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THE EVOLUTION OF SOIL AGROCHEMICAL PROPERTIES, UNDER THE INFLUENCE OF MINERAL FERTILISATION AND WATER EROSION, ON A NATURAL GRASSLAND LOCATED AT THE PREAJBA EXPERIMENTAL CENTRE IN THE GORJ COUNTY

Mihaela BĂLAN[1], Oana Alina NIȚU[2], Cristian POPESCU[1]

[1]University of Craiova, Faculty of Agronomy, 19 Libertatii Street, Craiova, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: oanaalinanitu1111@gmail.com

Abstract

The research was carried out at the Experimental Centre for Grassland Culture, located in Preajba in the Gorj County, on a Stagnic Luvisol on a relief with a 10-12% slope, on parent material represented by fluvial terrace deposits, where the depth of groundwater is 5-10 m with a natural vegetation represented by grassland with acidophilus species which is characterised by a profile of type Aț, Ao, El(w), ElBt, Bt1(w), Bt2(w). These consisted in setting up an experiment on natural grassland with 3 versions and 3 repetitions, following the method of isolated blocks, in order to highlight the evolution of soil agrochemical properties under the influence of erosion and mineral fertilisation. Research has shown that mineral fertilisation had beneficial effects both on yields and indirect effects on soil protection against loss of humus and fertilising elements. Thus, the evolution of the agrochemical properties of the soil in the experimental versions is influenced by the amount and intensity of rainfall, the mass of eroded soil, the degree of vegetation cover and the doses of fertilisers applied.

Key words: *water erosion, natural grassland, slope, Stagnic Luvisol, chemical indicators, mineral fertilization.*

INTRODUCTION

Soil is recognised as an essential and limited resource, the main means of production in agriculture, the inexhaustible storehouse of food resources for mankind (Răuţă et al., 1992). Soil is one of the most important natural resources for the survival and well-being of mankind, being a fragile resource that can easily undergo degradation processes so that mankind must take into account the promotion of optimal land use, maintenance and improvement of soil productivity and conservation of soil resources (Bălan, 2020). The impact of agricultural technologies on the soil has become a current and urgent problem, because through the agricultural work carried out under conventional technologies, various changes take place, which lead to the appearance of negative phenomena such as increased erosion or reduced humus content etc. (Muşat et al., 2021; 2023). The increase in the world's population, resulting in the intensive development of agriculture, requires the rational use of soil, improved cultivation technologies to avoid the degradation of agricultural land. Lately, agriculture is facing a large number of challenges imposed by population growth, climate change, geostrategic changes, economic gaps, but also by the obligation to minimize as much as possible the negative effects on the environment (Mărin et al., 2023).

Of the processes affecting soil quality, erosion is of greatest interest, both in terms of the damage it causes, and the areas affected. Erosion affects soil fertility because erosion removes the fertile layers in the upper horizons, which contain a large amount of organic matter and nutrients. Runoff caused by erosion reduces crop yields, affects the soil water regime and is also an important means of transporting chemical pollutants into the river system (Ailincăi et al., 2008).

In the Gorj County, erosion is the most widespread form of soil degradation and affects an area of 139,027.95 ha which represents about 57.03% of the total agricultural area, contributing to the reduction by almost half of the production of various crops (Bălan et al., 2011). In the Gorj County, agriculture and breeding are significant sectors in the local economy, primarily for sustaining the livelihood of the local population. The grasslands in this region can play an important role in supporting livestock, such as grazing for farm animals, especially sheep and cattle, but also for hay production. Farmers and livestock farmers use the meadows for animal feed, also contributing to the local economy. The way pastures are exploited is closely linked to their existence and can be easily "guided" from one extreme to another: abandonment or intensive exploitation (Marușca et al., 2010). To maintain the health of grasslands and promote their sustainable use, farming and land management practices play a crucial role. These may include crop rotation, avoidance of over-harvesting and implementation of organic farming techniques. For this reason, it is necessary to know as much as possible about the soil, its fertility, but especially the processes that influence its productive capacity. Grassland floristic composition and productivity yield are the result of a complex set of physiological, ecological and evolutionary interactions in demographic and physical processes. In most cases increased plant productivity due to fertilisation leads to a decrease in the number of plant species coexisting in a given area.

Mineral fertilisation is known to have a profound impact on the floristic composition of grasslands, especially in acidic pH, calcareous pH and saline habitats. Following the application of fertilisers, semi-natural pastures were gradually converted into intensively managed pastures (Nösberger & Messerli, 1998). To date, national and international experiments have shown that species diversity decreases with the intensification of pasture systems, leading to the establishment of species with higher forage value and better productivity (Bogdan, 2012; Briemle & Opperman, 2003; Cirebea, 2017; Cristea, 2004; Păcurar, 2005; Rotar, 2003; Rotar et al., 2016).

The floristic composition is established on the basis of scientific criteria, depending on climatic conditions, farming methods and agro-techniques used, resulting in a higher quality and quantity of forage on temporary pasture than on permanent pasture (Naie et al., 2017). Different pasture types react differently (Rotar, 1997). The optimum NPK fertiliser rates recommended vary within narrow limits from one pasture type to another, as follows: 150-200 kg N/ha, 50-100 P_2O_5/ha and 0-50 kg K_2O/ha (Cardașol & Daniliuc, 1979).

Rotar et al. (2016) analysed the effect of mineral fertilisation on the biodiversity and productivity of a *Festuca rubra* pasture. When pastures were fertilised there were significant increases in pasture yields, leading to a significant increase in livestock value. Floristic diversity has been shown to decrease with increasing applied dose.

MATERIALS AND METHODS

The Experimental Centre for Grassland Culture is located on the administrative territory of the Tg. Jiu locality, on the Bălăneștilor Hill, in the Preajba locality, 12 km North-East of the Tg. Jiu municipality, and at a distance of about 5 km from the Tg. Jiu - Rm. Vâlcea national road. The field of experience is located at an altitude of about 300 m, on the highest terrace of the river Jiu (5th terrace), on a South-East facing slope, with a gradient of 10 to 15%. Average temperatures are lowest in December (0.4°C) and January (-1.1°C) and highest in July (21.9°C) and August (21.2°C). The average rainfall amounts to 736.9 mm, 434.1 mm respectively for the growing season, values that characterise a humid climate, specific to the hilly area.

The research was carried out on a Stagnic Luvisol, located on a 10-15% slope, on parent material represented by fluvial terrace deposits, where the depth to the water table is 5-10 m with natural vegetation represented by meadows with acidophilic species. The Stagnic Luvisol on which the experiments were located is characterised by a profile of the type Aț, Ao, El(w), ElBt, Bt1(w), Bt2(w). It has a strongly acidic reaction, the pH being maintained throughout the depth of the profile at between 5.1 and 5.4. In terms of chemical element supply, the soil has a very low content of mobile P (6 ppm) in the surface horizon, decreasing to 1 ppm in the following horizons. The degree of mobile K supply in ppm is good in the Steel and Ao surface horizons, with a value of 174 ppm and 144 ppm respectively, and a medium supply in the AEl horizon (76 ppm) and in the El horizon (46 ppm) and a poor supply in the Bt1, BC and C horizons where the value is below 40 ppm.

In the experimental field, in the natural grassland, *Agrostis capillaris* dominates, accompanied by *Festuca rubra, Cynosurus cristatus, Anthoxanthum odoratum, Chrysopogon gryllus, Poa pratensis, Poa bulbosa, Lolium perenne, Trifolium pratense, Trifolium repens, Trifolium molinerii, Trifolium dubium, Lotus corniculatus, Medicago lupulina, Vicia* sp., *Galium vernum, Ranunculus ficaria, Prunella vulgaris, Euphorbia amygdaloides* etc.

The research consisted in setting up an experiment on a natural meadow with 3 versions and 3 repetitions, according to the method of isolated blocks, in order to highlight the evolution of soil agrochemical soils under the influence of erosion and mineral fertilization. Thus, in this respect, the existing natural grassland at the experimental centre was raked of old vegetation, and in April, at the beginning of the growing season, the experimental versions were fertilised as follows: control version V_1 was left as an unfertilised control, version V_2 was fertilised with $N_{60}P_{60}K_{60}$, and version V_3 was fertilised with $N_{100}P_{90}K_{60}$. All experimental versions were mowed after each flowering to determine the yields obtained from mineral fertilisation. Also, in order to analyse the evolution of the agrochemical soil contamination, under the influence of mineral fertilisation and water erosion, soil samples were collected with agrochemical probes, two samples each from two different experimental versions:

- sample A was taken from the upstream part of the plot or from the upper half of the plot, from 10 randomised points;
- sample B was taken from the downstream part of the plot or from the lower half, from 10 randomised points.

In order to highlight the evolution of soil agrochemical insusceptibilities, soil samples were collected as follows: in April, before fertilisation, then two weeks after fertilisation and at the end of the growing season (1st October). Soil samples were analysed in the laboratory according to ICPA methodology.

For the determination of chemical properties, the following analytical methods were used:

- pH (potentiometric method in aqueous suspension at soil/water ratio of 1/2.5 - SR 7184 /13-2001);
- Sum of basic exchange basic ions (SB) by hydrochloric acid extraction 0.1 N according to the Kappen method, Chiriță modified;
- hydrolytic acidity, extraction with sodium acetate at pH 8.2;
- base saturation degree, V% (Kappen Schoffield method);
- organic matter (humus): volumetric determination, (Walkley-Black humidification method, STAS 7184/21-82);
- the nitrogen content, by calculation, based on the humus content and the degree of saturation with bases (IN = humus x V/100);
- mobile phosphorus content (Egner-Riehm-Domingo method and colorimetric molybdenum blue, Murphy-Riley method ascorbic acid reduction);
- mobile potassium content (Egner-Riehm-Domingo extraction and flame photometry).

RESULTS AND DISCUSSIONS

The hay yields obtained on natural grassland are shown in (Table 1, Figure 1). The following conclusions can be drawn from their examination:

- hay yields were favourably influenced by fertilisers;
- in the version fertilised with $N_{60}P_{60}K_{60}$, compared to the no-fertilisation control, a percentage increase of 107.3% and a very significant 1.6 t/ha yield increase was achieved;
- in the version fertilised with $N_{100}P_{90}K_{60}$, compared to the control version, a yield of 4.04 t/ha was recorded, which means a percentage increase of 117.6% and a harvest increase of 2.54 t/ha, also very significant;
- natural grassland therefore responded favourably to nitrogen, phosphorus and potassium fertilisation.

The very significant crop yields observed with mineral fertilisation indicate the positive impact of this fertilisation practice on plant growth and productivity.

Table 1. Hay production in natural meadows

Version	Dose	Production			Meaning
		t/ha	%	±d/mt	
V_1	$N_0P_0K_0$ (Ct)	1.5	100	–	–
V_2	$N_{60}P_{60}K_{60}$	3.1	207.3	1.60	***
V_3	$N_{100}P_{90}K_{60}$	4.04	217.6	2.54	***

DL 5% = 0.199 t/ha
DL 1% = 0.328 t/ha
DL 0.1% = 0.616 t/ha

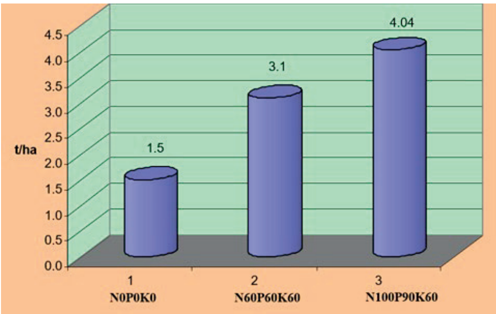

Figure 1. Influence of mineral fertilisation on hay production

Experimental values of agrochemical indicators: sum of exchangeable bases SB, hydrolytic acidity Ah, exchangeable aluminium Al, pH of aqueous soil suspension, humus H, total nitrogen N, mobile phosphorus P_{AL}, mobile potassium K_{AL} and calculated values of agrochemical indicators: total basic ion exchange capacity T, base saturation V and nitrogen index IN, are listed in Tables 2-4.

The annual variation of soil nutrients under the influence of climatic and anthropogenic factors is difficult to interpret because it depends on many variables.

Table 2. Values of main soil agrochemical indicators in experimental plots in April

Version	pH	SB	Ah	T	Al	V, %	H, %	IN	Nt, %	P_{AL}, ppm	K_{AL}, ppm
		me/100 g soil									
Natural grassland Ct A	4.95	5.69	5.53	11.22	0.44	50.71	3.10	1.57	0.135	8.38	46.85
Natural grassland Ct B	5.07	5.74	5.58	11.32	0.40	50.71	3.11	1.58	0.136	8.75	46.48
Natural grassland $N_{60}P_{60}K_{60}$ A	5.00	5.62	5.54	11.16	0.54	50.35	3.08	1.55	0.133	9.13	46.45
Natural grassland $N_{60}P_{60}K_{60}$ B	5.07	5.58	5.44	11.02	0.48	50.63	3.10	1.57	0.135	8.90	46.33
Natural grassland $N_{100}P_{90}K_{60}$ A	4.91	5.61	5.52	11.13	0.50	50.40	3.13	1.58	0.137	1.15	46.18
Natural grassland $N_{100}P_{90}K_{60}$ B	4.96	5.50	5.41	10.91	0.56	50.41	3.09	1.56	0.134	9.40	46.50

Table 3. Values of main soil agrochemical indicators in experimental plots in May

Version	pH	SB	Ah	T	Al	V, %	H, %	IN	Nt, %	P_{AL}, ppm	K_{AL}, ppm
		me/100 g soil									
Natural grassland Ct A	5.01	5.25	5.35	10.60	0.90	49.53	3.15	1.56	0.137	8.45	47.88
Natural grassland Ct B	5.11	5.22	5.27	10.49	0.90	49.76	3.08	1.53	0.135	8.85	47.50
Natural grassland $N_{60}P_{60}K_{60}$ A	5.07	5.28	5.38	10.66	1.00	49.53	3.17	1.57	0.137	9.35	47.48
Natural grassland $N_{60}P_{60}K_{60}$ B	5.10	5.13	5.24	10.37	1.02	49.47	3.04	1.50	0.132	9.15	47.35
Natural grassland $N_{100}P_{90}K_{60}$ A	4.97	5.30	5.40	10.70	1.20	49.53	3.13	1.55	0.137	10.20	47.17
Natural grassland $N_{100}P_{90}K_{60}$ B	5.02	5.32	5.33	10.65	1.18	49.95	3.10	1.55	0.134	9.80	47.50

Table 4. Values of main soil agrochemical indicators in experimental plots in October

Version	pH	SB	Ah	T	Al	V, %	H, %	IN	Nt, %	P_{AL}, ppm	K_{AL}, ppm
		me/100 g soil									
Natural grassland Ct A	4.88	5.81	5.76	11.57	0.80	49.78	3.12	1.55	0.136	8.39	47.23
Natural grassland Ct B	4.96	5.77	5.69	11.46	0.72	49.65	3.10	1.54	0.135	8.76	46.25
Natural grassland $N_{60}P_{60}K_{60}$ A	4.91	5.68	5.67	11.35	0.94	49.95	3.09	1.54	0.133	9.18	46.81
Natural grassland $N_{60}P_{60}K_{60}$ B	4.98	5.88	5.85	11.73	0.74	49.87	3.08	1.54	0.134	8.98	46.95
Natural grassland $N_{100}P_{90}K_{60}$ A	4.93	5.86	5.83	1.69	0.44	49.87	3.14	1.57	0.138	10.33	46.78
Natural grassland $N_{100}P_{90}K_{60}$ B	4.92	5.79	5.72	11.51	1.30	49.69	3.11	1.55	0.135	9.72	47.73

Nutrient content, humus content and soil reaction have seasonal fluctuations (variations) depending on the amount and intensity of rainfall, the mass of eroded soil, the nature of the crop, the specific phenophase, with repercussions on the intensity of nutrient uptake, the doses of fertilisers applied and their nature, the activity of soil micro-organisms which in turn depends on temperature, the degree of soil aeration and the pH of the aqueous soil suspension.

Some factors may act in the same direction, others in opposite directions. Thus, for example, high rainfall intensity and duration, as well as peak nutrient consumption phenotypes (first phases of vegetation, flowering) acts synergistically on the amount of eroded soil and on soil nutrient losses. Together, they contribute to increased mass of eroded soil and increased nutrient losses.

High intensity and duration of rainfall and wind on the one hand and fertilizer application and low soil reaction on the other act in opposite directions, the former leading to nutrient losses from the soil due to erosion, the latter (fertilizers and soil reaction) leading to nutrient accumulation in the soil through anthropogenic input and slowing down the physiological activity of plants, thus slowing down nutrient consumption.

From the data in Tables 2-4 it can be seen that agrochemical indicators vary over time in relatively narrow value ranges, maintaining soil homeostasis as an ecological system.

The changes of the main agrochemical indicators pH, humus, total nitrogen, mobile phosphorus and mobile potassium, according to their initial and final values, under the influence of erosion and different fertilisation, are shown in Tables 5 to 9. These data lend themselves best to interpretations of the influence of erosion and fertilisation on the evolution of soil properties.

Variation of soil reaction

The pH variations of aqueous suspensions are listed in Table 5.

Table 5. Variation of soil reaction by initial and final pH values of aqueous soil suspension

Version	Soil reaction		Variation of soil reaction, %	Range of variation of soil reaction
	Initial Values April	Final Values October		
$N_0P_0K_0$ Ct A	4.95	4.88	-1.41	4.82-5.11
$N_0P_0K_0$ Ct B	5.07	4.96	-2.17	
$N_{60}P_{60}K_{60}$ A	5.00	4.91	-1.80	
$N_{60}P_{60}K_{60}$ B	5.07	4.98	-1.78	
$N_{100}P_{90}K_{60}$ A	4.91	4.93	+0.41	
$N_{100}P_{90}K_{60}$ B	4.96	4.92	-0.81	

This table shows:

- for the control version, the pH of the suspension decreased by approx. 1.7%;
- for the version fertilised with $N_{60}P_{60}K_{60}$ there was a decrease of approx. 1.8%;
- for the version fertilised with $N_{100}P_{90}K_{60}$ there was a decrease of 0.4%.

The pH decrease is justified by the physiological reaction of the mineral fertilisers used in the experiments.

Humus content variation

The variation in humus content is shown in Table 6, which shows that:

- in the control version there is a decrease in humus content, small by approx. 0.15%;
- in the fertilised version, experimental data indicate a maintenance of humus content when fertilising with $N_{60}P_{60}K_{60}$ and a slight increase of approx. 1% in humus content when fertilising with $N_{100}P_{60}K_{60}$, due to the administration of chemical fertilisers.

These variations can be explained by the fact that erosion, which increases in the unfertilized control version and decreases in the fertilised versions (and thus conserves humus less efficiently, in the same sense). Agricultural practice has proven that humus is formed, and especially accumulated, in reducing environments. By taking into cultivation, due to tillage, there is a slight increase in aeration porosity, soil surface exposed to air, thus oxygen. As a result, the soil state is converted from a reducing to an oxidising environment, favouring the oxidative decomposition of humus through the activity of soil microorganisms. This may explain why the humus content has remained high.

Table 6. Variation of soil humus content by initial and final values

Version	Humus content, %		Humus content variation, %	Range of variation of humus content
	Initial April	Final October		
$N_0P_0K_0$ Ct A	3.10	3.12	+0.65	3.04-3.21
$N_0P_0K_0$ Ct B	3.11	3.10	-0.32	
$N_{60}P_{60}K_{60}$ A	3.08	3.09	+0.32	
$N_{60}P_{60}K_{60}$ B	3.10	3.08	-0.65	
$N_{100}P_{90}K_{60}$ A	3.13	3.14	+0.32	
$N_{100}P_{90}K_{60}$ B	3.09	3.11	+0.65	

Change in total nitrogen content

Variations in total nitrogen content are almost identical to variations in humus, which can be explained by the fact that about 92-98% of soil nitrogen - in topsoil - is found in humus. Thus, Table 7 shows the following:

- in the control version there is a decrease in total nitrogen content, higher for the maize crop (about 2-3%) and lower for the other crops (0-0.7%);
- in the version fertilised with the dose of $N_{60}P_{60}K_{60}$ no change in total nitrogen content on average;

- in the version fertilised with the dose of $N_{100}P_{90}K_{60}$ there is an increase in total nitrogen content, which is higher (about 0.8%).

Table 7. Variation of total soil nitrogen content by initial and final soil nitrogen values

Version	Total nitrogen content, %		Change in total nitrogen content, %	Range of variation of total nitrogen content, %
	Initial April	Final October		
$N_0P_0K_0$ Ct A	0.135	0.136	+0.74	0.133-0.141
$N_0P_0K_0$ Ct B	0.136	0.135	-0.74	
$N_{60}P_{60}K_{60}$ A	0.133	0.133	+0.00	
$N_{60}P_{60}K_{60}$ B	0.135	0.134	-0.74	
$N_{100}P_{90}K_{60}$ A	0.137	0.138	+0.73	
$N_{100}P_{90}K_{60}$ B	0.134	0.135	+0.75	

Variation in mobile phosphorus content

The analytical values are shown in Table 8:

- in the control versions, there is an increase of 0.11%;
- in versions fertilised with $N_{60}P_{60}K_{60}$ there is an increase of 0.3%;
- in versions fertilised with $N_{100}P_{90}K_{60}$ there is an increase of 2.6%.

The relatively large variations in mobile phosphorus content are due to the high variation of phosphorus content on the soil profile, the very high concentrations being in the surface layer subject to erosion, as well as the precipitation of mobile phosphorus due to the high content of exchangeable aluminium which forms with phosphate ions hardly soluble aluminium phosphates.

Table 8. Variation of soil mobile phosphorus content by initial and final soil mobile phosphorus values for different crops

Version	Mobile phosphorus content in ppm		Variation in mobile phosphorus content %	Range of variation of mobile phosphorus , ppm
	Initial April	Final October		
$N_0P_0K_0$ Ct A	8.38	8.39	+0.12	8.5-12.41
$N_0P_0K_0$ Ct B	8.75	8.76	+0.11	
$N_{60}P_{60}K_{60}$ A	9.13	9.18	+0.55	
$N_{60}P_{60}K_{60}$ B	8.90	8.98	+0.90	
$N_{100}P_{90}K_{60}$ A	10.15	10.33	+1.77	
$N_{100}P_{90}K_{60}$ B	9.40	9.72	+3.40	

Variation in mobile potassium content

The concentrations of mobile potassium in the soil are listed in Table 9, which shows that:

- for the control version there is a slight increase of 0.2%;
- for the version fertilised with $N_{60}P_{60}K_{60}$ an increase of approx. 1%;
- for the version fertilised with $N_{100}P_{90}K_{60}$ there was a 2% increase.

These increases are due to compensation for potassium losses through the addition of fertilisers.

Table 9. Variation in soil mobile potassium content by initial and final soil potassium values for different crops

Version	Mobile potassium content, ppm		Variation in mobile potassium content, %	Range of variation of mobile potassium content
	Initial April	Final October		
$N_0P_0K_0$ Ct A	46.85	47.23	0.81	46.10-48.16
$N_0P_0K_0$ Ct B	46.48	46.25	-0.49	
$N_{60}P_{60}K_{60}$ A	46.45	46.81	0.78	
$N_{60}P_{60}K_{60}$ B	46.33	46.95	1.34	
$N_{100}P_{90}K_{60}$ A	46.18	46.78	1.30	
$N_{100}P_{90}K_{60}$ B	46.50	47.73	2.65	

CONCLUSIONS

The evolution of soil agrochemical properties in the experimental versions, under the influence of erosion and fertilization, is influenced by the amount and intensity of rainfall, the mass of eroded soil, the crop, i.e. the specific phenophase, with repercussions on the intensity of nutrient uptake, the doses of fertilizers applied and their nature, the activity of soil microorganisms which in turn depends on temperature, the degree of soil aeration and the pH of the aqueous soil suspension.

From the data presented it was found that in natural grassland, the application of different doses of fertilizers leads to differences in pH and nutrient content of the soil. These variations are caused by: natural non-uniformity of the soil profile; area micro-relief (bumps, dips etc.) which may lead to small accumulations of organic material or mineral fertilisers; uneven erosion of the land, as well as the contribution of various materials carried by the wind from the upper parts of the slope, including the plateau; analytical errors in nutrient determination.

The changes in the main agrochemical indicators pH, humus, total nitrogen, mobile phosphorus and mobile potassium, according to their initial and final values, under the influence of erosion and different fertilization, can be explained by the fact that erosion, which increases in the unfertilised control version and decreases in the fertilised versions, causes losses in the same direction.

These sources of deviations must be taken into account when assessing all other agrochemical parameters.

Given the inertia of the main agrochemical indicators and their tendency to resist the influence of external factors, a short-term experiment on a slope with a shallow gradient can only give an approximate assessment of the tendency of agrochemical parameters to evolve under the influence of erosion and fertilisation.

This trend is a slight increase in humus and total nitrogen concentration, an increase in phosphorus and potassium concentration and a decrease in pH of aqueous soil suspensions.

Fertilisation with high doses of nitrogen, phosphorus and potassium has led to very significant production yields.

However, long term nitrogen fertilisation provides an increase in soil nitrogen content both at rates of 100 kg N/ha and 60 kg N/ha, but also causes a marked acidification of the soil. To increase crop productivity and ensure sustainable agriculture, the use of organic and inorganic nutrient sources together with limestone amendments is recommended.

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