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Evaluation and Recommendations for Salinization Management and Control of Coastal Ecosystems in Pinar del Rio, Cuba

Enrique Márquez Reina [1] Duniesky Domínguez Palacio [2], Marianela Cintra Arencibia[3] & Anabel Medina Redonet[4]

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ABSTRACT

The aim of this study was to evaluate the factors that cause salinization on the low south coastal plain in the municipality of Los Palacios, Pinar del Rio, Cuba. Vegetation, climate, relieve, biodiversity, hydrology and conditions of the coastline were evaluated. Soil agro productivity was determined for rice as the main crop, along with other crops used for rotation. It was concluded that the area studied has a fragile ecosystem, with a salinization threat caused by superficial ground water, inefficient irrigation systems and drainage networks, water loss during supply, and flatness, as well as inadequate conditions of irrigation and drainage systems. Works on mangrove forest recovery he along the coastline were recommended to rehab the water canal and drainage network, implement crop rotation, eliminate double rice harvest, preserve soil coating in areas with less than five meters above sea level, perform constant monitoring and evaluation of local salinity, fix the drainage network, and invest in the efficiency of water supply and its use.

KEY WORDS/: salinization, coastal ecosystems, land sustainable management

INTRODUCTION

The degradation of soil and the environment in agrosystems and agricultural production units is the result of a set of complex degrading processes, which take place under the influence of natural and human factors. Today, the soils of the southern coastline in the province of Pinar del Rio, Cuba, along with the environmental conditions in the area have compelled several local and national institutions to develop particular studies with the purpose of creating a local positive impact. This situation has been caused by degradation in many areas and permanent danger of desertification observed in some specific locations, as a result of poor ecosystem management in

[1] Agronomy engineer, full researcher, Head of the Research Department, Soil Institute UCTB Pinar del Rio: investigador@suelopri.minag.cu
[2] Agronomy engineer, full researcher, Research Department, Soil Institute UCTB Pinar del Rio: investigador2@suelopri.minag.cu
[3] Agronomy engineer, associate researcher, Head of the Research Department, Soil Institute UCTB Cienfuegos: grupoinv@suelos.gtm.minag.cu
[4] Agriculture Education bachelor, specialist in Quality Management System, Soil Institute UCTB Pinar del Río: investigador6@suelopri.minag.cu

which the local characteristics, including edaphic and climate conditions were ignored. The southern low coastline plain in Los Palacios is a good example of the above situation, caused by the natural conditions of the area and the inadequate use and management of soils and crop systems, leading to increased salinity or sodicity, or both (Gálvez *et al*., 1998) cited by Otero *et al*. (2007). The general goal of this paper was to evaluate the factors that originate salinity in rice production areas near height 5, at the *Sierra Maestra* Grain Company (UEBA), in the municipality of Los Palacios, province of Pinar del Rio, in order to recommend adequate management and minimize the effects of salinization.

MATERIALS AND METHODS

The agricultural ecosystem and study site is located in the southern low coastline plain, Los Palacios, on coordinates 268 000 - 280 000 E and 283 000 - 290 000 N, at the *Sierra Maestra* Grain UEBA. During the initial stage all cartographic charts and technical reports of the area (vegetation, climate, geography, biodiversity, hydrology, state of the coastline, etc., were collected. All the information was corroborated and validated after field assessment with the UEBA management, and the MINAG and CITMA delegations.

The information about rainfall and temperatures was collected and assessed in maps. Soil agro productivity was also assessed using AGRO-24, for rice cultivation, as the main crop, and for tomato, maize, and beans, as possible species for crop rotation.

Quality assessment of water was made by composition analysis to determine classification and possibilities of use in three categories: Superior (quality I), First (quality II), and Second (quality III), according to the NC 1048: 2014 applied.

RESULTS AND DISCUSSION

Evaluation of the main factors causing salinity

Topography

Low plain and low swamp plain, located to the south of the municipality of Los Palacios, encompassed in the south plains of the province of Pinar del Rio. Sloppy low and slightly fluvial–marine dissected plain, with a flat south area, especially swampy, with low fertile soils caused by salinity, gleying, erosion, rock formations and concretions. The ground water is shallow and it complements the topography of the terrain. Drainage of highland water salts may raise the ground water level to the surface of low lands, causing a temporary flow, or forming permanent salty lakes. Under such conditions, the ascending flow of ground water or evaporation of surface water lead to saline soils (Richards, 1974), cited by Leonardo *et al*., (2009).

Soils

The predominant soil is ferrallitic gley or ferruginous nodular gley (Hernández, *et al*. 1999), in which reduction and/or oxidation processes alternate depending on the permanent or transient water saturation in the profile. Hence, the soil takes gley properties observed in the top 50 cm of depth, so the soil becomes gray-red-yellowish, brown-reddish, and yellow-reddish, with dark manganese and iron nodules with variable hardness. These are shallow soils, partially saturated, with a slightly acidic pH in KCL, and low O.M. tenors. Inner drainage is also poor, mostly caused by the emergence of an impermeable clay layer 25 cm deep.

Irrigation methods

The traditional irrigation method applied to rice is through gravity, with very low application and conduction efficiency (30-70%), and there are no adequate measuring systems for distributed and applied volumes. This irrigation method commonly uses water in excess, causing losses due to percolation, and subsequent fluctuations of ground water levels in areas where natural drainage is very poor because of the very flat fields without natural water elimination. These fluctuations, along with high rates of evapotranspiring (Leonardo *et al*., 2009) make the soluble salts rise and accumulate on the soil surface, producing salinization.

State of irrigation and drainage systems

Secondary and tertiary conduits suffer considerable water losses, since most canals are not coated against leaks, causing superficial water flows. Water conduction efficiency on dirt canals have been estimated as 70 - 80%, (IMTA, 2001) cited by Leonardo *et al*., (2009). The percent of wasted water caused by percolation, and the water diverted for irrigation annually are two of the main reasons for superficial water flows.

Evaluation of natural factors

The absence of drainage maintenance (Fig. 1) is a problem that sometimes changes from its drainage condition into a reloadable source, back into the ground water.

Figure 1. State of drainage and irrigation canals

Soil coverage

In general terms, the areas covered with sickle bush predominate to the extent that there are no native sites in the area. Besides the main crop and the invading species, there is no evidence of other species over the vast plain, excluding the river banks and concrete remains of the *Mamposton* Hunting site.

The recently sickle bush-cleared soils still had rice remains from previous harvests, which work as mulch to protect against evaporation in the soils and in favor of washing. Spontaneous vegetation was also observed to have burn spots in sites not covered by the mulch.

The study area has little tree coverage, loss of natural mangroves due to agriculture, cutting, poaching, introduction of exotic invading species, hurricanes, etc.

The loss of biological diversity was apparent, as a consequence of birds on rice fields, airborne practices, soil, water, and airborne degradation and pollution caused by pesticides, herbicides and fungicides.

Climatic variables

Fig. 2 shows the behavior of rainfall and temperatures in the municipality of Los Palacios, with temperature values higher in the plains and lower in the mountains, depending on the altitude.

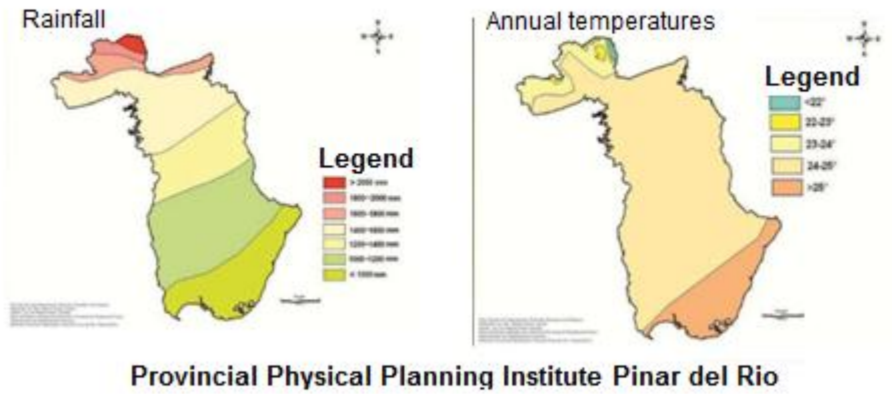

Figure 2. Behavior of rainfall and temperatures in Los Palacios

On the contrary, the rainfall values have historically been lower in coastal areas and higher in the mountains or adjacent areas. These two conditions favor salinization, which is added to the poor conditions of drainage and irrigation canals, thus speeding soil degradation. In addition to it, the records for the last 12 years of rainfall in the area tended to a decrease.

Quality of water for irrigation

Electric conductivity has been the most widely used parameter to estimate salinity. It relies on the speed electric current moves through a saline solution, which is proportional to salt concentration in a solution. Therefore, EC shows the concentration of soluble salts in the dissolution, and it is a very useful parameter to estimate quality; it provides crop assessment of toxicity with the corresponding osmotic effect and yield decline at high concentrations.

Table 1. Chemical composition of water used for irrigation

Indicators	Irrigation water	Assessment cut off (superior quality)
Electric conductivity (dS.m-1)	0.26	0.56
Dissolved soluble salts (mg.L-1)	179.38	< 360
Adjusted RAS (mmol.L-1)0.5	0.33	< 8
Na+1 concentration (mmol.L-1)	0.4	3.0

Cl+1 concentration (mmol.L-1)	0.8	4.0
Concentration of residual carbons (mmol.L-1)	-1.69	< 1.25
Mg_2+ percent (%)	0.94	< 50

The chemical composition of the water used for irrigation supplied from reservoirs and suitable Electric Conductivity values (EC below 0.56 dS. m-1) (Table 1) was classified as superior quality, or quality I, with no restrictions or limitations for use on any crop (NC 1048: 2014). Moreover, dissolved soluble salt concentrations (SSD) below 360 mg.L^{-1} for soil cluster II corroborate the excellent quality of the water for irrigation in the studied areas.

Nevertheless, the ground waters supplied from local wells classified as poor quality, according to NC 1048: 2014, with electric conductivity (EC) higher than 5 dS.m^{-1}, not suitable for irrigation, and classified as a controlled source of pollution.

Assessment of soil agro productivity

In the spatial distribution of agro productive categories for winter rice and their minimum potential yields (Figure 3) most soils are category III, with strong limitations and minimum potential yields of 2.2 t. ha^{-1}.

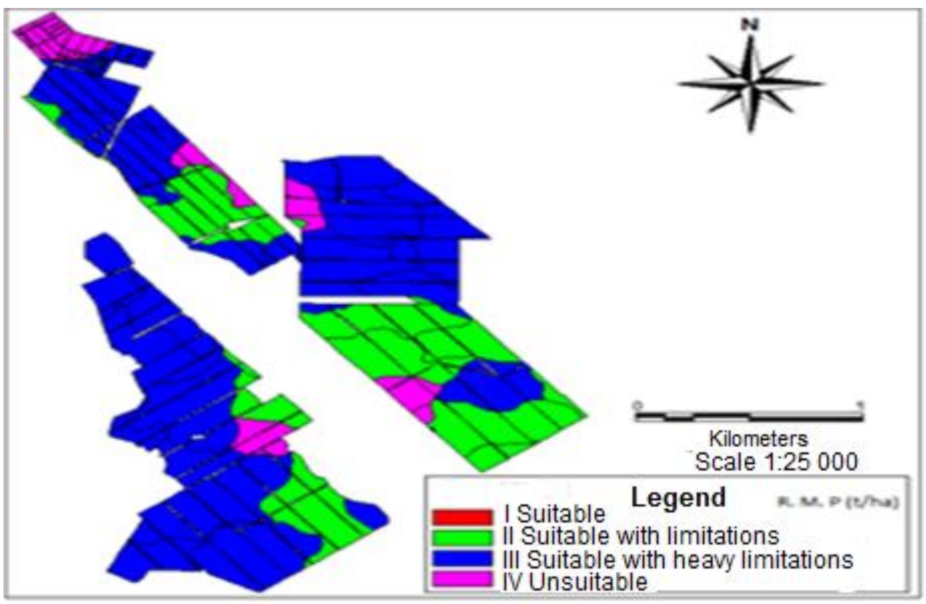

Figure 3. Soil agro productivity for rice in the studied area

Generally, soil agro productivity for tomato is category III, with strong limitations (drainage, pH, OM, effective depth, and minimum potential yield of 5.4 t. ha^{-1}.

CONCLUSIONS

The area studied is a potentially saline, fragile ecosystem, with natural and landscaping values worth preserving in terms of ecology and sustainability.

Damage is evident in the coastline and the sub-coastline stripe, mostly caused by invading animals and plants, which have become contaminating elements in the area. Additionally, extreme climate elements, like hurricanes have had a negative impact.

The main causes of soil salinization are, saline superficial ground water, inefficient irrigation methods, water loss during conduction and flat topography, and inadequate state of drainage and irrigation canals.

Some components in the system are altered, such as, the poor state of drainage and irrigation canals, utilization of areas under height 5 and little use of higher areas.

The halt placed on well-water use, the implementation of irrigation with high quality water, and the invasion of sickle bush (natural barrier), have contributed to a withdraw of soil salinity, to less than 3.5 meters above sea level.

RECOMMENDATIONS

Mangrove recovery works along the coastline must be done to rehab the canal and drainage network, implement crop rotation, eliminate double rice harvest, preserve soil coating in areas less than five meters above sea level, and perform constant monitoring and evaluation of the local salinity. Also, the drainage network must be fixed and investment must take place in water supply efficiency systems.

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