective mineral fertilization (N₁₂₀P₁₂₀K₁₂₀) determined highly statistically significant increases in plant growth compared to the unfertilized control both in 2006 and in 2007.

Importance of mattress works on the slopes of the former bauxite quarry at Zece Hotare is supported by the fact that spruce trees planted in such conditions had higher annual growth, statistically assured, compared with increases determined at the spruce trees planted on a versant with the same slope, but not be provided with mattress works.

Installing of the natural vegetation in the former bauxite quarry

The degree of coverage with herbaceous vegetation the various areas of the former bauxite quarry increased from one year to another. Thus, in 2006 in the leveled area were determined 13 plants/m² in the flattened depression, and 7 plants/m² in the high leveled area, 8 plants/m² in the interval equipped with mattress works and 3 plants/m² on the slope without erosion works, but with the spruce planted on the direction of the level curves. In 2006, the number of plants in these locations increased to 23 plants/m², 14 plants/m², 75 plants/m² and 5 plants/m² and in spring 2008 the fewest plants per unit area were recorded on the slope without mattress works, 7 plants/m². The area with the most plants on m² was the leveled depression area with 31 plants/m², on the slope with mattress works were determined 26 plants/m², and in the high leveled area there were 14 plants/m². The beech forest in the neighboring area, in the summers of 2006 and 2007 there were determined 8 plants/m² of the species *Poa pratensis* (meadowgrass) and in spring 2008 there were also highlighted 2 plants/m² of *Allium ursinum* (Ramsons).

The plant species found in all 4 locations was *Tussilago farfara* (coltsfoot). In the flattened depression area, the dominant plants are the ones who prefer moist areas or excess moisture: *Juncus inflexus* (Rush) *Equisetum arvense* (Horsetail), *Polygonum persicaria* (Lady's thumb), next to which they encountered the species *Calamagrostis epigeios* (Bushgrass), *Cirsium arvense* (Creeping Thistle) and caesius *Rubus* (European dewberry). In the high leveled area besides the dominant species *Tussilago farfara* (coltsfoot) there were encountered *Cirsium arvense* (thistle), caesius *Rubus* (european dewberry) and *Hypericus perforatum* (St John's wort). On slope with mattress works with besides the dominant species *Tussilago farfara* (coltsfoot) there were also determined the species *Calamagrostis epigeios* (Bushgrass) and *Cirsium arvense* (thistle), while on the slope without erosion works, together with *Tussilago farfara* (coltsfoot) they identified only caesius *Rubus* species (european dewberry). On the slopes fitted with mattressworks, the number of plants per unit area decreased with increasing the slope. Measurements conducted in spring 2008 highlighted a number of 26 plants/m² at 10% slope, 22 plants/m² at 20% slope, 18 plants / m² slope of 31% and 13 plants/m² at 44% slope. Absence of mattress works on the slope of 44% led to just 1 plant/m² (*Tussilago farfara*).

At a slope of 10% the dominant species is *Tussilago farfara* (coltsfoot) and on the slopes of 20%, 31%, 44%, the dominant species is *Calamagrostis epigeios* (59%, 61% and 54%).

On the slopes of 31% and 44% was determined species *Polytrichum commune* (haircap moss). On slopes of 10% and 20% there were determined species *Cirsium arvense* (thistle), *Fragaria vesca* (wild strawberry), *Euphorbia cyparissias* (cypress spurge), *Viola odorata* (violets), and *Taraxacum officinale* (dandelion).

On the plateau region but also on the slopes of the former bauxite quarry at Zece Hotare spontaneous woody vegetation is present: *Salix alba* (white willow), *Betula pendula* (birch).

Influence of the slope and mattress works on the erosion on slopes at the former bauxite quarry

Measurements made on the slopes with a slope of 20%, 31% and 44% improved with mattress works and spruce plantations shows that in spring 2013 vegetation covered 89% of the slope with a slope of 20%, 7.6% of the slope with slope of 31% and 64% of the slope with a slope of 44%.

Under these conditions, the ground losses recorded after the consolidation works was of 7.5 t/ha on the slopes with a slope of 20%, with 59% more on the side slope of 31% and with 191% more on the slope of 44% (Table 4).

Table 4

Influence of slope on soil loss on the slopes with mattress works and spruce plantations in the former bauxite quarry from Zece Hotare, Bihor 2013

Versant slope	The degree of cover with vegetation - %	Loss of soil		Difference	
		t/ha	%	t/ha	%
20%	89	7.5	100	-	-
31%	76	11.9	159	4.4	59
44%	64	21.8	291	14.3	191

The importance of executing mattress works on eroded slopes at the former bauxite quarry is reflected by the determinations made on a side slope of 10%. With mattress works executed and with planting of spruce trees, the loss of soil is only 6.6 t/ha, also the improvement work permitted the installation of spontaneous vegetation, therefore the degree of vegetation coverage rose to 96.6%. The absence of the mattresses determined a cumulated soil losses of 127.8 t/ha, with 1836% more than the soil losses from the hillside without mattresses (table 5).

Table 5

The mattress works influence on the loss of soil on the slopes from the former bauxite quarry Zece Hotare, Bihor 2013

Variant	The degree of cover with vegetation		Loss of soil		Difference	
	%	%	t/ha	%	t/ha	%
Versant with a 10% slope, with consolidation works and planted with spruce	96.6	100	6.6	100	-	-
Versant with a 10% slope, planted with spruce, without mattresses	21.2	22.0	127.8	1936	121.2	1836

CONCLUSIONS

The researches carried out during 2005-2013 in the research field placed in a former bauxite quarry from Zece Hotare, Padurea Craiului Mountain determined the following conclusions:

- physical parameters (bulk density, total porosity, penetration resistance, hydraulic conductivity), chemical properties (pH, humus, mobile phosphorus and potassium) and enzymatic activity, (actual and potential dehydrogenase activity, acid and potential phosphatase activity, catalase activity, non-enzymatic catalase activity, urease activity) of the terrain from there location – high levelled area, low levelled, hillside- are less favorable than the soil parameters from beech tree forest situated in adjacent area both in 2005 and in 2013.

- the vegetation installing in the former bauxite quarry and in the experiment placed in the leveled area emphasized the positive influence on the growth rhythm of the acacia area tree (*Robinia pseudocacia*) of the manure, chemical fertilizer and especially of the organic + chemical fertilization. The mattresses on the hillside determined a better growth rhythm in comparison with, the growth rhythm of the spruce-tree (*Pinus silvestris*) from the hillside without mattresses. The installing of the herb natural vegetation was influenced by the place of determination (high leveled plateau, low levelled plateau and hillside).

- the covering degree with herb natural vegetation is influenced by the hillside slope; in 2013 the covering degree was of 89% at 20% slope, 73% at 76% slope and 64% at 44% slope; as consequence the smallest cumulated soil losses were determined at 20% slope, 7.5 t/ha and the biggest cumulated soil losses were determined at 44% slope. The placement of the mattresses on the hillside with 10% determined a bigger covering degree and a smaller cumulated soil losses in comparison with the hillside without mattresses: 96.6% vs 21.2% and 6.6 t/ha vs 127.8 t/ha.

The results research emphasize the need of the melioration works (planting, fertilizers, mattresses, etc.) in the landscape reconstruction process.

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