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LIVING LAB – A SYSTEMIC INNOVATION APPROACH TO RESTORING SOIL HEALTH ON UNPRODUCTIVE LAND IN THE JIU VALLEY

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Abstract: *The Living Lab is an innovative and effective approach to restoring soil health on unproductive land. Through collaboration between different researchers and the use of adaptable and sustainable solutions, this method can transform degraded land into valuable resources, contributing to agricultural sustainability and the development of local communities. The establishment of a Living Lab on the non-productive lands of Jiu Valley as a systemic approach to innovation in which all interested parties are involved in the research and application of solutions to restore soil health is a challenge. The paper presents the methods used, the working hypotheses, the data analysis and the interpretation of the results obtained in the living lab created to study the cultivation of biomass, its energy utilization and the obtaining of biofertilizers. Multiple approaches regarding the obtained biofertilizers and their application to restore soil health are presented. The limits and conclusions of the innovative research carried out so far in the Living Lab are presented.*

Keywords: *Living Labs, unproductive land, biomass, innovative research, soil health*

1. Introduction

The development of human society has been realized over time with serious consequences on the environment and indirectly on the quality of life. The burning of fossil fuels, the practice of intensive agriculture, the unsustainable exploitation of natural resources, the development of infrastructure have led to air and water pollution, the destruction of the ozone layer, the loss of biodiversity, soil degradation. The long-term effects have resulted in the intensification and increase in scale of extreme weather events, heavy rainfall storms, floods and landslides, heat waves, fires and droughts resulting in loss of life and property. Climate change and environmental degradation threat en future generations, that's why the European Union adopted the European Green Pact to transform Europe into a climate-neutral and efficient economy from the point of view of resource use. One of the EU initiatives that is put into practice until 2050 is the EU Soil Strategy [1] which underlines the importance of soil for life considering the fact that It is estimated that approximately 60 to 70% of the Union's soils are not healthy [1]. It underlines the fact that the soil hosts more than 25% of the entire biodiversity on the planet and is at the base of the food chains that feed humanity and, on top of that, biodiversity [1] and aims that, by 2050, all soil ecosystems in the EU they will be healthy and therefore more resilient, but for this, very firm changes are needed during this decade [1]. The ambitious objective requires collaboration between different researchers and the use of adaptable and sustainable solutions and an integrated, innovative and effective approach to restore soil health on unproductive lands [2].

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The reduction of pollution to zero, the sustainable use of chemical substances, the transition to a green and circular bioeconomy, the mitigation and adaptation of climate change are EU initiatives in synergy with the EU Soil Strategy. The strategy provides for the creation of a „network of excellence of practitioners" and a network favorable to the inclusion of ambassadors of sustainable management of the academic soil and agricultural actors. For this purpose, the respective networks will be based on the activity of living laboratories [1]. These living labs (Living Labs) are constituted as a systemic approach to innovation in which all interested parties are involved in the research and application of solutions to restore soil health [3-7]. Such a living laboratory was created in the Jiu Valley with the aim of contributing to the restoration of the health of unproductive lands affected by mining activity and the transformation of these dumps into valuable resources that contribute to the development of local communities. Non-productive lands „comprise degraded lands with excessive degradation processes, which are practically devoid of vegetation. I belong to this category [8, 9]. Dumps belong to this category - land on which sterile material resulting from industrial activities and mining operations has been stored [10, 5].

2. Presentation of the working hypotheses - the choice of the experimental batches of the Living Lab

In order to choose the non-productive lands on which living labs was established, the tailings dumps in Jiu Valley were inventoried. These waste dumps do not fall into the category of dumps with problems from the point of view of stability [11] but the lands are unproductive, on them there are waste deposits resulting from mining activities, from the exploitation of coal. They represent 38% of all the degraded land in the Jiu Valley, i.e. approximately 299 ha [12].

The non-productive lands chosen for Living Labs were selected taking into account several criteria such as: the fact that no more excavation works have been carried out on them since 2015; some gradual subsidence of the base land is visible on the surfaces between the piling branches, as a result of the underground exploitation; they are not located in areas with many springs and water stagnations in the form of puddles and lakes between the dump branches; the surface is covered with grass, shrubs and small trees, without being affected by instability phenomena; the angles of the slopes vary between 14o and 35o; waste from Petrila Preparation was stored on these lands, which could lead to the presence of heavy metals and other specific pollutants; the administrator of the dump which is the Petrila City Hall, a local public administration interested in identifying solutions to restore the health of the soils within its radius. Petrila City Hall made the non-productive land selected for Living Labs available to the University of Petrosani, through a Lease Agreement (Figure 1).

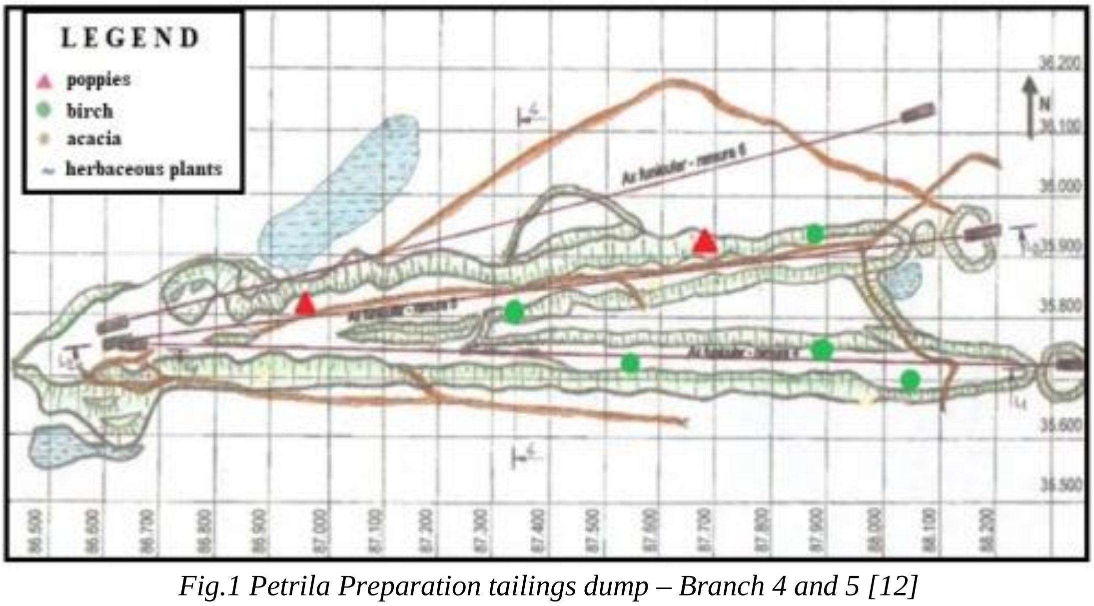

Fig.1 Petrila Preparation tailings dump – Branch 4 and 5 [12]

2.1. Layout of experimental plots for Living Labs

The plots for Living labs were made on the non-productive lands of the waste dump of the Petrila Preparation, where the experimental lots were set up for the cultivation of biomass. Vegetation has already been installed on the identified landfill area; the first necessary works are the removal of the already installed vegetation and the realization of land development works and the identification of the suitable area for planning the experimental plot and determining its size (Figure 2).

Fig.2 Arrangement of the experimental plots with the 3 types of crops on the Petrila tailings dump [4]

The plots were established at the size of 500 m2, arranged in 3 experimental lots for the three types of biomass. In each batch, 3 experimental plots were established, so in total 9 such plots, necessary for carrying out the research. Soil monitoring devices as well as other tools needed to collect crop performance data were also placed on the plots.

2.2. Layout of experimental plots for Living Labs

Physico-mechanical analyzes were performed on the soil samples from the unproductive lands, the soil samples from the 9 experimental plots were collected, after which they were prepared in the laboratory. The collection of soil samples was carried out from representative areas on non-productive lands. The 18 sampling points were chosen to obtain a more complete picture of the soil characteristics of the experimental area. Appropriate equipment, such as a corer or sampling tube, was used to obtain representative soil samples from various depths.

After collection, the preparation of the soil samples followed, by removing impurities and fragments of plants or stones from the soil samples. Samples were homogenized by mixing and drying in a controlled environment to remove excess moisture and prepare them for analysis. Analyzes were performed to determine the natural humidity and the apparent density. The natural humidity is influenced by the genesis, the lithological nature, the shape and size of the component particles and the porosity. Natural humidity varies within very wide limits, being influenced by the climate regime. Figure 1 shows the soil samples for determining natural humidity (Figure 3).

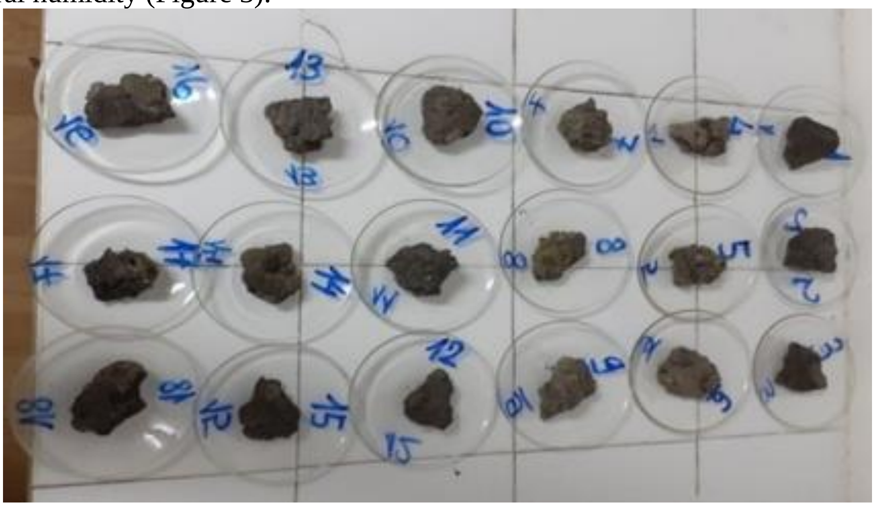

Fig.3 Soil samples for determining natural moisture

Knowing the natural humidity and the saturation humidity is of particular importance for the quantitative and qualitative description of soils; an increase in humidity leads to a decrease in the mechanical characteristics of the earth. Soil moisture is a crucial factor in the establishment and management of agricultural crops, including biomass crops. Understanding the relationship between natural soil moisture and saturation moisture is critical to optimizing production and improving soil health. Biomass crops, in addition to the production of renewable energy, have multiple benefits on soil quality and the environment.

Natural moisture and saturation moisture are interconnected through the physical properties of the soil. Fine-textured soils, such as clays, have a higher water-holding capacity and therefore have higher saturation moisture compared to sandy soils.

Table 1 shows the experimentally determined values - June 2023.

Table 1. Experimentally determined values - June 2023

Rock type: Dump material						
No. sample	**No. watchglass (container)**	**m_u [g]**	**m_d [g]**	**m_c [g]**	**Natural humidity w_n[%]**	
					Sample	**Average**
Sample 1	1	59.7701	55.1562	25.0993	15.3506	
Lot 1 Plot 1	2	72.1657	66.7781	33.5198	16.1993	**15.5123**
Maize	3	62.3999	58.1149	29.5236	14.9871	
Sample 1	4	64.7271	60.4898	34.6950	16.4270	
Lot 1 Plot 2	5	71.5865	66.4441	39.2191	18.8885	**19.6326**
Maize	6	78.8464	72.1175	43.5838	23.5823	
Sample 2	7	72.9764	67.7394	41.8349	20.2166	
Lot 2 Plot 3	8	55.3881	50.9443	32.4098	23.9758	**20.2062**
Soya	9	75.6176	70.3013	37.9365	16.4262	
Sample 3	10	86.2772	78.2285	42.5575	22.5637	
Lot 2 - Parcel 2	11	87.4001	79.6679	46.1371	23.0600	**23.0564**
Soya	12	71.0057	65.4405	41.8047	23.5456	
Sample 4	13	82.0977	75.8558	47.4321	21.9602	
Lot 3-Plot 1	14	61.1316	55.2751	31.9738	25.1338	**23.7779**
Sorghum	15	57.7677	53.0467	33.5704	24.2397	
Sample 5	16	61.3425	55.0778	30.1861	25.1678	
Lot 3-Plot 3	17	74.2008	68.0138	42.7326	24.4727	**24.9379**
Sorghum	18	87.2752	78.6247	44.2608	25.1732	

The specific density is determined in the laboratory by the pycnometer method. The method consists in determining the mass of the solid particles of the earth by weighing, determining their volume using the pycnometer and calculating the density. Figure 4 shows the soil samples for determining the apparent density by the hydrostatic weighing method - June 2023. Determination of soil bulk density is a crucial aspect in agronomy and ecology, having direct implications on the productivity of agricultural crops, including biomass crops. Bulk density provides essential information about soil structure, water holding capacity, aeration and nutrient availability. This information is fundamental to the establishment and effective management of biomass crops. The root systems of biomass plants can be sensitive to soil compaction. A high bulk density can restrict root growth, reducing the plant's ability to access water and nutrients.

Fig.4 Soil samples for determining the apparent density by the hydrostatic weighing method - June 2023

Bulk density affects soil porosity and, implicitly, its ability to retain water. Soils with high bulk density have small pores and low water infiltration and storage capacity, which can lead to water stress for biomass crops, especially during periods of drought. Soils with high bulk density have poor aeration, which affects root respiration and the activity of soil microorganisms. This can negatively influence the growth and development of biomass plants. Bulk density influences the mobility and availability of nutrients in the soil. Compacted soils can limit the diffusion of essential nutrients to plant roots, thus affecting the productivity of biomass crops. Figure 4. Soil samples for determining the apparent density by the hydrostatic weighing method - June 2023.

In table 2, experimentally determined values are centralized - apparent density. Determination of soil bulk density is essential for the establishment and effective management of biomass crops. This directly influences the soil's ability to retain water, aeration, nutrient availability and root system growth. By properly assessing and managing bulk density, farmers can optimize growing conditions for biomass crops, thereby ensuring maximum productivity and contributing to improved long-term soil health.

Table 2. Experimentally determined values - apparent density

Rock type: Dump material						
No. sample	**No. watchglass (container)**	**m_0 [g]**	**m_1 [g]**	**m_2 [g]**	**Apparent Density ρ_ax 10^3[kg/m^3]**	
					Pe probă	Media
Sample 1	1	28.3054	32.2779	10.6789	1.6379	1.6160
Lot 1 Plot 1	2	30.7418	35.1373	11.2549	1.6091	
Maize	3	31.1568	35.3772	11.3297	1.6011	
Sample 1	4	25.9732	28.4858	10.8437	1.7419	1.8176
Lot 1 Plot 2	5	18.5471	20.7587	8.2441	1.8344	
Maize	6	34.0947	37.3627	15.6417	1.8765	
Sample 2	7	24.0079	27.3302	7.743	1.5027	1.5091
Lot 2 Plot 3	8	17.3212	19.5201	4.9789	1.4255	
Soya	9	26.8156	30.0649	9.7644	1.5992	
Sample 3	10	30.6998	33.4367	11.3178	1.6036	1.5991
Lot 2 - Parcel 2	11	24.2688	26.3441	8.6076	1.5677	
Soya	12	34.4298	37.5616	12.9824	1.6260	
Sample 4	13	22.8019	24.6987	8.2576	1.5857	1.5521
Lot 3-Plot 1	14	18.9289	20.6014	6.5571	1.5482	
Sorghum	15	14.1612	15.8292	4.714	1.5224	
Sample 5	16	24.5198	26.8385	9.4726	1.6517	1.6090
Lot 3-Plot 3	17	33.1961	36.6264	12.7043	1.6439	
Sorghum	18	21.8268	23.9948	7.3868	1.5315	

The conclusion of the interpretation of the results of the performed analyzes led to the conclusion that on the experimental lots on the productive lands, soil mobilization works can be carried out for the establishment of biomass crops. These works were carried out in compliance with good agricultural practices to ensure maximum biomass production and protect the environment. The choice of biomass species for the establishment of crops was made according to their ecological characteristics and their potential to be transformed through anaerobic digestion and pyrolysis into biofuels and organic fertilizers (digestate and biochar). Research has highlighted the fact that corn, soybeans and sorghum are used in biomass crops, being drought-resistant species, due to their ability to produce large amounts of biomass per surface unit and due to its benefits for the soil and the environment. They are species that have the ability to fix nitrogen and help improve soil fertility. They use water efficiently, which makes them suitable for these unproductive lands with limited water availability. Corn, soybeans, and sorghum can be grown successfully on soils with a low pH and can even help reduce soil acidity by releasing basic compounds during its growth. Crops of corn, soybeans and sorghum for obtaining biomass can be affected by several limiting factors, among which are plant densities, water availability, deficiency of nutrients such as nitrogen, these can reduce biomass production. These plant species can be affected by a number of limiting factors that can influence yield and production quality. Soils that are too poor in nutrients or soils with inadequate pH can affect the yield and quality of production. Soils that are too clayey or too sandy can affect drainage and lead to moisture

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problems. Considering these aspects, corn, soybean and sorghum cultures were established on the experimental plots. Figure 3 shows a corn plot from experimental lot 1, June 2023. It can be seen that the water deficit and low soil fertility have affected the growth and development of corn, soybean and sorghum crops.

3. Results

Field evaluations concluded that maize crop development is uneven, with maize being less developed in areas where there is soil mixed with stones and in areas where moisture is in excess. Figure 5 shows the comparison of biomass crops in July 2023, two weeks after sowing.

Fig.5 Plot 1 with corn from experimental lot 1 - June 2023 [4]

Fig.6 Biomass crops – June 2023

Figure 6 shows the development of corn and soybean crops in experimental plots - June. On the experimental lots, the soil is not very fertile, no nutrients were applied, and therefore biomass production is reduced. Also, too high temperatures led to reduced soybean production.

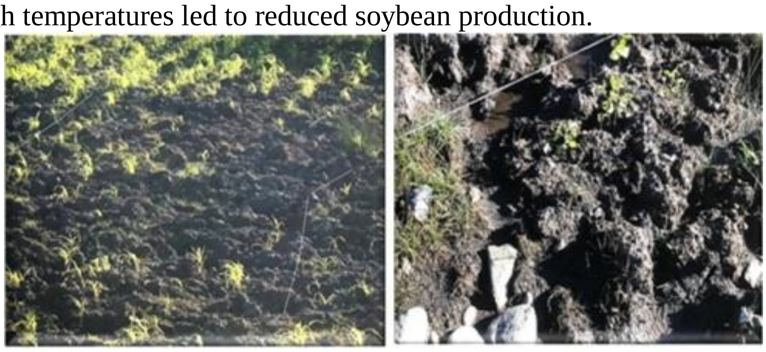

Fig.7 Development of corn and soybean crops in experimental plots - June

Figure 8 shows the development of sorghum culture in experimental plots, June and the sorghum culture diminished by extreme soil conditions - June.

Fig.8 Development of sorghum culture in experimental plots, June and sorghum culture diminished by extreme soil conditions - June

Sorghum culture needs a sufficient amount of water to produce a large amount of biomass. Lack of water led to poor plant growth and low sorghum production in the experimental plots. As can be seen, the soils in the experimental plots have physical-mechanical characteristics that lead us to the conclusion of the need for work to improve these characteristics.

The lack of soil fertilization makes it possible to obtain reduced amounts of corn, soybeans and sorghum on the experimental plots. The application of biofertilizers will lead to the improvement of the quality of the soils on the experimental plots.

For the production of biofertilizers, research will be carried out in the living lab with a view to the anaerobic digestion and pyrolysis of the biomass grown on the experimental plots and obtaining digestate and biochar as biofertilizers.

4. Conclusions

Living Lab is an innovative approach that makes a significant contribution to restoring soil health on unproductive land. This methodology involves collaboration between various stakeholders, including researchers, farmers, authorities and local communities, to develop sustainable and effective solutions for restoring soil health and sustainable development of non-productive mining areas.

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