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INTEGRATED MANAGEMENT FOR THE SUSTAINABLE USE OF SALT-AFFECTED SOILS IN CUBA

Manejo integrado para el uso sostenible de los suelos afectados por salinidad en Cuba

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RESUMEN. Las principales causas y fuentes de la salinización de los suelos de Cuba, su extensión y distribución por Provincia, la definición usada para describir los suelos salinos, el impacto ambiental y económico de la salinidad en el país y las soluciones tecnológicas empleadas para combatir dicho fenómeno se analizaron en este ensayo. Se discuten algunos aspectos sobre el Plan Nacional para el mejoramiento y manejo de los suelos afectados, así como las necesidades de investigación y cooperación internacional. Se concluye que los estudios desarrollados en Cuba han permitido diagnosticar la fase actual del proceso de salinización de los suelos. Sin embargo, aun es necesario recopilar, validar y almacenar suficientes datos de calidad que sean susceptibles de verificarse o calibrarse según un sistema de información geográfica para desarrollar un plan estratégico de recuperación. Además, es necesario el desarrollo de un sistema de alarma temprana para la dirección y toma de decisiones que permita prevenir el avance de la salinización y dar seguimiento al impacto de las tecnologías de rehabilitación y manejo de los suelos afectados. La elaboración y ejecución de proyectos nacionales e internacionales de ayuda técnica y económica son imprescindibles para: 1) incrementar la eficiencia del plan de acción contra la salinización, 2) aumentar la productividad de la tierra, y 3) proporcionar empleo local en actividades complementarias a la producción agrícola.

Palabras clave: suelos, salinización, uso sostenible, Cuba

ABSTRACT. The main causes and sources of the salt-affected soils in Cuba, their extension and distribution by Province, the definition used to describe the saline soils, the environmental and economic impact of the salinity in the country, the technological solutions use to combat this phenomenon are pointed out. Some aspects on the National Plan are discussed for the improvement and handling of affected soils, as well as the research requirements and the international cooperation. It is concluded that the studies developed in Cuba have provided evidence on the current phase of the salinization process of soils. However, it is still necessary to gather, validate and store sufficient reliable quality data susceptible to be verified or calibrated according to a geographical information system in order to develop a strategically recovering plan. In addition, it is necessary to develop an early warning system to prevent the spread of salinization and to establish techniques of improvement, management and rehabilitation of salt-affected soils. The execution of cooperative national and international projects of technical and economic assistance are essential to: (1) increase the efficiency of the national action plan against the salinization, (2) enhance the soil productivity, and (3) provide local employment in complementary activities to the agricultural production.

Key words: soils, salinization, sustainable use, Cuba

INTRODUCTION

Cuba is a small country with 110 992 km^2 (11.09 million ha). It is located in the Caribbean Sea, between 19 - 23° N, and 74 - 84° E. Its climate is tropical with rainfalls. It receives about 1 145 mm per year; 24 °C is the mean temperature and 60-80 % the relative humidity. The population is almost 11 million, with more than 80 people per km^2. Projections for the country show that, for the year 2020, the population will remain stable (Urquiza *et al.* 2000).

Agricultural activities account for 30-35 % of the gross domestic product and support 65 % of employment. This kind of activity has an important role in the Cuban economy, and it will continue to play a vital role in achieving self-sufficiency in food, in reducing rural poverty and in fostering economic development at least for the foreseeable future. The total agricultural land in Cuba extends to 7.09 million ha, mostly for sugar cane, rice, coffee, tobacco and pasture production. Most of the agricultural land undergoes various degradation processes: 46 % of it is affected by low and unbalanced fertilities, 69 % is low in organic matter content, 31 % is affected by wind and water erosion, 24 % has acid soils, and 14% is saline (Urquiza et al. 2000).

Soil salinity is a phenomenon that negatively affects the agricultural production, because it sensibly reduces the crop yields. Moreover, when soil salt concentration is very high, it makes the soil totally unproductive. This problem is presented in one million ha of the total agricultural lands, and it constitutes a potential phenomenon for other 1.5 million of ha (Obregón 1990; González-Núñez 2000). Such situation is complex as the salt-affected soils occur in the plain territories of the Island, where the technical agricultural operations are more feasible, and where the majority of the rural population lives. Hence, the Cuban government has invested and will invest in numerous research projects, rehabilitation, managing and conservation programs of the salt-affected soils.

The present review analyses the extent, causes and formation processes of salt-affected soils in Cuba, to point out the necessity to develop a National Management Program and to generate a reliable database for the monitoring of areas by a geographical information system (GIS) to implement in the future adequate rehabilitation programs and practices.

DEFINITIONS TO DESCRIBE SALT-AFFECTED SOILS IN CUBA

Since the beginning of the 20th century, the most diffused and generalized soil classifications around the world, according to saline soils, were the ones edited by the russian pedologists, who divided the saline soils in three main groups: Solonchak, Solonetz and Solod (Guerasimov and Glazovskaya 1960). An important advance was the soil classification proposed by the American scientists where saline soils are divided in three groups: saline (according to Solonchack), alkali soils (according to Solonetz), saline-alkali soils (according to Solod). Later, Follet *et al.* (1981) and Abrol *et al.* (1988) proposed a new division for the American classification: saline, sodic, and saline-sodic. This last categorization was easily related with the soils classifications used around the world. Currently, this classification (Table 1) is used in Cuba and in the rest countries of the world (Flores *et al*. 1996; Mashali 1999; Anonymous 2000).

Table 1. Salt affected soils classification.
Tabla 1. Clasificación de suelos afectados por sal.

Characteristics	Soils Type		
	Saline soils	Sodic soils	Saline-sodic soils
EC of the saturation extract	< 4 dS/m	> 4 dS/m	> 4 dS/m
Exchangeable sodium percentage (ESP)	< 15	> 15	> 15
pH	< 8.5	8.5-10	< 8.5
Relationship between pH and ESP	Not well defined	Clearly defined	Not well defined
Dominant soluble cation Na	Na	Na	
Bivalent cations	Considerable quantities of Ca and Mg	Less quantities of Ca and Mg	Considerable quantities of Ca and Mg
Presence of soluble calcium components	Meaningful quantities of gypsum.	Gypsum is absent	Meaningful quantities of gypsum.
Clay fraction	Floculated in presence of excesses of natural soluble salts	Hy dispersion	Floculated in presence of excesses of natural soluble salts
Structure	Stable	unstable	stable

EXTENSION AND DISTRIBUTION OF SALT-AFFECTED SOILS IN CUBA

The areas affected by salinity are shown in the New National Atlas of Cuba (Obregón 1989) in a scale of 1:25000, using a legend from 1 800 ppm total soluble salts to 7 200 ppm and more. They also distinguish salt accumulation at the surface and at depth. The techniques for mapping salt-affected soils and the permissible soil salinity limits of specific crops were described by Obregón (1990).

The salinity maps are mostly isoline maps, which employ the newest techniques, such as contemporary salinity sensors and geostatistics (Tóth *et al*. 1997). González-Posada *et al.* (1999) used 250 x 250 regular grid sampling in the Cauto Valley. They observed the ranges of spherical semivariograms between 650 and 1100 m. At smaller distances, other ranges were found, which showed the composite effects acting upon salinization (López *et al*. 1999). The natural vegetation as saline pasture is an indicator for predicting soil salinity (Tóth *et al*. 1997).

The Cuban climate is considered humid, with very humid zones in some mountain areas, and semi-humid in the valleys of the east of the country and some coastal zones (Ortega 1986a). The semi-arid climate, in which solonchak soils are found in their total developed stage, can be found only in a narrow band of the southern coast of the Guantanamo Province. This situation indicates that nearly in all territory, the climate must favor the natural salt leaching and not their accumulation. The observations carried out on the Guantanamo Valley during several years demonstrated this hypothesis: since annual rains reaching nearly 700 mm, the trend was toward the natural leaching of salts in 1 m depth from the soil layer surface (Klimes-Szmik & Nagy 1975). In spite of the above-mentioned observations, at present is common to find saline soils in Cuba.

In Cuba, salinity affects negatively the agricultural production as it causes a decrease in crop yields, and the greater salt accumulation makes the soils unproductive (Obregón 1990; González-Núñez 2000; Valdés 1996). Therefore, more than 20 % of the agricultural areas are in danger of salt affectation (this calculus must be carried out from 6 097 838 ha that are not yet saline). Although 35 000 ha are not saline yet, but they can be affected by the rise of saline water table; 650 000 ha could be affected by the

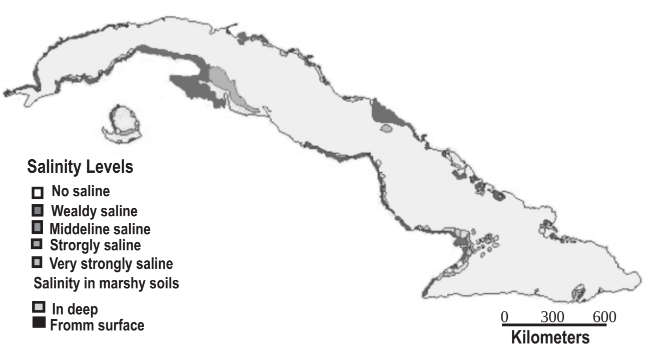

Figure 1. Map of Salt-affected areas in Cuba.
Figura 1. Mapa de areas afectados por sal en Cuba.

Table 2. Salt affected agricultural areas (in thousands of hectares) in Cuba. S_2, weekly saline (0.09-0.19% of SST); S_3- moderately saline (0.2-0.39% of SST), S_4- strongly saline (0.6-1.0% of SST) and S_5- very strongly saline (>1.0 % of SST).
Tabla 2. Áreas de agricultura afectadas por sal (en miles de hectáreas) en Cuba. S_2, débilmente salina (0.09-0.19% of SST); S_3- moderadamente salina (0.2-0.39% of SST), S_4- fuertemente salina (0.6-1.0% of SST) and S_5- muy fuertemente salina (>1.0 % of SST).

Province	S_2	S_3	S_4	S_5	Total
Isla de la Juventud	5.9	1.6	2.1	0.7	10.3
Pinar del Río	34.4	6.2	2.9	10.5	54.0
La Habana	9.8	3.0	2.6	0.6	16.0
Matanzas	4.2	12.0	1.2	0.0	17.4
Cienfuegos	1.5	0.2	0.4	0.0	2.1
Villa Clara	51.0	7.9	5.4	16.9	81.2
Sancti Spiritus	53.5	26.0	17.8	2.7	100.0
Ciego de Avila	31.2	14.1	19.8	12.0	77.1
Camagüey	61.9	32.5	41.0	10.7	146.1
Las Tunas	28.4	5.9	4.5	2.3	41.1
Granma	79.0	59.4	64.1	24.8	277.3
Holguín	87.6	36.7	35.7	20.5	180.5
Santiago de Cuba	16.3	3.6	1.3	0.2	21.4
Guantánamo	10.9	4.8	10.5	1.4	27.6
Total	475.3	213.9	209.3	103.3	1002.1

marine intrusion; and 550 000 ha are in danger, due to the use of irrigation water with high sodium content (high SAR) or with high mineralized water. In total, it is estimated that 1 235 000 ha are in danger of being damaged; that will cause the appearance of salinity or alkalinity in places, where today it is not yet appreciated. This problem can be observed at Ciego de Avila red soil plain, the northern part of Matanzas, Manacas, The Cienagas de Zapata contiguous areas, and Maisi. The distribution of salt-affected areas in Cuba is shown in Figure 1, and the classification by Provinces is presented in Table 2.

Within the potentially saline areas, it is recommended to correlate the percentage of the total cultivated country territory against the percentage of swamps and marshes. Among these, occupy 650 000 ha and are not included, 60 or 100 thousand are already saline. Moreover, the peat exploitation can cause sea intrusion, which has an effect on some wetlands and contiguous lands. However, these would not be in real danger if some protection measures against the sea entry would be followed by adequate conservation practices. As a consequence, the agricultural use of the desiccated peat-bogs must be made with great technical rigor to avoid their salinization.

CAUSES AND FORMATION PROCESSES OF SALT-AFFECTED SOILS IN CUBA: SALT SOURCES

Marine pulverization

The marine aerosol has influenced hundreds of kilometers off the coast (Sharma 1998). This fact, as well as the extensive coastal areas located in Cuba, has produced serious salinity problems. The idea that marine pulverization has great importance in Cuban soil salinization (Ortega 1986a). It has been supported by the high sodium levels detected on the analysis of the exchange complexes of some of the soils (Klimes-Szmik & Nagy 1975).

Ancient marine sediments

From the superior Jurassic to the beginning of the Cretaceous, there was a shallow sea in the northern part of central Cuba where the conditions for evaporating sediment formation were favorable (Ortega 1986a). The great amount of the gypsum and common salt manifestation in Cuba soils is associated to those sediments. Through the transition, between the Oligocene and Miocene, similar conditions existed in southeastern Cuba, where saline sand stones and gypsum became sediment. These saline sediments were considered the principal cause of soil salinization in the eastern extreme of the country (Hernández 1982). In spite of their extension, these saline soils cover was not large, since the saline sediments were covered by younger sequences.

In wet or semi-humid tropical climatic conditions, during weathering and soil genesis, the salts released from these sediments were leached and drained into the sea, diminishing the possibilities of saline soils formation from alluvium of these materials.

The groundwater circulating in those sediments was enriched with salts. If groundwater reached rivers, the mineralization increased, and if that water infiltrated deeper zones, the water table and soil would be affected by salinity. For example, in the semi-humid region of the Guantanamo Valley, saline areas ocurred from the existent geology as the emerged water gets through the saline sediments.

Continental sediments of the Quaternary

During the Pleistocene glacier (Ortega 1986a), Cuban climate was substantially dryer than the current one. In depressional zones with arid climate part of its load was lost. This favored the continental accumulation of Pleistocene saline sediments in the Cauto-Guacanayabo depression, Guantanamo Valley and the northern part of the Central Provinces.

The Holocene rains caused the salt leaching of the surface soil covers, also causing extremely low permeability of these soils and sediments, and the saline layers were maintained in depth. The depth of saline water table was from 10 to15 m in remote zones from the coast, but near it , the depth of saline water was less than 2 m. The thickness of saline sediments could surpass 50 m in the west zone of the Cauto Valley, where sedimentation was in synchrony with the moistening along the Pleistocene period (Ortega 1983).

The seawater intrusion of the karstic aquifers opened to the sea

Calcareous rocks constituted the 75 % of the Cuban territory and the most of these became sediments in the Miocene. Those calcareous rocks have been strongly karstified through 10 million years that have passed since they emerged. The karstification occurred also in later glacial periods, when the sea had not reached the current level. Thus, under the sea, a cavernary system was found (Ortega 1986a). Near the coast, the underground water is always a little bit saline, as a consecuense of the direct communication of the sea with the cavernary system that is found under the sea level.

NATURAL SALINE SOILS

In Cuba, natural saline soils occupy narrow areas, associated with the muddy zones nearby the sea. Salinization is typically caused by hurricanes, due to the influence of the sea during unusual tides. The peat and calcareous sediments, which constitute most of the Cuban seaside wetlands, have intermediate salt concentrations. The saline peat is fibric type and mostly originated from the *Cladium jamaicense* peat formation; usually the sapric peat has a low salt content and is found in places farther from the sea (Núñez 1968; Obregón 1985; Obregón 1990). The next prevailing soil in the wetlands is the marls, formed by quite pure carbonate. The salinity degree varies in wide ranges, depending on the sedimentation conditions of marls.

In the southeastern part of the Guantanamo Valley, as well as in small coastal valleys of that province, the average yearly precipitation is less than 700 mm; therefore, it is possible to find fully developed solonchak soil of primary origin. These can be found in small areas where brackish water emerges or saline sediments are present. Such cases are found in the Guantanamo Valley and Yateras Valley (Klimes-Szmik & Nagy 1975).

In the southeastern part of the Guantanamo Valley, saline-sodic soils can be found, without structural B -horizon. These soils are considered to be formed from natural leaching of ancient solonchak soils, which have been produced by the intensive rains at the beginning of the Holocene period. In this same zone, as well as in regions located towards the northwest, grayish brown soils can be found with secondary carbonates (Obregón 1985) and brown soils with secondary carbonates, those which possess a dense B horizon and this horizon could be a fingerprint of an ancient solonetz horizon.

OTHER CAUSES OF SALT-AFFECTED SOILS IN CUBA

Natural saline soils occupy restricted areas, mainly in the coastal zone. In most of salt-affected soils in Cuba, salinity is secondary. Other causes are:

The highland deforestation

The forest ecosystems of the country occupied 80 % of the territory at the Spanish arrival (Borhidi & Herrera 1977; Ortega 1986a). The intensive exploitation of the forests began very early, as Cuba, during the XVI century, was an important shipbuilding industry; and afterwards the cutting of forests was even intensified in order to provide fuel for the sugar mills. From the beginning of the XIX century, coffee growing in the mountain zones was stimulated, therefore many forests were destroyed.

As a consequence of the intensive deforestation, the soil water regime was altered, soil erosion was intensified, and the rivers began to settle large quantities of clays and sand in the outlets and margins. This situation caused the floods to be more frequent, and on the other hand, the water table of the low zone was increased; therefore, the territory of the wetland zones increased, and the water table became saline and shallow, and the soils became salt-affected.

Coastal vegetation deforestation

There was a valuable tree growing, fundamentally *Hibiscus elatus*, which was forming keys in the high zones. For facilitating the exploitation of mangrove forests, channels were built from the XIX century to the end of the XX century to transport cut trunks to the sea. In dry seasons, these channels changed radically the water regime of the wetlands, as the soils were artificially drained and it began to desiccate, causing the capillary rise of salts into the soils. At the same time, the sea began to penetrate easier into the depresional zone that is found behind the coastal bar; and there, secondary coastal solonchak soils began to be formed. In the closed channels, where there is stagnant water good quality, the sea does not invade the land, but in the channels where the water flows, the sea penetrates very profoundly into the wetlands so the environment is affected by salinity.

Mangroves protect the outer edge of coasts and wetlands. The red mangrove (*Rhizophora mangle*) grows in the most external zone. This species was vastly exploited in the past, it was used it in the skin tanning industry. At the present time, the cutting of this tree is frequent in the coastal towns, since it is thought to be responsible for the mosquito proliferation. The next important plant species in importance is *Conocarpus erectus*, which almost disappeared from the coasts as its wood was used to bum charcoal. As a consequence, the coastal bar remained unprotected and in many zones the sea has destroyed it. The disappearing of the bar caused more frequent sea penetration and the salt wetlands increased (Labrada *et al*. 1995).

Use of saline water when seawater intrusion

The intensive exploitation of groundwater in karstic zone has permitted salinization. This problem began in 1950 in the Pinar del Rio Southern Plain, related with the rice production in the lands of agricultural companies. After the groundwater salinization, the company managers kept on watering the rice fields up to salinization made the crop unstable. With such practices, many lands of the south of Pinar del Rio were damaged.

The same problem began at that time and degree intensively in the south of Havana Province, because of the intensive use of irrigation in some crops of great water demand, and as a consequence of the new pumps implemented for the water supply of the city of Havana. The use of that water in the irrigation affected the soils, but in a smaller degree than in Pinar del Rio, since there the prevailing soils had better drainage.

This phenomenon was also manifested in the Ciego de Avila province, and it can occur in all the areas sustained on calcareous cavernous rocks, unless the use of the water designated for irrigation and the population supply was restricted. It is necessary to avoid the seawater intrusion, with the parental material as calcareous rocks and the origin of saline groundwater.

Water table rise

After the Cuban revolution victory the irrigation and construction of water reserves began; which has generated an increase in the salinized areas due to the salts raised from the groundwater table. The regions where this phenomenon is manifested coincide with the arid zone during Pleistocene, that keep large reserves of salt in the subsoil. This salts are fundamentally sulfate - hydrochloric, neutral or weakly alkaline. The groundwater table mineralization degree can reach 20-45 g/L (Ortega 1980). In this process Vertisols and hydromorphic heavy clay soils are mostly affected. In these soils, the water conductivity is very low and the capillary water ascends with great difficulty. In the dry season, the desiccation rate is faster than the capillarity processes preventing salts to reach the surface. The use of irrigation without drainage turns up the balance and allows the water from the water table to reach the soil surface and cause its salinization.

Use of poor quality irrigation water

The water of the river formed in saline sedimentary rocks or that receives water from these areas is frequently used for irrigation. In the eastern provinces, there are names as «Salty River», «Bitter Stream», and others indicating poor quality water (EC > 2mS/cm). In some cases, the good quality water is carried into the fields through channels, running along saline soil zones and therefore salinized. The increase of the use of industrial water for irrigation magnifies this problem, making necessary further control measures. In general, the use of poor quality water constitutes a potential danger, due to insufficient drainage of most of salt-affected soils in Cuba.

When soil desalinization projects are set up, it is necessary to carry great volumes of brackish water into the sea and there is a new problem emerging, related to the drainage outlet's course where the water is poured. In the provinces with remote saline areas from the coast, as Granma and Holguin, this will become a great problem. The Cauto River would be converted into a collector of drainage water. The use of the river water should be strictly regulated and checked in order to protect its quality. In Cuba, salinization has had an impact since salt-affected soils occupy fundamentally the plain areas, where the mechanization of the intensive agriculture was developed; and because in these areas greater rural populations are concentrated. Salinization induced by irrational irrigation with poor drainage in the Cauto and Guantanamo Valleys in the eastern part of Cuba, are examples of reduction of the acreage of agricultural land due to salinization.

ENVIRONMENTAL AND SOCIOECONOMIC IMPACT OF SALT-AFFECTED SOILS IN CUBA REDUCTION OF ACREAGE OF AGRICULTURAL LAND BY SECONDARY SALINIZATION

In Cuba, the use of inadequate agricultural practices has caused soil secondary salinization. 90 % of the salt-affected soil in Cuba is due to human-induced salinization.

Table 3. Recovery cost of salt affected soils in million of dollars
Tabla 3. Costos de recuperación de suelos afectados por sal en millones de dólares

Province	Recovery cost			
	Soils S_5	Soils S_3+S_4	Soils S_2	Total
Isla de la Juventud	4	6	3	13
Pinar del Río	3	12	17	32
La Habana	4	8	5	17
Matanzas	0	14	3	17
Cienfuegos	0	1	1	2
Villa Clara	102	19	25	146
Sancti Spiritus	17	62	26	105
Ciego de Avila	72	54	15	141
Camagüey	65	115	30	210
Las Tunas	14	15	14	43
Granma	148	188	40	376
Holguín	123	137	15	275
Santiago de Cuba	2	6	8	16
Guantánamo	9	26	5	40
Total	563 (39%)	663 (46%)	207 (15%)	1433

The continuous exploitation of soils with drainage problems and the use of saline water to irrigate rice areas in Granma have increased the salt soil levels causing the diminishing of areas or the low rice yields in others. The excessive water extraction at the wells of the Rice Enterprise “Sur del Jibaro” has motivated a water salt enrichment and therefore the well disabling. In addition, in soils with drainage problems and high water table, the addition of chloride and sulfate fertilizers have caused secondary soil salinization and affected the crops.

AGRICULTURAL PRODUCTION INFLUENCED BY SALINIZATION

In strongly salt-affected soils, the crop growth reduction, low yield and poor quality of agricultural production are common. Salinity restricts uptake of water and nutrients by crops (González-Núñez 1996). Moreover, high concentration of sodium and chloride ions has particular toxicity to crops emergence and growth. High or low pH of the soil caused by salinity also leads to the inhibition of crop growth and yield. In the Granma Province, crop yield reduction by salinization and sodicity Province is between 20-40 %, and in the Guantanamo Province yield reduction is more serious, ranging from 30 to 70%. Hence, high input asso-ciated to low output caused by salinization effects agriculture and the economy. The direct losses in the Guantanamo Province are annually estimated in four million of dollars (Klimes-Szmik & Nagy 1975; Ortega 1986b). This loss includes only damages in productive salt-affected areas, but excludes the loss originating on abandoned saline areas.

The crop adaptability to soils is influenced by salinity. Saline lands are not suitable for many salt-sensitive or moderately sensitive crops such as beans, corn and sunflower. Under high salinity, crops could die completely, or give a very low yield. Through breeding of salt tolerant species, planting of crops is possible in salt-affected land. However, there can be losses in quality and yield of crops. Salinization is often associated to poor fertility level of land. Photosynthesis of plant, its efficiency, and rate of protein

Table 4. Individual parameter variations after leaching, surface drainage, deep subsoiling and sloth application in the Guantánamo Valley (Valdéz 1996) (IC: Interchangeable capacity; I Ca P: Interchangeable calcium percentage; I Mg P: Interchangeable magnesium percentage; I S P: Interchangeable sodium percentage; I K P: Interchangeable potassium percentage).

Tabla 4. Variaciones de parámetros individuales después de lixiviación, drenaje superficial, aplicación lenta en subsuelo profundo en el Valle de Guantánamo (Valdéz, 1996) (IC: Capacidad de intercambio; I Ca P: Porcentaje de calcio intercambiable; I Mg P: Porcentaje de magnesio intercambiable; I S P: Porcentaje de sodio intercambiable; I K P: Porcentaje de potasio intercambiable).

Parameter	In the soil solution		The exchange complex	
	before	after	before	after
PH	6.90	5.30	-	-
EC dS/m	3.01	1.60	-	-
Ca mmol$^{(-)}$/100g	1.13	0.48	15.74	24.93
Mg mmol$^{(-)}$/100g	1.31	0.23	11.65	12.23
Na mmol$^{(-)}$/100g	3.68	2.04	4.72	3.20
K mmol$^{(-)}$/100g	0.02	0.03	0.35	0.26
Ca:Mg	0.86	2.09	1.35	3.04
Ca:Na	0.31	0.24	3.33	7.69
Mg:Na	0.36	0.11	2.44	3.85
Ca + Mg:Na	0.66	0.35	5.88	11.11
HCO_3 mmol$^{(-)}$/100g	0.76	0.96	-	-
Cl mmol$^{(-)}$/100g	2.00	0.68	-	-
SO_4 mmol$^{(-)}$/100g	3.39	1.49	-	-
HCO_3:Cl	0.38	1.41	-	-
HCO_3:SO_4	0.22	0.64	-	-
HCO_3:Ca + Mg	0.31	1.35	-	-
IC mmol$^{(+)}$/100g	-	-	32.05	40.89
I Ca P	-	-	49.11	60.97
I Mg P	-	-	36.35	29.91
ISP	-	-	14.73	7.83
IKP	-	-	1.09	0.64

accumulation of crops could be inhibited by low water and low fertilizer availability and specific ion toxicity associated with salinization, which makes poor quality of crops in varying degrees.

INFLUENCES OF SALINIZATION ON FORESTRY AND ANIMAL HUSBANDRY

Salinization has caused forestry and pasture degradation. The acreage of the Granma province is 277 181 ha. The largest area of salt-affected agricultural land in this province is located in the Cauto Valley, which at the same time represents an important agricultural zone in the eastern part of the country. Approximately 45 % of this Valley is dedicated to pasture legumes and forage for animal production. The Cauto Valley has registered considerable loss in total agricultural production, particularly in forage value, as large areas are severely affected by salinity. The degraded grasslands are characterized by less grass species (López *et al*. 1997) poor grass quality and quantity, low grass production, as well as thinner vegetation, influencing animal husbandry.

SOCIO- ECONOMICAL IMPACT

The consequences of soil salinity are manifested in terms of decline in agricultural production at national level, which affect gross domestic product. The rehabilitation cost of salt-affected soils is not easy to calculate, since it depends on the salt concentration and ion types, the level of the water table, hydrophysical soil properties, available technology, and reclamation materials among other factors. The rehabilitation cost of severely affected land in Cuba has been estimated in 6 000 dollars/ha, 2 000 for the strongly saline, 1000 for the moderately and 500 for the weakly ones. Hence, it is necessary to invest $1 500 million dollars (Ortega 1986b; García 1997) to recover the total salt-affected soils in the country (Table 4).

The rehabilitation of affected soils must be approached according to a strategic plan at national scale, taking into account the available resources and an investment recovery plan of reasonable periods. First the rehabilitation of moderately salt-affected lands must be carried out. The strongly salt-affected areas do not occupy more than 10 % of the total affected areas (1 % of the country agricultural areas), but their recovery would take 40 % of the financial resources and 60 % of the additional water for the leaching. Although the necessary expenses to eliminate salts of the weakly salt-affected soils do not surpass 15 % of the broader expenses, the increase in production will remain masked by the effect of additional complementary factors (leveling, parceling drainage, etc) that the agricultural company should compulsory carry out to improve production. Those areas should be improved gradually by the producers, employing the adequate cultural methods.

The principal prevention measures are the construction and rehabilitation of the drainage systems, parceling drainage, reconstruction of the irrigation systems that present problems, quality control of the irrigation water, sewage disposal control, and salinity monitoring. The conditions to make the evaluation do not exist yet, even there is a lack of studies on the possible costs. At the present, the investment of 4 million dollars annually would be totally justified, before the treat of investing at least 500 additional million in recovering lands that could be affected, and before additional annual losses of other millions dollars.

Besides the very significant impact on agricultural production, salinization also causes environmental and ecological problems. Although impact of salinization on environment shows differences in pattern and extent, the common character is that it leads to lower environmental quality and damage of natural resources directly or indirectly. Some impacts already exist and others show long term hazard and will appear in the future, including impact of salinization on soil properties and local resources, as well as on vegetation and climate, on environment of water resources, on touristic resources and on living natures.

TECHNOLOGIES APPLIED IN THE COUNTRY TO COMBAT SALINIZATION

It is imperative to adopt different amelioration measure and method to reduce the adverse effect of salinity on physical, chemical and biological properties of the soils, and to control soil fertility degradation, creating a sound ecological environment for a normal crop growth guaranteeing a rational exploitation of salt-affected soils and hence sustainable development of the agriculture. Therefore, selection of methods for reclamation and management of salt-affected soils should not only depend on the soils properties, but also take into consideration the natural conditions and social economy of the area which might affect the possibility and success or failure of the salt-affected soils reclamation and agricultural utilization.

In Cuba, the improvement policy for salt- affected soil has been fundamentally driven toward those soils with middle salt content. This policy include agricultural practices as soil leaching, the drainage system establishment, cultural methods to benefit these soils, and the introduction of intensive production systems in the case of soils devoted to the rice production. At the present time, Cuba has obtained experience and reasonable achievements in controlling soil salinization, thus laying down scientific basis for rational exploitation of the saline soil resources and agricultural development. The main solutions and technologies applied in Cuba for combating salinization and for using salt-affected soils include:

Establishment of drainage-irrigation systems: Soil salinization often occurs in areas with inadequate river hydrological and hydrogeological conditions for natural drainage. The drainage canals and field drainage engineering systems are applied for ameliorating and utilizing salt-affected soils. Soil salinization is quite common and serious in arid and semi-arid areas where irrigation is essential to combat drought. Likewise, the irrigation has two functions, one is to meet the water demand of crops, and the other is to leach salts out of the soil. The increase of the water volume diverted through the irrigation ditch system, and irrigation quota or to flood the soils intentionally to leach salts out requests a drainage system with suitable capacity to control groundwater table, hence to maintain water balance in the irrigation area.

Complete and rational drainage-irrigation systems are essential for salt-affected areas rehabilitation or to improve water-salt regime, to control the salt movement in the soil, preventing accumulation of salts in the soil surface, and accelerating steady desalinization, which in turn facilitate overall. In some areas of the country with inadequate hydrology for irrigation, and highly mineralized ground water, most saline areas have fairly rich fresh ground water resources, shallow or deep. In Cuba, in the last ten years, pump wells have been developed (30-70 m deep) in saline areas to use ground water resources for irrigation and setting up irrigation-drainage engineering systems with several combination forms of wells-ditches and canals that have contributed greatly to the management of salt- affected lands. The use of saline land and agricultural development is common in Cauto and Guantanamo Valleys.

Organic matter application to improve soil fertility

The increase of the input of organic matter represent one of the most important agrobiological measures to managing salt-affected lands, as it helps to improve soil physical properties, enhance salt leaching, reduce surface evaporation, and diminish salt accumulation in the soil surface. Organic matter available for use includes crop stems and straws, rice husk, green manure, barnyard manure, compost, and sloth. Long-term application of organic manure can ameliorate the saline land, and also increase the accumulation of organic matter in the soil and accelerate the surface soil layer maturation. The researches in salt-affected soils in the Cauto and Guantanamo Valleys showed that the mature surface soil layer has reached 15-20 cm in thickness. The soil organic matter content reached values over 1.6 %, which contributed significantly, to improving soil moisture, physical properties, reducing surface evaporation and diminishing salt accumulation in the soil surface (Valdés 1996; González-Núñez & Ramírez 2003). Besides growing green manure plants solely in the field, rotation, inter-planting and intercropping of pasture legumes can also be adopted to expand fertility, reduce salt accumulation, as well as to promote combination of agriculture with animal husbandry.

Draining and rice-planting

This is one of the traditional practices of reclaiming and utilizing saline land in Cuba. This practice usually does not need special leaching. After flooding the field with diverted water, rice can be planted and yield 4-5 t/ha/year. During the rice growing period, the field is often flooded, thus accelerating soil desalinization and increasing the desalinization rate. With the continuing rice-planting year after year, the desalinized soil layer in depth and in areas with better drainage facilities ground water is gradually desalinized. Research results show that by this practice, the mineralization degree of the ground water lowered between 1-3 g/L, the thickness of the fresh water layer increased to 2 m and soil salt content was reduced. After rice cultivation the land can be cultivated again with rice, pasture, legume crops or other rotation system.

When this measure is adopted in sodic soils, application of organic manure and chemical amendments such as gypsum, sulfuric acid, etc. helped to achieve better results. Planting rice to ameliorate salt-affected soils must be carried out under an integrated planning, and rice and upland crops are appropriate to prevent the soils from secondary salinization. It could be necessary to contrast this information with those done before of salinization in a rice culture with already salinized water and soils with bad drainage.

Use of salt-tolerant crops

Crops differ widely in their tolerance to salt stress conditions. A proper choice of crops is therefore very important, considering the soil conditions. To identify promising germplasm, the limits of stress tolerance in different crops have been studied in field and under controlled conditions in pots and microplots. Even planting or protecting natural halophyte vegetation also contributes for the further control of salinization of the soil; what is more, some of the salt-tolerant plants can be used as forage for animals and can be taken as the direct economic profit from saline lands. The claim effect of growing salt-tolerant rice varieties in saline and sodic soils is well known in Cuba (González-Núñez 1996; González-Núñez *et al*. 1997; González-Núñez *et al*. 2000).

Other management practices to reduce salinization

In the pilot areas of the Guantánamo Valley, it was possible to obtain yields from 152 to 218 t of sugar cane per hectare and from 21.07 to 30.93 t/ha of sucrose content

Table 5. Variations after leaching, surface drainage and sloth application in the Cayama zone (Otero *et al*. 1994) (I Ca P: Interchangeable calcium percentage; I Mg P: Interchangeable magnesium percentage; I S P: Interchangeable sodium percentage; I K P: Interchangeable potassium percentage; IC: Interchangeable capacity).
Tabla 5. Variaciones después de lixiviación, aplicación lenta en drenaje superficial de la zona Cayama (Otero *et al.* 1994) (I Ca P: Porcentaje de calcio intercambiable; I Mg P: Porcentaje de magnesio intercambiable; I S P: Porcentaje de sodio intercambiable; I K P: Porcentaje de potasio intercambiable; IC: Capacidad de intercambio).

Parameter	**In the soil solution**		**In the exchange complex**	
	Before	**After**	**Before**	**After**
PH	8.05	7.79	-	-
EC dS/m	3.26	1.28	-	-
Ca mmol$^{(-)}$/100g	0.42	0.58	17.60	21.24
Mg mmol$^{(-)}$/100g	0.23	0.26	5.80	7.26
Na mmol$^{(-)}$/100g	3.02	1.50	6.40	5.84
K mmol$^{(-)}$/100g	0.03	0.03	0.20	0.42
Ca:Mg	1.83	2.23	3.03	2.93
Ca:Na	0.14	0.39	2.75	3.64
Mg:Na	0.08	0.17	0.91	1.24
Ca + Mg:Na	0.22	0.56	3.66	4.88
HCO_3 mmol$^{(-)}$/100g	0.98	1.26	-	-
Cl mmol$^{(-)}$/100g	2.26	0.81	-	-
SO_4 mmol$^{(-)}$/100g	0.72	0.45	-	-
HCO_3:Cl	0.43	1.68	-	-
HCO_3:SO_4	1.36	3.02	-	-
HCO_3:Ca + Mg	1.51	1.62	-	-
IC mmol$^{(+)}$/100g	-	-	30.00	30.25
I Ca P	-	-	58.67	70.21
I Mg P	-	-	19.33	24.00
ISP	-	-	21.33	19.31
IKP	-	-	0.67	1.39

through hidrotechnical improvement (leaching and buried drainage), combined with the sloth application (100 t/ha) and deep subsoiling. The recovery progress was monitored during 66 days (Table 5). From the physical point of view, the applied treatments produced an increase in the soil permeability from 2.5 mm/h to 40-50 mm/h raising the infiltrated water volume below the root zone. In treatments, in which sloth was not applied, the subsoiling effect was eliminated quickly after the first leaching. This result indicated that the rehabilitation of these soils must be directed to control the mineralized groundwater regime in order to avoid secondary salinization and to maintain the trend of natural leaching in near-surface horizons. The infiltration speed should increase with deep subsoiling, combined with the sloth application. Therefore, the construction of drainage networks is indicated, so that soil is rehabilitated for natural route and to avoid that new areas are turned salt-affected.

In the Cayama zone, upon recovering soils with granulometric light composition with the capital leaching application (13 168 m^3/ha), surface drainage and sloth application (Otero 1993), the following variation appeared into a 0-1 m depth (Table 6).

At the present time, in the recovered areas the sugar cane yields are over 200t/ha respect to 120t/ha before the rehabilitation soil practices (Otero 1993), and some forage legumes as *Sesbania emerus* reach dry matter yields of 78t/ha (Mesa 2003).

The establishment of a package for the rehabilitation and management of salt-affected soils devoted to rice cropping is another example of the technologies applied in Cuba. This included optimum drainage parameters (drain spacing of 150-200 m with a 1.2 and 2.5 m of depth), subsoiling (distance between chisels 5 m at 40-60 cm of depth), an irrigation norm (15 m^3 of water/ha). The used of this technology permitted the leaching of 50-100 ppm of total soluble salt in the first irrigation (1 to 3) avoiding the puddles and lagoons formation in the soils.

Also, organic amendments (sloth and manure at the rate of 60 t/ha) and chemicals (calcium sulfate at the 20 t/ha rate) were applied and a new defined NPK fertilization formulation (161-100-50 t/ha). The joint application of the package has permitted the rice yields to increase from 1.5 to 4 t/ha, and that the advance of salinization was halted. Said technology has been introduced successfully in salt-

Table 6. Chemical soil properties at 0-40 cm depth, after biological amendment (SLR: Sugar liquid residue).
Tabla 6. Propiedades químicas del suelo a 0 – 40 cm de profundidad después de restauración biológica (SLR: residuo de melaza).

Parameter	Before leaching	After leaching	After cropping	To 3 months of the cropping	After 2 months of the cropping
		Water leaching			
% Na	10.67	4.92	6.67	6.92	14.77
Ca/Na	5.12	14.21	13.45	13.94	7.87
PH	7.52	8.85	8.32	8.50	8.70
% HCO_3	9.00	17.06	18.43	20.60	19.84
% SST	0.1657	0.1546	0.0705	0.1050	0.0898
		Leaching + 5 t/ha of rice husk			
% Na	11.19	5.97	-	5.05	7.44
Ca/Na	5.00	14.85	-	16.79	11.76
PH	7.70	7.30	-	8.05	8.55
% HCO_3	14.05	11.39	-	12.71	20.05
% SST	0.1712	0.1391	-	0.0862	0.0946
		Leaching + 5:125 t/m^3/ha sloth:SLR			
% Na	10.96	5.93	5.60	4.15	6.63
Ca/Na	5.60	10.14	11.11	18.93	9.98
PH	7.60	8.72	8.22	8.20	8.42
% HCO_3	14.00	21.29	20.20	23.42	22.74
% SST	0.1701	0.1063	0.1003	0.0830	0.1022
		Leaching + 30 t/ha sloth			
% Na	10.94	6.50	6.80	4.80	8.06
Ca/Na	4.80	9.39	7.31	10.30	5.90
PH	7.62	8.45	8.55	8.60	8.55
% HCO_3	10.00	7.39	14.96	15.41	10.86
% SST	0.1742	0.1957	0.1787	0.1802	0.1784

Table 7. Structural (C) and dispersion (K) factors of treated soils after leaching.
Tabla 7. Factores estructurales (C) y de dispersión (K) de suelos tratados después de lixiviación

VariantsDepth (cm)	**Leaching**		**Rice husk**		**Sloth:SLR**		**Sloth**		**Original**	
	C	**K**	**C**	**K**	**C**	**K**	**C**	**K**	**C**	**K**
0-40	14.78	85.22	62.96	37.03	36.71	63.28	46.73	53.27	31.64	64.44
40-100	65.15	34.84	81.14	18.85	84.63	15.36	87.37	12.62	41.66	58.34

affected areas of the Cauto Valley (more than 10 000 ha), in the state and private sector. In the same zone, but in sodic soils, the chemical amendments (gypsum pap and sulfur) that have been employed joing with leaching, reduce the water norm up to 47 %, with a consequent increase of Ca/Mg and Ca/Na relationships, and a decrease in Na/K ratio (Table 7). As well as with the biological amendments (sloth and rice husk), that application also achieved beneficial effects on soil chemical (Table 8) and structural (Table 9) properties, with rice yields increase as a consequence (Table 10). These demonstrative pilot areas have served to transmit the knowledge on management and this permitted to accelerate the assimilation of available technologies.

Currently, work is carried out in various national and territorial projects related to the following topics, which are sponsored and financed by the Cuban Ministry of Science,

Table 8. Influence of biological amendment in saline soils in rice yields (cv - coefficient of variability, SE - Standard error)
Tabla 8. Influencia de la restauración biológica en suelos salinos productores de arroz (cv – coeficiente de variabilidad, SE – Error estándar).

Treatment	Harvest		
	First	Second	Third
5 t/ha husk	6.65 [a]	6.47 [a]	5.07 [a]
5:125 t/m^3/ha sloth: SLR	5.71 [ab]	5.12 [ab]	4.47 [b]
30 t/ha sloth	4.51 [b]	4.82 [bc]	4.40 [b]
Water	4.43 [b]	4.17 [c]	2.73 [b]
cv	21.30	19.50	21.56
SE	0.707	0.061	0.082

Table 9 Biological mass and NPK vegetative content of the legumes with better behavior in saline soils (González-Núñez & Ramírez 2003).
Table 9. Contenido vegetativo NPK y masa biológica de las legumbres con mejor comportamiento en suelos salinos (González-Núñez & Ramírez 2003).

Legumes	Green mass (t.ha^{-1})	Dry Matter (t.ha^{-1})	N(kg.ha^{-1})	P(kg.ha^{-1})	K(kg.ha^{-1})
Sesbania rostrata	11.4	1.39	25.0	2.95	13.24
Cannavalia ensiformis	9.2	0.82	30.0	5.20	22.60
Crotalaria juncea	10.54	1.00	42.0	2.50	14.62

Table 10. Soil behavior after treatment (pH, exchangeable sodium percentage and salt content as electrical conductivity) (González-Núñez & Ramírez 2003).
Tabla 10. Comportamiento del suelo después del tratamiento (pH, porcentaje de sodio intercambiable y contenido de sal como conductividad eléctrica) (González-Núñez & Ramírez 2003).

Treatments	Soil before treatment			Soil after treatment			Yield(t.ha^{-1})
	pH	EC (ds.m^{-1})	ESP (%)	pH	EC (ds.m^{-1})	ESP (%)	
T-1 Control	7.9	8.32	1.50	7.8	8.35	1.48	10.52
T-2 Leaching	7.6	9.42	1.36	7.4	5.14	1.04	16.30
T-3Leaching+organic matter	7.7	9.34	1.72	7.6	4.53	1.02	19.22

Technology and Environment: (1) information system, monitoring and integral technology to preserve the soils from salinity and the impact of possible climatic changes in some agroecosystems with current and potential problems of salinization, (2) parameters of most important chemical and technical indicators to define the improvement of saline soil productivity in Cuba, and (3) alternative methods of rehabilitation and management of sodic soils in order to ensure stable and economically sustainable rice production.

OTHER ISSUES FOR CONTROLING SALT-AFFECTED SOILS

The government, scientists, extension services, and farmers play important role in controlling salt-affected soils in Cuba. In regions where salt-affected soils are spread, local government institutions at different levels are responsible to reclaim and use salt-affected lands. Scientists put forwards technologies and measures as well as set demonstration experiments for the control of salinity, based on experience and practice. The extension services make the demonstration in large scale and work on the extension of the technologies to the farmers. The government encourages the participation of all institutions in the control of soil salinization.

The legal aspects related to the control of salt-affected soils in Cuba appear the 2nd February 1993 in the 179 decree as one of the principal national legislations related to the environment (González & García 1998), specifically on protection, use and soil conservation. It is necessary to emphasize that such law states that any new system or management practice must protect the soil against salinization, in spite of property distribution, land tenure, and use intensity. Before the rehabilitation of the salt-affected lands, a planning strategy adapted to avoid environmental effects, economic losses and social conflicts, is required.

The irrigation in salt-affected areas with an inadequate drainage system is not permitted according to the application of the law in Cuba. However, in the case of these soils, in the Genetic Enterprise "Manuel Fajardo", in the Granma Province, the adoption of other practices such as the preservation and multiplication of the existent biodiversity and the forest repopulation encouragement, assuring the regulatory tree effect on the water and climate could also be recommended. In other places, where the soils are strongly saline and the recovery task results very expensive; the lands have been turned from cropland into pasture for cattle raising (López *et al*. 1997; González-Núñez *et al*. 2002; González-Núñez & Ramírez 2003).

At a governmental administrative level, the regionalization of integrated management and the prevention of salinization are considered under scientific and practical basis for fighting the soil salinity problem. Such regionalization can be conducted at different scales for different purposes: small scale regionalization is often used for administrative macro-scale decision-making of high level governmental bodies, while moderate scale regionalization can be used for references in management and control of salinization for other areas. In Cuba, some successful regionalization has been contributed significantly to the management and use of salt-affected soils.

In Guantanamo and Cauto Valleys, which are densely populated zones and have most of the salt affected soils, the fundamental objective has been to introduce gradually a rehabilitation and management system that permits to stabilize the local populations, to improve their living conditions, and to prevent environmental damages.

In addition to the efforts of the Cuban government, technical and economic assistance is required and will be required, through international co-operation projects based on the planning of the land-use at community level, to fight this phenomenon, to increase the soil productivity and to provide local employment in different, but complementary activities to those of agricultural production.

RESEARCH REQUIREMENTS

For the control of the salinization process, the planning of recommended practices is hampered because of the lack of information to support decisions on most appropriate options to be applied for land and soil management. The following aspects must be covered:

Monitoring of soil salinity and development of models for the prediction of salinization

A salinity monitoring system should be created to suit spatial variance and a dynamic change of salinity due to alterations of climate, vegetation, soil-forming conditions and human activities. Middle or large-scale lysimeter studies are necessary to apply fundamental research on salt-water dynamics and on the formation of secondary salinization. Remote sensing and GIS techniques can be used as tools for middle and long-term monitoring of salinity evolution and even prediction of secondary salinization. Based on information and data collected from a survey, monitoring and remote sensing, some practical computer model should be developed for salinity assessment and prediction, using GIS and by simulating different management activities under different land utilization patterns (González-Posada *et al*. 1999).

Optimal technological systems for use and management of salt-affected soils

The development of effective techniques for the control and management of salinization, as well as the establishment of a set of practical models to suit various bioclimatic zones and social-economical regions are valuable research areas. The irrigation management of salt-affected or potential salt-affected soils, land management with the use of brackish saline water, exploitation of salt-affected lands leading to sustainable agricultural utilization, biotechniques in salinity management and agriculture, and countermeasures of secondary salinization should be emphasized. The model should be integrated with as many choices of techniques of salinity management as possible, to be suitably used in different natural conditions, management patterns, agricultural layouts. Efficiency, reliability, cost, practicability of techniques and model should be considered mostly. Because of the soil salinization susceptibility, in Cauto and Guantánamo Valleys, such model and technique system should be developed in more detail. Development of an expert system from the output of above mentioned model would be desirable. Based on the scientific experience and numerical simulation of processes, such expert system could instantly recommend a set of optimal management measures and practical techniques for the control of soil salinization, through the use of relevant input information to the expert system (González-Núñez & Ramírez 2003).

Multiple-objective decision making supporting system

Control of salinization and management of salt-affected soils does involve not only natural, but also in social, economical and environmental aspects. In most situations, not all those aspects could be arranged to the optima. Therefore, a system should be developed to assess, analyze and compare all advantages and disadvantages of those aspects, and to help on decision making in an optimal manner. The multiple-objective decision making supporting system can be integrated with objectives of current economical benefits, long-term sustainability of development, resources utilization and management, and environmental compatibility. Such system will be designed to support decision-making at various levels and for different purposes.

Salinization and environment interaction

Human-induced salinization has certain impact on environment, ecology, and agriculture. Large-scale water projects usually have greater impact than others, because such projects cover a wide area and make significant alterations of regional salt- and water dynamics. Therefore, alteration of regional salt- and water dynamics and their regulation, and countermeasures of the negative impact of such projects on agriculture and environment, and regulative countermeasures should be focused on. The sea water intrusion due to sea level raise caused by greenhouse effects or by other human activities is also included in this project.

NATIONAL AGRICULTURAL PLAN AND INTERNATIONAL PROJECTS FOR THE IMPROVEMENT AND MANAGEMENT OF SALT-AFFECTED SOILS

The plan emphasizes the importance of maintaining the physical integrity and production capacity of these soils and the prevention of the ecosystem balance alteration. The Cuban government provides the credit and technical assistance for this plan. Several public and private institutions are involved in the plan execution, that stimulate the training of farmers for the conservation and management of salt-affected soils and to generate conservation services in the local, provincial and national areas, taking into account the possibilities and needs of each zone within the country.

COOPERATIVE PROJECT WITH FAO

Currently, the improvement and management of salt-affected soils devoted to pasture, specifically in the Cauto Valley in the Granma province, has been developed in the "Jorge Dimitrov" Institute through a cooperative project with the FAO. This project entitled "Salt affected soils rehabilitation in the Cauto Valley, Cuba" started in January 1999 and its strategy is the use of legume pasture species for animal production. The main objective of that project is to strengthen field experimental programs and the extension of appropriated management techniques for increasing productivity of salt affected soils in Cauto Valley as well as increase farmer income through a sustainable production of pasture legumes species for livestock.

A botanical census of the species and the isolation of *Rhizobium* strains from legumes were carried out to characterize and to evaluate the genetic diversity for salt-tolerance. The selection of the more effective combinations *Rhizobium*-legumes based on the salt effects on germination, growth and dry matter yield for different pasture legumes. In Jucarito, an area was selected (soil 1) to evaluate 51 legumes species trough the determination of some physiological parameters as : green and dry biological production ; nitrogen, phosphorus and potassium soil levels as incomes after legumes sowing. The results showed that *Sesbania rostrata*, *Cannavalia ensiformis* and *Crotalaria juncea* were the species of better behavior in saline soils, with the highest biological mass production and nutrient incomes to the soil (Table 11). Then, *Sesbania rostrata* was selected in a research carried out in the same experimental area where the soil was leveled with laser and divided in three parts, to evaluate three treatments : T1- control ; T2- leaching (130mm) before sowing ; T3- leaching (130mm) before sowing and application of organic matter (40 t/ha). In that research the potentialities of the legumes as saline soil amendment were approved (Table 12).

In Jiguaní, another area was selected (soil 2) divided in five equal parts (2000m^2), they were evaluated four rhizobium- legumes combinations but without soil leaching: T1- Control; T2- *Leucaena leucocephala* – strain Jd15; T3 –

Table 11. Effect of the rhizobium-legume combinations on pH and soil salinity (González- Núñez & Ramírez 2003).
Tabla 11. Efecto de las combinaciones de rhizobium-legumbre sobre el pH y la salinidad del suelo (González-Núñez & Ramírez 2003).

Combinations	Soil before treatment			Soil after treatment		
	pH	EC (ds.m^{-1})	ESP (%)	pH	EC (ds.m^{-1})	ESP (%)
Control	8.3	10.00	1.34	8.30	10.02	1.34
L. leucocephala - strain Jd15	8.0	9.77	0.90	7.80	5.14	0.54
S. rostrata – strain Jd14	8.3	15.34	0.22	8.00	4.53	0.11
M. atropurpureum – strain Jd10	8.0	8.32	1.50	7.90	6.23	0.80
C. ternatea - strain Jd19	7.9	9.28	1.00	6.50	7.40	0.62

Table 12. Soil behavior after treatment (pH, exchangeable sodium percentage and salt content as electrical conductivity) (González-Núñez and Ramírez, 2003).
Tabla 12. Comportamiento del suelo después del tratamiento (pH, porcentaje de sodio intercambiable y contenido de sal como conductividad eléctrica) (González-Núñez y Ramírez, 2003).

	Soil before treatment			Soil after treatment			
T reatments	pH	EC (ds.m^{-1})	ESP (%)	pH	EC (ds.m^{-1})	ESP (%)	Yield (t.ha^{-1})
T-1 Control	7.9	8.32	1.50	7.8	8.35	1.48	10.52
T-2 Leaching	7.6	9.42	1.36	7.4	5.14	1.04	16.30
T-3Leaching+organic matter7.7	9.34	1.72	7.6	4.53	1.02	19.22	

Table 13. Effect of the rhizobium-legume combinations on pH and soil salinity (González- Núñez and Ramírez, 2003).
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	Soil before treatment			Soil after treatment		
Combinations	pH	EC (ds.m^{-1})	ESP (%)	pH	EC (ds.m^{-1})	ESP (%)
Control	8.30	10.00	1.34	8.30	10.02	1.34
L. leucocephala - strain Jd15	8.00	9.77	0.90	7.80	5.14	0.54
S. rostrata – strain Jd14	8.30	15.34	0.22	8.00	4.53	0.11
M. atropurpureum – strain Jd10	8.00	8.32	1.50	7.90	6.23	0.80
C. ternatea - strain Jd19	7.90	9.28	1.00	6.50	7.40	0.62

Sesbania rostrata- strain Jd14; T4- *Macroptilium atropurpureum*- strain Jd10 and T5- *Clitoria ternatea* – strain Jd19. In this experiment the effectiveness of the rhizobium - legume combinations were demonstrated by the reduction of salts dissolved in the soil (diminishing of electrical conductivity and the exchangeable sodium percentage) respect at control (Table 13).

Finally, the studies accomplished in Cuba have permitted to verify the current stage of soil salinization; however, it will be necessary to gather, validate and store sufficient reliable quality data under a GIS in order to carry out a strategical recovering plan. There is also a requirement to develop expert systems and an early warning system to prevent the spread of salinization and to improve management and rehabilitation techniques of salt-affected soils.

Considering the requirements and possibilities to produce foods for Cuban people for the future, it should be emphasized the improvement of management, conservation and exploitation systems for affected areas by salinity, particularly those areas with potential possibilities for food production. Thus, it is necessary to rationally increase and use inputs, especially water.

The establishment of cooperative national and international projects for technical and economic assistance will improve the efficiency of the national achievement to reduce the saline areas with the increase of soil productivity, providing local employment in several agricultural complementary activities.

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