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EVALUATION OF THE SUITABILITY OF NON-PRODUCTIVE LAND FOR BIOMASS CULTIVATION AND ITS ENERGY RECOVERY

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Abstract:*The work is part of the efforts to restore unproductive land in a green and circular economy. The results of the research carried out on non-productive land in the Jiu Valley are presented regarding the suitability of the soil and the cultivated biomass for its energy utilization and obtaining the digestate as fertilizer. The traceability of heavy metals from soil to biomass and the suitability of using biomass for its energy recovery are evaluated.*
Keywords: *biomass, biogas, unproductive land, inorganic pollution*

1. Introduction

The Circular Economy Package adopted by the European Commission in 2015, which will contribute to the EU's efforts to develop a „sustainable, low-carbon, resource-efficient and competitive economy” [1]. Moving from the model of a linear economy to a circular economy „means that materials are recovered from products at the end of the product's life cycle by connecting waste with resources” [2]. In this context, organic waste recycling technologies were put into practice through their anaerobic digestion or their co-digestion with biomass in biogas installations [3]. The biogas obtained through this technology is used for energy and the resulting digestate can be used as biofertilizer, it has a rich content of nitrogen, phosphorus, potassium and micronutrients, and is successfully used in the fertilization process, including degraded lands and unproductive lands. Therefore, through the anaerobic decomposition of the biomass grown on the non-productive lands in Jiu Valley or its mixture with organic waste, the digestate can be obtained as a biofertilizer, which, under certain conditions, can be applied as a fertilizer on these lands to restore the non-productive lands.

2. The limits of innovative research regarding the possibility of energy utilization of biomass and obtaining biofertilizers

The lands on which the experimental plots were established were affected by the activity of coal extraction and processing through pollution with chemical substances, especially with heavy metals. In order to identify the presence of heavy metals in the corn, sorghum and soybeans grown on the experimental lots, it was necessary to carry out chemical analyzes to evaluate the concentration of heavy metals in the soil on which the corn, sorghum and soybeans grown on the experimental lots were grown [4-6]. Thus, the soil content of copper, lead, chromium, cobalt, nickel, zinc, cadmium, manganese, iron and barium was determined. The results obtained were compared with the provisions of Order 756/1997 for normal soils, the conclusions are the following:

The research carried out until now has led to the conclusion that trace elements, such as iron, nickel, cobalt, selenium, molybdenum and tungsten, are important for the development and survival of anaerobic bacteria in the biomass digestion process.

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However, in large quantities, heavy metals and persistent contaminants can cause problems and inhibit the biomass fermentation process. For this reason, the contaminant content of the feedstock as well as the digestate must be carefully monitored. Contaminant concentrations in digestate must not exceed legal limits. The biomass was cultivated on the experimental plots on the non-productive lands within the administrative radius of the Petrila place. These lands were affected by the coal extraction and processing activity and therefore it was necessary to carry out chemical analyzes in order to identify the presence of heavy metals in the corn, sorghum and soybeans grown on the experimental plots [7]. Biomass (corn, soy and sorghum) was chemically analyzed in order to determine the content of heavy metals: copper, lead, chromium, cobalt, nickel, zinc, cadmium, manganese, iron, barium. The obtained results were compared with the provisions of Order 756/1997 for normal soils. The analyzes were carried out within the project Restoring soil health on non-productive lands through biomass crops for sustainable energy - Soil - Biomass - Sustainability - SOBIOSUS", PNRR [7].

To determine and evaluate the degree of soil pollution with heavy metals, soil samples are taken avoiding their contamination, unrepresentative samples, unlabeled samples, etc. Reference samples were used to confirm the accuracy and precision of the analytical techniques used. These reference samples were analyzed together with samples taken from each area of the land and all samples were analyzed with the appropriate methodology, according to the standards in force [8].

The following tables show the results obtained and the normal and attention limits imposed by the legislation in force [8]: The variation of elemental copper in the three experimental batches is presented in table no. 1, the values being comparable values for the three types of biomass; It is found that the normal values allowed are exceeded, but it is lower than the alert threshold for sensitive soils (<100) [9].

Table 1. Variation of elemental copper in the three experimental batches

Date	**Sample / code**	**Drysample mass (g)**	**Final volume (ml)**	**Dilution**	**Reading ICP-OES (mg/l)**	**Final (mg/kg)**	**LQ=10 (mg/kg)**
Cu (0.5-7.5 (mg/l))							
28.06.2023	L1 P1-1	0.5119	50	1	0.6059	59.18	>20
Maize	L1 P1-2	0.5382	50	1	0.6452	59.94	>20
	L1 P1-3	0.5522	50	1	0.8262	74.81	>20
	L1 P1-4	0.4758	50	1	0.5381	56.54	>20
	L1 P1-5	0.4762	50	1	0.5854	61.47	>20
	L1 P1-6	0.4956	50	1	0.5566	56.15	>20
	L1 P1-7	0.5028	50	1	0.4898	48.71	>20
	L1 P1-8	0.5388	50	1	0.7028	65.22	>20
	L1 P1-9	0.5968	50	1	0.5243	43.93	>20
	L1 P1-10	0.5593	50	1	0.6281	56.15	>20
Soybean	L2 P1-1	0.4859	50	1	0.5005	51.51	>20
	L2 P1-2	0.4871	50	1	0.6483	66.54	>20
	L2 P1-3	0.5064	50	1	0.6327	62.47	>20
	L2 P1-4	0.4956	50	1	0.5941	59.94	>20
	L2 P1-5	0.5077	50	1	0.5927	58.37	>20
	L2 P1-6	0.5126	50	1	0.5222	50.94	>20
	L2 P1-7	0.5785	50	1	0.6975	60.28	>20
	L2 P1-8	0.5019	50	1	0.6659	66.34	>20
	L2 P1-9	0.6302	50	1	0.6001	47.61	>20
	L2 P1-10	0.5635	50	1	0.5417	48.06	>20
Sorghum	L3 P1-1	0.5410	50	1	0.6180	57.11	>20
	L3 P1-2	0.4887	50	1	0.5008	51.24	>20
	L3 P1-3	0.4962	50	1	0.5814	58.59	>20
	L3 P1-4	0.4972	50	1	0.6187	62.22	>20
	L3 P1-5	0.5721	50	1	0.6812	59.54	>20
	L3 P1-6	0.5042	50	1	0.6109	60.58	>20
	L3 P1-7	0.5404	50	1	0.7407	68.54	>20
	L3 P1-8	0.5141	50	1	0.5344	51.97	>20

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
Cu (0.5-7.5 (mg/l))							
	L3 P1-9	0.4848	50	1	0.5205	53.68	>20
	L3 P1-10	0.5112	50	1	0.4218	41.25	>20
Blank		0.5082	50	1	0.5283	51.98	>20

The results of chemical analyze regarding the variation of elemental lead in the three experimental batches is presented in table 2. Elemental lead is found below the maximum allowed value for normal soils (<20), with the exception of one sample that was determined on soybean culture, the determined value being >20 (20.48 mg/kg) [9].

Table 2. Variation of elemental lead in the three experimental groups

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
Pb (0.5-7.5 mg/l)							
28.06.2023	L1 P1-1	0.5119	50	1	0.147	14.36	<20
Maize	L1 P1-2	0.5382	50	1	0.162	15.04	<20
	L1 P1-3	0.5522	50	1	0.219	19.85	<20
	L1 P1-4	0.4758	50	1	0.139	14.64	<20
	L1 P1-5	0.4762	50	1	0.109	11.43	<20
	L1 P1-6	0.4956	50	1	0.150	15.18	<20
	L1 P1-7	0.5028	50	1	0.153	15.17	<20
	L1 P1-8	0.5388	50	1	0.209	19.38	<20
	L1 P1-9	0.5968	50	1	0.158	13.27	<20
	L1 P1-10	0.5593	50	1	0.172	15.38	<20
Soybean	L2 P1-1	0.4859	50	1	0.134	13.78	<20
	L2 P1-2	0.4871	50	1	0.138	14.22	<20
	L2 P1-3	0.5064	50	1	0.167	16.46	<20
	L2 P1-4	0.4956	50	1	0.150	15.17	<20
	L2 P1-5	0.5077	50	1	0.186	18.31	<20
	L2 P1-6	0.5126	50	1	0.168	16.41	<20
	L2 P1-7	0.5785	50	1	0.153	13.23	<20
	L2 P1-8	0.5019	50	1	0.206	20.48	>20
	L2 P1-9	0.6302	50	1	0.179	14.23	<20
	L2 P1-10	0.5635	50	1	0.182	16.13	<20
Sorghum	L3 P1-1	0.541	50	1	0.171	15.84	<20
	L3 P1-2	0.4887	50	1	0.179	18.28	<20
	L3 P1-3	0.4962	50	1	0.131	13.24	<20
	L3 P1-4	0.4972	50	1	0.158	15.88	<20
	L3 P1-5	0.5721	50	1	0.180	15.76	<20
	L3 P1-6	0.5042	50	1	0.155	15.35	<20
	L3 P1-7	0.5404	50	1	0.136	12.60	<20
	L3 P1-8	0.5141	50	1	0.138	13.43	<20
	L3 P1-9	0.4848	50	1	0.157	16.18	<20
	L3 P1-10	0.5112	50	1	0.131	12.84	<20
Blank		0.5082	50	1	0.170	16.68	<20

The variation of elemental chromium in the experimental batches is presented in table 3. It is found that elemental chromium is below the maximum value allowed for normal soils (<30) for corn and soy crops. On the other hand, for the sorghum crop, it is found that elemental chromium is found below the maximum value allowed for normal soils (<30) for 6 samples and above the maximum value allowed for normal soils (>30).

vol. 30, selected papers from the 11th edition of
UNIVERSITARIA SIMPRO / 2024, pp. 114-122

Table 3. Variation of elemental chromium in the three experimental groups

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
Cr (0.5-7.5 mg/l)							
28.06.2023	L1 P1-1	0.5119	50	1	0.238	23.27	<30
Maize	L1 P1-2	0.5382	50	1	0.282	26.18	<30
	L1 P1-3	0.5522	50	1	0.255	23.07	<30
	L1 P1-4	0.4758	50	1	0.222	23.36	<30
	L1 P1-5	0.4762	50	1	0.214	22.52	<30
	L1 P1-6	0.4956	50	1	0.206	20.75	<30
	L1 P1-7	0.5028	50	1	0.211	20.96	<30
	L1 P1-8	0.5388	50	1	0.208	19.32	<30
	L1 P1-9	0.5968	50	1	0.294	24.60	<30
	L1 P1-10	0.5593	50	1	0.237	21.21	<30
Soybean	L2 P1-1	0.4859	50	1	0.271	27.90	<30
	L2 P1-2	0.4871	50	1	0.182	18.70	<30
	L2 P1-3	0.5064	50	1	0.214	21.13	<30
	L2 P1-4	0.4956	50	1	0.260	26.19	<30
	L2 P1-5	0.5077	50	1	0.282	27.75	<30
	L2 P1-6	0.5126	50	1	0.277	27.05	<30
	L2 P1-7	0.5785	50	1	0.311	26.89	<30
	L2 P1-8	0.5019	50	1	0.255	25.36	<30
	L2 P1-9	0.6302	50	1	0.268	21.27	<30
	L2 P1-10	0.5635	50	1	0.264	23.44	<30
Sorghum	L3 P1-1	0.5410	50	1	0.256	23.62	<30
	L3 P1-2	0.4887	50	1	0.193	19.79	<30
	L3 P1-3	0.4962	50	1	0.338	34.04	>30
	L3 P1-4	0.4972	50	1	0.285	28.70	<30
	L3 P1-5	0.5721	50	1	0.328	28.65	<30
	L3 P1-6	0.5042	50	1	0.405	40.15	>30
	L3 P1-7	0.5404	50	1	0.818	75.64	>30
	L3 P1-8	0.5141	50	1	0.230	22.33	<30
	L3 P1-9	0.4848	50	1	0.400	41.30	>30
	L3 P1-10	0.5112	50	1	0.408	39.91	>30
Blank		0.5082	50	1	0.296	29.15	<30

The variation of elemental cobalt in the experimental batches can be found in table 4. It is found that elemental cobalt, for most of the analyzed samples, is below the maximum value allowed for normal soil (<15). There is a sample analyzed on the soil cultivated with corn with double values compared to the maximum allowed value (35.76 mg/kg compared to 15mg/kg). Also, there is one sample analyzed on soybeans and two samples analyzed on the soil cultivated with sorghum with slight excesses of the maximum allowed value.

Table 4. Variation of elemental cobalt in the three experimental groups

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
Co (0.5-7.5 mg/l)							
28.06.2023	L1 P1-1	0.5119	50	1	0.114	11.10	<15
Maize	L1 P1-2	0.5382	50	1	0.125	11.60	<15
	L1 P1-3	0.5522	50	1	0.395	35.76	>15
	L1 P1-4	0.4758	50	1	0.111	11.70	<15
	L1 P1-5	0.4762	50	1	0.112	11.81	<15
	L1 P1-6	0.4956	50	1	0.113	11.39	<15

	L1 P1-7	0.5028	50	1	0.125	12.45	<15
	L1 P1-8	0.5388	50	1	0.135	12.56	<15
	L1 P1-9	0.5968	50	1	0.131	10.93	<15
	L1 P1-10	0.5593	50	1	0.132	11.82	<15
Soybean	L2 P1-1	0.4859	50	1	0.126	13.00	<15
	L2 P1-2	0.4871	50	1	0.105	10.75	<15
	L2 P1-3	0.5064	50	1	0.157	15.52	>15
	L2 P1-4	0.4956	50	1	0.107	10.84	<15
	L2 P1-5	0.5077	50	1	0.142	14.01	<15
	L2 P1-6	0.5126	50	1	0.122	11.94	<15
	L2 P1-7	0.5785	50	1	0.123	10.60	<15
	L2 P1-8	0.5019	50	1	0.127	12.64	<15
	L2 P1-9	0.6302	50	1	0.172	13.64	<15
	L2 P1-10	0.5635	50	1	0.117	10.34	<15
Sorghum	L3 P1-1	0.541	50	1	0.177	16.34	>15
	L3 P1-2	0.4887	50	1	0.113	11.53	<15
	L3 P1-3	0.4962	50	1	0.127	12.81	<15
	L3 P1-4	0.4972	50	1	0.162	16.32	>15
	L3 P1-5	0.5721	50	1	0.156	13.63	<15
	L3 P1-6	0.5042	50	1	0.134	13.28	<15
	L3 P1-7	0.5404	50	1	0.102	9.45	<15
	L3 P1-8	0.5141	50	1	0.119	11.55	<15
	L3 P1-9	0.4848	50	1	0.139	14.34	<15
	L3 P1-10	0.5112	50	1	0.123	11.98	<15
Blank		0.5082	50	1	0.123	12.14	<15

The variation of elemental nickel in the three experimental groups is presented in table 5. It is found that elemental nickel is found in all samples, above the value allowed for normal soil (<20), in general below the value for the alert threshold for sensitive soil (<75). There are samples analyzed on the soil cultivated with corn (1 sample with the highest value of those analyzed of 106.78 mg/kg) and sorghum in particular (4 samples), where the value for the alert threshold for sensitive soil (<75) is exceeded.

Table 5. Variation of elemental nickel in the three experimental batches

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
Ni (0.5-7.5 mg/l)							
28.06.2023	L1 P1-1	0.5119	50	1	0.573	56.00	>20
Maize	L1 P1-2	0.5382	50	1	0.684	63.52	>20
	L1 P1-3	0.5522	50	1	1.179	106.78	>20
	L1 P1-4	0.4758	50	1	0.601	63.13	>20
	L1 P1-5	0.4762	50	1	0.508	53.36	>20
	L1 P1-6	0.4956	50	1	0.541	54.54	>20
	L1 P1-7	0.5028	50	1	0.578	57.44	>20
	L1 P1-8	0.5388	50	1	0.685	63.60	>20
	L1 P1-9	0.5968	50	1	0.639	53.57	>20
	L1 P1-10	0.5593	50	1	0.619	55.32	>20
Soybean	L2 P1-1	0.4859	50	1	0.704	72.41	>20
	L2 P1-2	0.4871	50	1	0.607	62.29	>20
	L2 P1-3	0.5064	50	1	0.748	73.82	>20
	L2 P1-4	0.4956	50	1	0.561	56.58	>20
	L2 P1-5	0.5077	50	1	0.751	73.97	>20
	L2 P1-6	0.5126	50	1	0.591	57.66	>20
	L2 P1-7	0.5785	50	1	0.590	50.99	>20

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
	L2 P1-8	0.5019	50	1	0.752	74.94	>20
	L2 P1-9	0.6302	50	1	0.784	62.19	>20
	L2 P1-10	0.5635	50	1	0.601	53.29	>20
Sorghum	L3 P1-1	0.541	50	1	0.747	69.04	>20
	L3 P1-2	0.4887	50	1	0.553	56.58	>20
	L3 P1-3	0.4962	50	1	0.749	75.47	>20
	L3 P1-4	0.4972	50	1	0.800	80.45	>20
	L3 P1-5	0.5721	50	1	0.764	66.81	>20
	L3 P1-6	0.5042	50	1	0.676	67.05	>20
	L3 P1-7	0.5404	50	1	1.014	93.85	>20
	L3 P1-8	0.5141	50	1	0.621	60.40	>20
	L3 P1-9	0.4848	50	1	0.727	75.00	>20
	L3 P1-10	0.5112	50	1	0.658	64.31	>20
Blank		0.5082	50	1	0.627	61.67	>20

The variation of elemental zinc in the experimental batches is presented in table 6. The elemental zinc is below the maximum value allowed for normal soil (<100) for the soil samples analyzed with soybeans. For the soil cultivated with corn, there are two samples with a value above the maximum value allowed for normal soil (>100). For sorghum, there are 5 samples with a value above the maximum value allowed for normal soil (>100).

Table 6. Variation of elemental zinc in the three experimental groups

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
Zn (0.5-7.5 mg/l)							
27.06.2023	L1 P1-1	0.5119	50	1	0.905	88.36	<100
Maize	L1 P1-2	0.5382	50	1	0.909	84.46	<100
	L1 P1-3	0.5522	50	1	0.884	80.07	<100
	L1 P1-4	0.4758	50	1	0.938	98.61	<100
	L1 P1-5	0.4762	50	1	0.915	96.06	<100
	L1 P1-6	0.4956	50	1	1.006	101.49	>100
	L1 P1-7	0.5028	50	1	0.788	78.33	<100
	L1 P1-8	0.5388	50	1	1.139	105.71	>100
	L1 P1-9	0.5968	50	1	0.929	77.80	<100
	L1 P1-10	0.5593	50	1	0.780	69.75	<100
Soybean	L2 P1-1	0.4859	50	1	0.840	86.47	<100
	L2 P1-2	0.4871	50	1	0.793	81.45	<100
	L2 P1-3	0.5064	50	1	0.680	67.14	<100
	L2 P1-4	0.4956	50	1	0.860	86.72	<100
	L2 P1-5	0.5077	50	1	0.986	97.06	<100
	L2 P1-6	0.5126	50	1	0.906	88.38	<100
	L2 P1-7	0.5785	50	1	0.932	80.56	<100
	L2 P1-8	0.5019	50	1	1.002	99.79	<100
	L2 P1-9	0.6302	50	1	0.847	67.21	<100
	L2 P1-10	0.5635	50	1	0.800	70.96	<100
Sorghum	L3 P1-1	0.541	50	1	1.204	111.28	>100
	L3 P1-2	0.4887	50	1	0.616	63.06	<100
	L3 P1-3	0.4962	50	1	0.770	77.56	<100
	L3 P1-4	0.4972	50	1	1.014	102.02	>100
	L3 P1-5	0.5721	50	1	1.241	108.48	>100
	L3 P1-6	0.5042	50	1	1.176	116.60	>100

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
	L3 P1-7	0.5404	50	1	0.532	49.18	<100
	L3 P1-8	0.5141	50	1	2.171	211.10	>100
	L3 P1-9	0.4848	50	1	0.760	78.43	<100
	L3 P1-10	0.5112	50	1	0.546	53.42	<100
Blank		0.5082	50	1	0.835	82.16	<100

The variation of elemental cadmium in the three experimental batches is presented in table 7. Elemental cadmium is found below the maximum value allowed for normal soil (<1) for the soil cultivated with soybeans, for the soil cultivated with corn a value above the maximum value allowed for normal soil, 2 values above the maximum value allowed for normal soil for soil cultivated with sorghum.

Table 7. Variation of elemental cadmium in the three experimental batches

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
Cd (0.5-7.5 mg/l)							
28.06.2023	L1 P1-1	0.5119	50	1	-0.004	-0.38	<1
Maize	L1 P1-2	0.5382	50	1	-0.007	-0.68	<1
	L1 P1-3	0.5522	50	1	-0.012	-1.13	<1
	L1 P1-4	0.4758	50	1	-0.008	-0.87	<1
	L1 P1-5	0.4762	50	1	-0.010	-1.01	>1
	L1 P1-6	0.4956	50	1	-0.008	-0.80	<1
	L1 P1-7	0.5028	50	1	-0.008	-0.81	<1
	L1 P1-8	0.5388	50	1	-0.008	-0.70	<1
	L1 P1-9	0.5968	50	1	-0.008	-0.64	<1
	L1 P1-10	0.5593	50	1	-0.008	-0.73	<1
Soybean	L2 P1-1	0.4859	50	1	-0.010	-0.99	<1
	L2 P1-2	0.4871	50	1	-0.009	-0.97	<1
	L2 P1-3	0.5064	50	1	-0.006	-0.63	<1
	L2 P1-4	0.4956	50	1	-0.009	-0.90	<1
	L2 P1-5	0.5077	50	1	-0.010	-0.95	<1
	L2 P1-6	0.5126	50	1	-0.009	-0.92	<1
	L2 P1-7	0.5785	50	1	-0.009	-0.74	<1
	L2 P1-8	0.5019	50	1	-0.009	-0.89	<1
	L2 P1-9	0.6302	50	1	-0.010	-0.81	<1
	L2 P1-10	0.5635	50	1	-0.009	-0.83	<1
Sorghum	L3 P1-1	0.5410	50	1	-0.008	-0.72	<1
	L3 P1-2	0.4887	50	1	-0.011	-1.12	>1
	L3 P1-3	0.4962	50	1	-0.012	-1.26	>1
	L3 P1-4	0.4972	50	1	-0.008	-0.84	<1
	L3 P1-5	0.5721	50	1	-0.010	-0.86	<1
	L3 P1-6	0.5042	50	1	-0.010	-0.94	<1
	L3 P1-7	0.5404	50	1	-0.010	-0.97	<1
	L3 P1-8	0.5141	50	1	-0.009	-0.92	<1
	L3 P1-9	0.4848	50	1	-0.007	-0.76	<1
	L3 P1-10	0.5112	50	1	-0.009	-0.85	<1
Blank		0.5082	50	1	-0.010	-1.01	>1

The variation of elemental manganese in the three experimental batches is presented in table 8. Elemental manganese is below the maximum limit allowed for normal soil (<900). There is a sample analyzed on the soil cultivated with sorghum in which the maximum limit allowed for normal soil for elemental manganese is exceeded (the recorded value is 1202.1 mg/kg).

Table 8. Variation of elemental manganese in the three experimental groups

Date	Sample / code	Drysample mass (g)	Final volume (ml)	Dilution	Reading ICP-OES (mg/l)	Final (mg/kg)	LQ=10 (mg/kg)
			Mn (5-100 mg/l)				
28.06.2023	L1 P1-1	0.5119	50	1	2.558	249.9	<900
Maize	L1 P1-2	0.5382	50	1	3.683	342.1	<900
	L1 P1-3	0.5522	50	1	5.174	468.4	<900
	L1 P1-4	0.4758	50	1	2.515	264.3	<900
	L1 P1-5	0.4762	50	1	1.982	208.2	<900
	L1 P1-6	0.4956	50	1	3.056	308.3	<900
	L1 P1-7	0.5028	50	1	3.316	329.7	<900
	L1 P1-8	0.5388	50	1	2.812	260.9	<900
	L1 P1-9	0.5968	50	1	4.471	374.6	<900
	L1 P1-10	0.5593	50	1	3.211	287.1	<900
Soybean	L2 P1-1	0.4859	50	1	3.096	318.5	<900
	L2 P1-2	0.4871	50	1	2.977	305.6	<900
	L2 P1-3	0.5064	50	1	4.890	482.8	<900
	L2 P1-4	0.4956	50	1	1.690	170.5	<900
	L2 P1-5	0.5077	50	1	3.714	365.7	<900
	L2 P1-6	0.5126	50	1	3.509	342.3	<900
	L2 P1-7	0.5785	50	1	3.923	339.0	<900
	L2 P1-8	0.5019	50	1	3.681	366.8	<900
	L2 P1-9	0.6302	50	1	4.099	325.2	<900
	L2 P1-10	0.5635	50	1	4.465	396.2	<900
Sorghum	L3 P1-1	0.541	50	1	4.064	375.6	<900
	L3 P1-2	0.4887	50	1	2.160	221.0	<900
	L3 P1-3	0.4962	50	1	3.118	314.2	<900
	L3 P1-4	0.4972	50	1	2.849	286.5	<900
	L3 P1-5	0.5721	50	1	3.978	347.7	<900
	L3 P1-6	0.5042	50	1	5.541	549.5	<900
	L3 P1-7	0.5404	50	1	12.993	1202.1	>900
	L3 P1-8	0.5141	50	1	2.982	290.0	<900
	L3 P1-9	0.4848	50	1	3.716	383.2	<900
	L3 P1-10	0.5112	50	1	4.234	414.1	<900
Blank		0.5082	50	1	4.500	442.8	<900

Heavy metals present in landfill soils can have significant effects on plant growth. These metals, such as cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu) and mercury (Hg), interfere with various physiological and biochemical processes of plants, leading to reduced growth and development. These heavy metals can inhibit the absorption and translocation of essential nutrients. For example, cadmium can block the absorption of calcium and magnesium, thus affecting the processes of growth and photosynthesis.

3. Conclusions

The research carried out regarding the assessment of the suitability of non-productive land for the cultivation of biomass and its energy utilization led to the following conclusions:

• The chemical analyzes carried out on the soil cultivated with corn, soybeans and sorghum harvested on the experimental plots from the unproductive lands consisted in determining the content of heavy metals: copper, lead, chromium, cobalt, nickel, zinc, cadmium, manganese, iron, barium.

The obtained results were compared with the provisions of Order 756/1997 for normal soils.

• The soil samples on which the biomass was grown contain trace elements important for the development and survival of anaerobic bacteria such as iron, nickel, cobalt, molybdenum. These are generally within the maximum admissible limits provided by Order 756/1997.

• However, it was found that, in the case of some samples, the maximum value allowed according to Order 756/1997 for some heavy metals is exceeded, which cause problems such as inhibition of the fermentation could process of the biomass grown on these soils.

• Considering that the cultivation of biomass was carried out on soils affected by coal mining activity and processing activity, it is necessary to carry out the research in two stages:

- the first stage includes research on the anaerobic digestion of corn, soybeans and sorghum each separately and their co-digestion with the aim of monitoring the influence of heavy metals and the possibility of their annihilation during the biomass fermentation process.

This stage will also include monitoring the traceability of heavy metals from biomass to digestate.

- the second stage of the research is the analysis of the possibility of co-digestion of the biomass grown on the experimental plots with the organic waste resulting from the processing of organic raspberries.

This stage will be carried out after obtaining and validating the results obtained in the first stage.

• Digestion and co-digestion of biomass requires monitoring the traceability of heavy metals throughout the process in order to evaluate the transfer of heavy metals from the fermented biomass to the obtained digestate.

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