Int. Symp. on Salt Affected Soils, Cairo, Egypt, 22-26 Sept. 1997.

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SALT BALANCE METHOD AS A TOOL TO EVALUATE SOLUTE TRANSFERS IN SOILS. Case of reclaimed soils in the Lower Casamance (Senegal).

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Introduction

Saline soils cover large areas in all continents and under all climatic conditions. The worldwide growth of irrigated farming often leads to a secondary increase in saline soils linked to the physical and chemical soil degradation and to inadequate irrigation. It must be possible to give an evaluation of salinity in cultivated soils with sufficient accuracy so as to avoid its negative effects on the agricultural production (RHOADES, 1984; SZABOLCS1 1989, GHASSEMI et al., 1995).
From 1989 to 1991, saline and acid sulphate soils in the lowlands of Djiguinoum (Lower Casamance) were reclaimed. Two rice-growing areas have been constructed in these sterile soils in order to show that the water management of an antisalt dam has a direct influence on their productivity. For this purpose, impounded waters have been drained off so that their chemical quality should be consistent with an adequate rice growth. The agronomic results obtained in terms of yield have been conclusive for several years (MONTOROI et al., 1993 ; MONTOROI, 1996).
However, they raise a few questions concerning their durability.

- Salts can be removed in a soil profile according to several ways : dissolution and removal by runoff waters and/or drainage waters... Can such processes be identified and evaluated ?
- Even though human action carried out in the dam proves to be effective on the general desalinization of lowlands, do some adequate cultivation techniques allow to strengthen it ?

In order to answer these questions, we make use of the salt balances.

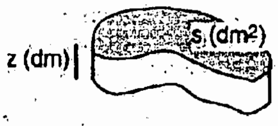
Materials and methods

Given a soil volume V (expressed in dm^3), the salt reserves Ms (expressed in g) contained in this volume V are calculated by the relationship :

$$Ms = CD_{ss}\,V_c = CD_{ss}\,H_v\,V \qquad (1)$$

where CD_{ss} is the dissolved salt content of the soil solution (in $g\,L^{-1}$),
V_c is the volume of water (in dm^3) contained in the soil volume V (in dm^3),
H_v is the volumetric water content (in $dm^3\,dm^{-3}$).

Given the sizes of the volume V, namely the thickness z (dm) and the area s (dm^2), the relationship (1) becomes :



$$Ms = CD_{ss}\,H_v\,z\,s\,.$$

The salt balance is established by calculating the variation in salt reserves (Δms) between two given periods. We have applied this principle to a given soil profile.
Two cases, a bare soil and a tilled soil, were studied in simulated conditions after antisalt dam waters were evaporated during dry season. The experiment was carried out with three rainfalls (60 mm during 1 hour) spaced by a 24 hour drainage. The last rainfall was higher (120 mm) for the tilled soil. Before and after experiment, soil cores was sampled for salinity (soil solution extract method) and water content (gravimetric method) measurements.
Bare soil case : considering a cubic volume (z = 1 dm, s = 1 dm^2), the salt reserves are calculated by cumulative method for a profile of 1 m in depth (z = 10 dm). In the upper soil volume, we have added the salt amounts of runoff water and the salt content of the soil volume.
Tilled soil case : we have considered a ridge cross-section which is 1dm thick, 5 dm deep, 5 dm wide in the top part and 11 dm wide in the bottom part. Before and after rainfall simulation, we have described the salt distribution in cross-section with four electrical conductivity (EC) classes (<3 dS m^{-1}, 3-5 dS m^{-1}, 5-10 dS m^{-1}, >10 dS m^{-1}). The cross-section area is divided in five horizontal layers. Each EC class occupied a part of the layer (s in dm^2) and determined a soil volume of 1 dm in thickness. We have calculated the salt reserves by cumulating the salt amounts of soil volumes for one layer and the salt amounts of all the layers.

For both profiles, the upper soil horizon was well-structured and 5 dm deep. Clay content ranged from 70 to 75 percent with a silt fraction of 20 per cent and pH value varied from 3.5 in the upper part to 2.5 in depth. The groundwater level was situated at 1.2-1.4 m with a pH of 4 and an electrical conductivity of 16 dS m^{-1}. Salts were precipitated on the surface and formed a weak crust mixed with clay particles.

Results

Desalinization of a bare soil profile under simulated rainfalls :

- The time evolution of runoff water shows that the last two rainfalls get a runoff coefficient close to 100 % (98 % and 97 %) and that steady flow (100 % of runoff) is reached within 10 mn. In the first rainfall, runoff is less, with however a high coefficient (74%). Steady flow is never reached.

The total amount of salt removed by surface runoff decreases with the successive rainfalls. It is twice less considerable between the first rainfall (about 380 g) and the third one (about 190 g). At the end of the experiment, the total amount of salt removed from the 1 m^2 plot reaches 822.2 g.

- In soil profile, given an area of 1 dm^2, a decrease in the amount of salt is observed at the upper layer (18.5 g), while it increases in the underlying layers (8.1 g). Therefore, salts transferred downward. In the first 35 cm, the cumulative salt balance shows a salt loss amounting to 2.2 g. This negative balance hardly varies in depth.

Desalinization of a tilled soil under simulated rainfalls :

Before rainfall, salts are accumulated in the ridge and interridge surface layer. Salinity increased from 1-2 dS m^{-1} in depth to more than 10 dS m^{-1} in surface. After rainfall, salts are distributed in the whole profile and salinity ranges from 2 to 7 dS m^{-1}. The upper layers are less saline and salinity has increased in depth.

For the considered ridge area, salts reserves have decreased by 56.9 g. When we interpolate this value to a 1 m^2 soil area, the decrease amounts to 517.3 g of salts. Compared with a bare soil, this amount is more than twice higher.

Conclusion

Salt balances allowed to identify the processes leading to accumulate salts in the lowlands of Djiguinoum and to quantify the short-term impact of the antisalt dam.

The prevailing salt transfers at the soil surface are due to the alternate periods of soil moistening and desiccation. An impermeable salt crust is formed between rainfalls and the salt and water movements are governed by the soil surface feature before each rainfall. In ridgy soil, vertical and subvertical flows are the main process and salts can be remove from soil profile by drainage.

The soil physical development plays a significant role on the internal salt movements. Vertical transfers are stimulated by the crack network. The space distribution of salts in the structural peds show that the crack network contributes to the transverse movements of solutions, to their concentration and dilution.

Therefore, the quantification of salt transfers is an interesting approach to evaluating the influence exerted by agricultural developments and to accounting for the soil dynamics in time and space. However, the weighted salt contents remain indicators for the calculations do not take account of the variability of salinity and moisture within the soil volumes considered.

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SUSTAINABLE MANAGEMENT OF SALT
AFFECTED SOILS IN THE ARID ECOSYSTEM

Cairo, Egypt, 22-26 September, 1997

ABSTRACTS VOLUME

Organized by :
UNIVERSITY OF AIN SHAMS
INTERNATIONAL SOIL SCIENCE SOCIETY

The organizing committee would like to thank Prof. **Dr.** ***Fouad Hanna*** **Soil dep. Fac. of Agric. Cairo Univ. Egypt, for preparing this valuable manuscript.**

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INTERNATIONAL SYMPOSIUM ON SUSTAINABLE MANAGEMENT OF SALT AFFECTED SOILS IN THE ARID ECOSYSTEM

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ORGANIZED BY

THE UNIVERSITY OF AIN SHAMS
(FACULTY OF AGRICULTURE, DEPARTMENT OF SOIL SCIENCE)
THE INTERNATIONAL SOIL SCIENCE SOCIETY
(ISSS, SUBCOMMISSION - A)

IN COLLABORATION WITH

THE MINISTRY OF AGRICULTURE & LAND RECLAMATION
FOOD AND AGRICULTURE ORGANIZATION (FAO)
EGYPTIAN SOIL SCIENCE SOCIETY (ESSS)

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The organizers want to express their gratitude and acknowledgement to the above Institutions and sponsors for making the Symposium possible.

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