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Original article

Agrochemical mapping and distribution of soils on “El Pitirre” farm

Cartografía agroquímica y distribución de los suelos de la finca “El Pitirre”, Pinar del Río

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ABSTRACT: A soil study was carried out at “El Pitirre” farm, belonging to the Science, Technology and Innovation Entity (STIE) “Sierra Maestra”, with the objective of elaborating maps of landscape forms, soils, pH in water, organic matter and assimilable phosphorus and potassium; through the application of a geographic information system. Soil sampling was carried out with an auger at a depth of 0-20 cm, at a rate five-six simple samples to form a composite sample per area. A total of 39 agrochemical plots were prepared as representative of the 100 ha. Chemical analyses were carried out using the analytical techniques employed in the National Institute of Agricultural Sciences soil laboratory. Agrochemical sampling results showed that soils have a slightly acidic reaction, followed by a neutral one; in relation to the organic matter content, medium predominates, followed by low content; and in general, they have low and very low content of assimilable phosphorus and potassium.

Key words: soil fertility, sampling, nutrition.

RESUMEN: Se desarrolló un estudio edafológico en la Finca “El Pitirre”, perteneciente a la Entidad de Ciencia, Tecnología e Innovación (ECTI) “Sierra Maestra”, cuyo objetivo fue elaborar los mapas de formas del paisaje, suelos, pH en agua, materia orgánica, fósforo y potasio asimilables; mediante la aplicación de un sistema de información geográfica. El muestreo de suelo se realizó con barrena a una profundidad de 0-20 cm, a razón de cinco-seis muestras simples, para conformar una muestra compuesta por área. En total se prepararon 39 parcelas agroquímicas, representativas de las 100 ha. Los análisis químicos se realizaron utilizando las técnicas analíticas empleadas en el laboratorio de suelos del Instituto Nacional de Ciencias Agrícolas. (INCA). Se pudo constatar, por los resultados del muestreo agroquímico, que los suelos tienen reacción ligeramente ácida y, en segundo lugar, neutro; en relación con los contenidos en materia orgánica, predomina el mediano, le sigue el contenido bajo y, en general, tienen contenido bajo y muy bajo en fósforo y potasio asimilables.

Palabras clave: fertilidad del suelo, muestreo, nutrición.

INTRODUCTION

Soil is the main source of nutrients for plants. In this sense, several authors state that crop growth, nutrition and yield depend on soil fertility (1). For nutritional diagnosis, soil analysis is the most commonly used tool, but in certain situations it is necessary to complement it or use other alternatives. Current technologies of satellite images, yield maps, soil maps and topographic maps are very useful to achieve a better definition of contrasting environments (2).

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The purpose of soil studies is to obtain predictions on specific land uses. To do this, it is necessary to determine the distribution pattern, dividing the surface of the land into relatively homogeneous areas, map these units and characterize their properties in order to infer their productive potential, as well as to evaluate their response to different management alternatives (3).

"El Pitirre" farm is used for the production of protein plants; however, only the results of the 1:25 000 soil map, with data from a soil profile, are available, which is insufficient to achieve an agriculture in which adequate yields are obtained without soil deterioration. In view of the above, the aim of this work is to evaluate the soil properties in order to obtain basic information that will help to achieve good yields of protein plants while maintaining good soil fertility.

MATERIALS AND METHODS

The study was carried out in "El Pitirre" farm in Los Palacios municipality, Pinar del Río province; located at the coordinates Latitude: 317, 319 N and Longitude: 269, 271 E, in an approximate area of 100 ha, using a map of the region 1:10 000 as a cartographic base. Thirty auger points were taken, according to the difference in relief and nine soil profiles, of which six were analyzed, which corresponds to one mapping point every 4 ha and one profile every 14 ha, approximately. This corresponds to a mapping scale of 1:10 000, according to current standards in Cuba (4).

Previous maps made in the study region were consulted, the genetic soil map 1: 250 000 (5) and the soil map 1: 25 000 (6). Soils were classified according to the Cuban Soil Classification (7).

Agrochemical sampling of the 100 ha was carried out at a depth of 0-20 cm, taking into account soil types, relief and soil use. A total of 39 agrochemical plots were prepared, taking about five-six simple samples for a composite sample, which gives a sampling density between 195 and 234 simple samples for 100 ha and also one agrochemical plot every 3.85 ha on average, resulting in more detail than the standards established for this work (4).

For the soil fertility characterization, agrochemical cartograms were drawn up, for which 39 plots were initially separated according to soil type and management (Figure 3), ranging from 0.5 ha to 2-3 ha. These plots were sampled by taking 5-6 partial samples at a depth of 0-20 cm to form a composite sample.

For each composite sample, pH in water, assimilable phosphorus and potassium (mg 100 g^{-1}) and organic matter (%) were determined. The analytical results were used to create the different agrochemical cartograms. The samples were analyzed in the Soil Chemical Analysis Laboratory of the Department of Biofertilizers and Plant Nutrition from INCA.

Cartograms that were carried out were pH in water; percentage of organic matter and assimilable phosphorus and potassium. For the elaboration of cartograms, the parameters established for the different levels were taken into account, according to the Cuban methodology (4), except for the levels of organic matter content (%), according to the criteria of the latest version of the Cuban soil classification (7), which are applied in the manual for the mapping and description of soil profiles (8).

The QGIS 2.18 GIS was applied to the soil map, by means of which the area of the soils and the cartograms can be obtained. Using GIS, maps were made of: landscape forms; soils; pH in water; organic matter and assimilable phosphorus and potassium.

RESULTS AND DISCUSION

Landscape form

In the formation and distribution of soils in the studied area, two different types of landforms and soils can be diagnosed. This makes it possible to differentiate between two landscape forms with different soil formations (Figure 1).

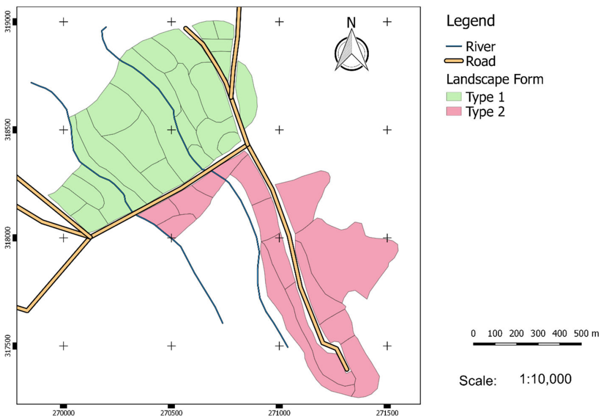

Figure 1. Landscape forms of the farm "El Pitirre"

Landscape I has slopes between 6 and 12 % and is well dissected by some streams that cross it. In this landscape, soil formation is mainly marked by weathering processes in the upper parts and slopes of the relief, giving rise to fersialitization with red-colored soils due to the accumulation of free iron. In the lower parts towards the streams there is a humidity accumulation in the soil formation, which results in the formation of spots and soft black concretions of ferro-manganic composition. As described above, this is the gleyzation process manifestation, which is negative for crops due to excess moisture (9).

In the study region, gleyzation occurs in flat and sometimes gently sloping strips along streams. The soils in this landscape form are humic and mellow Ferrallitic Red Leached, erogenous Fersialitic Red Leached and also Humic Gleysols.

In landscape II, the relief is different, it is less dissected, with slopes between 2 and 5 %, with terrace formations and elevations towards the dam. In this landscape, as the elevation decreases due to the terraces, the soil formation is under a much greater influence of moisture accumulation than at present. Due to the elevation of the terrain, as a result of neotectonic movements, the influence of this over-wetting was diminished, although marks of this process remained in the soil.

The formation of the soil is from fersialitization, but it is yellowish or orange in the Bt horizon, which allows it to be classified as Fersialitic Red Lixiviated gleyic and there is also the erogenic Humic Gleysol Humic soil.

In the lower part and outside the cultivated area, a somewhat different formation is found, as the surface soil has a marked prismatic structure and is classified as Vertic Chromic Gleysol.

Soil map and its distribution

For the soil map presented at a scale of 1:10 000, a non-conventional system of symbols had to be adopted for each soil contour, due to the scale of the work and the area comprising each contour (Figure 2). As can be seen in the map, the erogenous Red Fersialitic Leached Red Soils (FrsRL er) are found in landscape I, located on the left side of the Farm, with steeper slopes, and the erogenous Gleysol and Gleysol FrsRL (FrsRL erg), on the upper right side, towards the dam. Gleysols occupy the depressive areas, next to the streams. The area occupied by each soil is presented in Table 1.

In general, soils in the upper and stable parts of the relief in preserved areas are of the Amh-Btfrs-BCgr-Crca type (Amh-Btfrs-BCgr-Crca (Fersialitic Red Leached mellow and humic leached); in the upper and middle unconserved parts Aer-Btfrs-BCgr-Crca (erogenous leached red Fersialitic) or BAer-Btfrs-BCgr-Crca and in the lower parts of the relief Aer-Bg-CG (erogenous humic Gleysol), Ah-Bg-Cg (humic haplic Gleysol) or Av-Bg-G (chromic vertic Gleysol).

Soil fertility characteristics

The results obtained through the application of the genetic-geographical dokuchavian method in the study of the soils of the "El Pitirre" farm, show quickly and precisely the factors and processes of soil formation, the types and subtypes of soils, their distribution and the area they occupy, as well as their physical and chemical characteristics. In addition, the impact of man on soil degradation during the elimination of vegetation, giving rise to subtypes of erogenous soils.

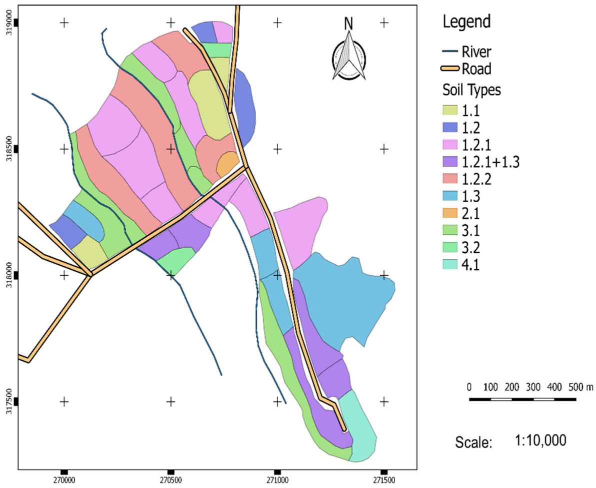

Figure 2. Soil map of "El Pitirre" Farm

Taking into account the above, agrochemical sampling of the soils is carried out, with the separation of 39 agrochemical plots, in order to obtain basic data for the future management of the fertility of the soils of the "El Pitirre" farm.

Figure 3 shows the 39 plots, which were separated taking into account the type of soil and its management, for the characterization of soil fertility in the study region.

Water pH cartogram

With respect to the pH cartogram (Figure 4), in the area under study it can be observed that this chemical property varies in four categories: slightly alkaline, neutral, slightly acidic and moderately acidic.

Table 2 shows that these soils are dominated by slightly acid pH (values between 6.1 and 6.5), with 21 plots (48.01 ha), followed by 13 plots (33.24 ha) with neutral pH (values between 6.6 and 7.5), only four plots (11.40 ha) with medium acid pH (values between 5.6 and 6.0) and one plot with slightly alkaline pH (0.71 ha).

One of the great challenges facing agriculture today is to guarantee food security for the population. In order to achieve this, it is necessary to have soils that have the appropriate conditions to maintain agricultural production in a sustainable way.

Table 1. Keys to the different soil subtypes of the "El Pitirre" farm, separated on the map and the area occupied by each of them

Soil	Key on the map	Area occupied (ha)
Fersialitic Red Leached humic and loamy. eutric	1.1	5.00
Fersialitic Red Leached erogenous, eutric, gently eroded without carbonates	1.2.1	29.04
Fersialitic Red Leached erogenous, eutric, moderately eroded, no carbonates	1.2.2	16.30
Fersialitic Red erogenous and gleyic, eutric. without carbonates	1.3	23.43
Brown erogenous, carbonate, strongly weathered and stony	2.1	0.71
Humic erogenic gleysol. eutric. gently eroded	3.1	13.69
Humic Gleysol, eutric haplic	3.2	2.41
Vertic Chromic Gleysol	4.1	2.78
Total		93.36

Among the appropriate conditions that a soil must have is the pH or soil reaction (10). It is known that soils with acid pH have unfavorable conditions for plant growth; on the one hand, due to the fact that most of the nutrients in the soil develop in pH between 6 and 7, rather neutral, and also that in acid pH conditions only fungi develop, as the activity of bacteria and actinomycetes is inhibited (11). In the presence of alkaline pH, nutrient assimilation and biological activity of the soil are also affected. At pH 8 or higher, exchangeable sodium may be present in the exchange complex, which can lead to the process of solonetization in soils, with very unfavorable conditions for crop development (12).

These soils are formed from basic and ultrabasic rocks, mainly basalt, with pH between 4.5 and 5.5, with intermediate formation between sialitic and ferrallitic soils, with formation of a mixture of clay minerals of the 1:1 type (kaolinites) and 2:1 (illites) and accumulation of iron oxides (similar to those classified today as Fersialitic). Likewise, other authors place them within the Fersialitic soil group, between the Sialitic and Ferrallitic soils (13).

On the basis of these results, it is convenient to apply amendments to improve the pH of soils with light and medium acid reaction in the studied area.

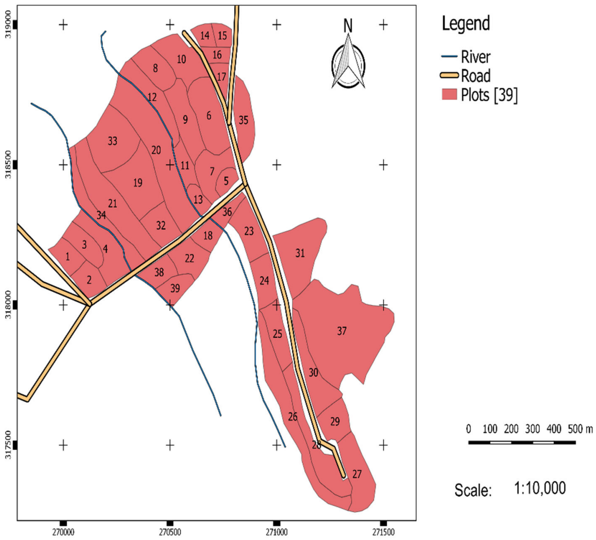

Figure 3. Separate plots for agrochemical cartograms for farm "El Pitirre"

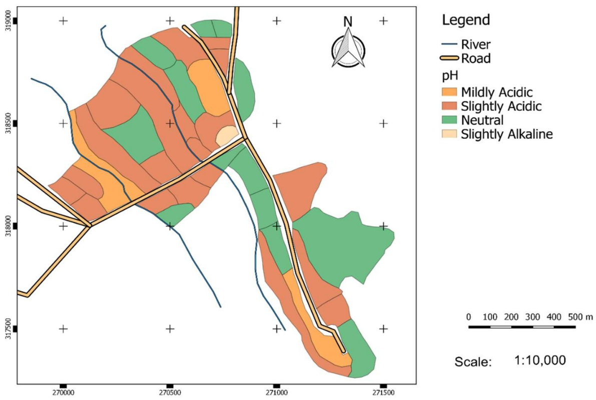

Figure 4. Cartogram of pH in water from the farm "El Pitirre"

Soil organic matter content

In this study region, a secondary vegetation type of marabú predominates, which should enrich the soil in organic matter over time. However, in most of the cultivated areas about 15-20 cm of topsoil thickness has been lost as a result of marabú removal, so that high organic matter contents are not found. However, the organic matter content is often not low or very low, but medium, which shows that under marabú vegetation the soil may have had 4-6 % organic matter in the first 20 cm of topsoil thickness.

The results obtained, both in the characterization of the profiles and in the organic matter content cartograms (Figure 5), show that the predominant content is medium in the region, as can be seen in Table 3, which shows the area occupied by the different organic matter contents in the region studied.

The data in Table 3 show that the predominant organic matter content is medium, with 57.68 % of the area, which is attributed to the fact that the initial vegetation was marabou and, in addition, that the leached red fersialitic soils have a certain evolution, with a relatively high content of free iron, estimated at 6-7 %. It should be noted that in these soils the rapid retention of organic matter is very important, due to their iron content, which is highlighted in other research (14). This constitutes one of the causes of carbon gain by the Red Ferrallitic Leached Soils of the karst plains of Mayabeque (15).

The organic matter content of the soil is one of the most important soil characteristics, as it is not only responsible for the nutrient content, especially nitrogen, but also for a number of other properties such as biological activity, soil structure, porosity, consistency and aeration regime.

In general, soils under forests, pastures and orchards have a high organic matter content, but cultivated soils systematically lose organic matter (16,17).

Table 2. Area occupied by the different pH values of the soils present in the "El Pitirre" farm in Pinar del Río

pH Value	Category	Number of plots	Hectares	% of area
7.6-8.0	Slightly alkaline	1	0.71	0.76
6.6-7.5	Neutral	13	33.24	35.60
6.1-6.5	Slightly acidic	21	48.01	51.43
5.6-6.0	Medium acidic	4	11.40	12.21
Total		39	93.36	100.00

Nowadays, the carbon content of soils in relation to their organic matter content is of great importance, and soil properties and their potential for carbon capture and sequestration are becoming increasingly important as a means of mitigating the effects of high CO_2 concentrations in the atmosphere. This is why, together with the organic matter content, soil OCR are also determined (15,18-23).

Assimilable Phosphorus content (P_2O_5 mg 100 g^{-1})

Phosphorus is one of the 17 nutrients considered essential for plant growth and development (24). It is characterized by being the most stable element in the soil, it is not lost by washing or volatilization; to a large extent, and it is fixed to the soil, either by calcium or by iron and aluminum, the latter being present in highly weathered tropical soils (11).

Phosphorus contents in tropical soils are highly variable. Total phosphorus in the topsoil decreases as the intensity of weathering increases (11). On the other hand, as the organic matter content of soils increases, the content of inorganic phosphates increases and, therefore, total phosphorus contents become higher.

In the area under study, with soils with a certain degree of weathering and a relatively high content of free iron, it is to be expected that the assimilable phosphorus content will not be high; bearing in mind, moreover, that these are soils that have been altered by man, by the clearing of the marabú, which may have taken 20-25 cm of the top layer of soil and, therefore, a good content of organic matter where there is enough assimilable phosphorus.

If the total phosphorus fractionation of the soil is analyzed, the fractions of iron-bonded and occluded phosphorus (which are non-assimilable forms) are likely to be high. For this reason, it is highly recommended to carry out trials in these soils with the application of mycorrhizal biofertilizers, since the network of hyphae of these fungi improves the assimilation of assimilable phosphorus, avoiding its high fixation by iron and, in addition, the mycorrhizae have the property of solubilizing the phosphorus in the soil (25).

The agrochemical cartogram with the results of the analysis per plot is shown in Figure 6.

Table 4 shows the results of the agrochemical cartograms of the 39 plots studied, with their assimilable phosphorus contents. The area occupied by the different assimilable phosphorus contents is also shown. These results show that there are low contents of this nutrient in the studied soils, where there is an extension of 87.56 ha of soils with very low contents of this nutrient.

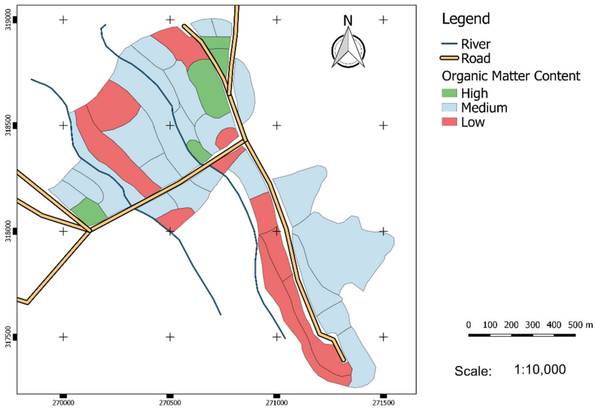

Figure 5. Cartogram of organic matter of the farm "El Pitirre"

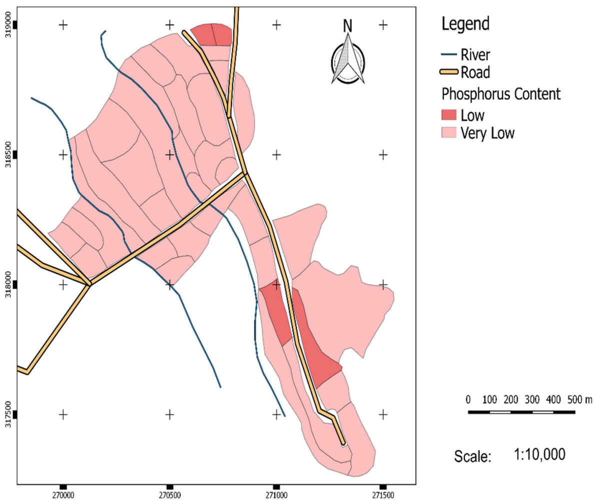

Figure 6. Assimilable Phosphorus Cartogram of "El Pitirre" Farm

The shortage of assimilable phosphorus is attributed, on the one hand, to the development of the soil, which is fersialitic, and also to its fixation due to its iron content. In this respect, Dr. Pedro Sanchez's recommendations for the use of Tithonia (*Tithonia diversifolia*). Taken from the new edition of his book "Suelos Tropicales: Su Uso y Manejo", which is currently being published in Spanish in Mexico. I It reports that Oxisols and related soils in humid and sub-humid areas of western Kenya, Uganda, Rwanda and Burundi have high P retention, in a similar range to that of Brazilian soils (Personal information).

The large differences in the content of phosphate forms in the main soils of sugar cane plantations in Cuba stand out;

Table 3. Area occupied by the different organic matter contents of the soil present in the "El Pitirre" farm in Pinar del Río

OM content (%)	Category	Number of plots	Hectares	% of area
4-6	High	5	4.69	5.02
3.0-3.9	Medium	24	53.85	57.68
2.0-2.9	Low	10	34.82	37.30
Total		39	93.36	100.00

Table 4. Area occupied by soils according to their assimilable phosphorus content on the "El Pitirre" farm in Pinar del Río

Content in P_2O_5 (mg $100g^{-1}$)	Category	Number of plots	Hectares	% of area
15-0	Low	4	5.80	6.22
< 15	Very low	35	87.56	93.78
Total		39	93.36	100.00

iron phosphates predominate in Ferrallitic soils, with a content of 59 % (26).

In conclusion, assimilable phosphorus is a very important element for the nutrition and adequate development of plants, which is why our work shows that it is very scarce in these soils as a result of its natural formation.

Assimilable Potassium content (K_2O mg 100 g^{-1})

Potassium is important for ammonium nutrition of crops. Potassium deficiency in the soil slows down many biochemical processes that affect plant metabolism.

In mineral soils, the greatest amount of potassium is found in association with silicates, feldspars and some clay minerals such as biotite and vermiculite (11,27). This is an element that does not enter into the composition of the organic compounds of the cells; therefore, organic fertilizers are not a source of potassium input to the soil.

In weathered soils, where the primary minerals are decomposed and potassium has mostly been washed out of the soil, there is usually a shortage of potassium. Likewise, the composition of the parent rocks has to be taken into account, because in case of basic and ultrabasic rocks, as a source of the soil parent mineral, the chemical composition of the rocks is ferromagnesian silicate with very little potassium (9).

These two characteristics, the type of parent rock in soil formation in this region (transported materials from ultrabasic rocks, which are poor in potassium) and the degree of weathering in the soil, in a climate with annual rainfall around 1500 mm per year (which causes relatively rapid washing out of potassium), This leads to a low potassium content on this farm, as shown in Figure 7 and Table 5, which shows the results of the potassium cartogram in the soils and the area occupied by the different assimilable potassium contents.

Table 5 shows that these soils have practically no assimilable potassium, as the high content does not reach 1 % of the territory. The shortage of potassium is due to the fact that the source material is basalt, in which iron and magnesium orthosilicates predominate, without feldspars, the latter being carriers of potassium. It cannot be ruled out that the climate with 1500 annual precipitations in soils with a fersialitic evolution also influences the washing of potassium from the soil.

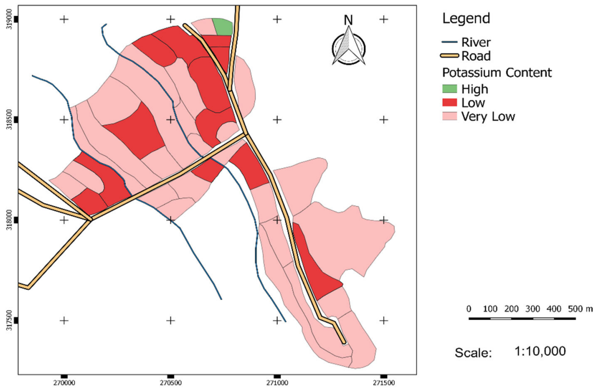

Figure 7. Potassium cartogram of the farm "El Pitirre"

It is important to take into account the low content of assimilable potassium in the mulberry plantations, as this plant is a strong extractor of potassium from the soil (28) and in the year in this plan, three cuts are made of the foliage of the plantations.

In relation to the shortage of potassium in the soil, it is stated that most of this element in the soil is found as part of feldspars, micas and the fraction of secondary minerals, finely dispersed in the soil, depending, to a large extent, on the rocks that gave rise to it, so its content is not uniform in nature (26).

In mineral soils, the greatest amount of K is associated with silicates, feldspars (orthoclase and plagioclase), micas (biotite and muscovite) and some clay minerals (vermiculite, illite, and chlorite) (11).

They also report that olivine minerals (peridotites) form part of basic and ultrabasic rocks and are orthosilicates of Fe and Mg ($Si0_4FeMg$), which are contributed to the soil.

Magmatic rocks have developed considerably in Cuba, with a large belt of hyperbasic rocks, from which ferritic soils are formed in northeastern Cuba and in Cajálbana, Pinar del Río, covering an area of 190,800 ha (29).

Table 5. Area occupied by soils according to their assimilable potassium content on the "El Pitirre" farm in Pinar del Río

Content in K_2O (mg $100g^{-1}$)	Category	Number of plots	Hectares	% of area
> 20	High	1	0.66	0.71
10-15	Low	11	22.55	24.15
< 10	Very low	27	70.15	75.14
Total		39	93.36	100.00

CONCLUSIONS

In general, the results of the agrochemical sampling show, in summary form, that soils of the "El Pitirre" farm have a slightly acid pH and, secondly, a neutral pH; in relation to the organic matter content, medium predominates, followed by low content and, in general, they have low and very low content of assimilable phosphorus and potassium.

RECOMMENDATIONS

- To study in depth the possible deficiency of phosphorus and potassium in the plantations, as well as the tendency of acidity, which could affect the adequate nutrition of protein plants.
- Take into consideration the results obtained to evaluate the inclusion of a new grouping of Erosol soils; as well as the genetic type of Fersialitic Red Leached and Humic Erogenic Gleysol, in the next version of the Cuban Soil Classification.

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