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STUDY OF FACTORS ACTING ON REFLECTANCE OF SALT AFFECTED AND ACID SOILS SURFACES IN CASAMANCE (SENEGAL)

FIRST RESULTS

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Study of factors acting on reflectance of salt affected and acid soils surfaces in Casamance (Sénégal) : First results

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ABSTRACT : Reflectances of surface states (vegetation, bare soils and water) of salt affected and acid soils are studied in a valley of Casamance (Sénégal). We used a SPOT simulation radiometer to make ground surveys on homogeneous choiced plots (20 m x 20 m). We defined 22 surface states by : coverage vegetation, soil color and roughness. Relationships between surface states and some chemical characteristics as salinity and acidity of soils and water-table are often correct. On bare soils, external phenomenas (rain, eolian dust...) can disturb soils surfaces and so modifie reflectance. Surfaces color, moisture and secondary roughness are main factors acting on reflectance. The repartition of reflectance on graphs (channels XS1/XS2 and XS2/XS3) shows a linear correlation for bare soils. The repartition of surface states in 6 groups gather various corresponding soils: others measuring will be necessary to improve that classification. These first results need to be repeated and extended in similar valleys to help the thematic study of the next SPOT satellite imagery on this region.

RESUME : Les réflectances d'états de surface de sols salés et acidifiés sont étudiées sur une vallée de Casamance au Sénégal en distinguant 3 grands groupes de thèmes : végétation, sols nus et eau. Nous avons utilisé un radiomètre de terrain de simulation du satellite SPOT sur des parcelles de 20 m x 20 m considérées comme homogènes. 22 états de surfaces ont été définis par les paramètres : couverture végétale, humidité, couleur, rugosité. Les relations entre la végétation, les états de surface des sols nus avec les sols et les nappes sont souvent corrects pour les facteurs "salinité et acidité". Sur les sols nus des phénomènes externes comme les pluies, les poussières et l'érosion éolienne peuvent modifier les états de surface et donc la réflectance. La couleur, l'humidité et secondairement la rugosité sont ici les facteurs essentiels influençant la réflectance. La répartition des réflectances sur les diagrammes (canal XS1/XS2 et XS2/XS3) permet d'établir une corrélation linéaire pour les sols nus. Les états de surfaces peuvent être séparés en 6 groupes mais correspondent chacun à des sols variés. D'autres mesures radiométriques seront nécessaires pour améliorer cette première classification. Ces mesures nécessitent d'être répetées et étendues à d'autres vallées en vue des prochaines études thématiques à partir d'images SPOT.

1 - INTRODUCTION

Salt affected and acid soils of mangrove surroundings in Casamance, in South Sénégal are in extension under the influence of drought (BOIVIN et al., 1986). Vegetation and bare soils surfaces can reflect some soils parameters and particularly in this environment : moisture, texture, salts, water-table and sometimes acidity. Studies and seasonnal following of surfaces states will be done with SPOT satellite imagery (SAINT et al. 1983).

This tool seems adapted to observe these evolutive situations : damages on vegetation and rice-fields, soils salinization (MACHANDA, 1983) and acidification. A preliminary experiment to understand the signifiance of satellite spectral signatures is to make ground surveys with a truth ground radiometer : influence of surface states on reflectance, type and quantity of measurements necessary to characrize the relations between surface states and soils. Numerous studies have been realised with various radiometer (ARROUAYS, 1984, KING, 1984). This paper presents the first results obtained with a SPOT simulation radiometer in Casamance.

2 - MATERIAL AND METHOD

We have used a new truth ground radiometer (CIMEL CE 310) That simulates the spectral bands of the SPOT Satellite : Channels XS1 (500-590 nm, green), XS2 (610-680 nm, red) and XS3 (790-890 nm, near infra-red). This radiometer has two heads and gives direct measurements of the reflectance factor (or, reflectance) in percent : radiance on irradiance (or, their absolute value) without necessity to adjust zero or change gain (GUYOT, 1984).

The good stability of spectral measurements has been verified by daily tests on a white painting panel.

The coefficient of variation is lower than 1.5 % during one week, with a constant sunlight, without clouds. We have worked without difficulties 3 hours before and after the sun maximum. Vegetation (1.5m, maximum high for bush) don't induced great problems.

The radiometer is holded vertically 2 meters above soil surface. The surveyed surface is about 40 cm in diameter. The measurements are not affected on homogeneous plot by variations of altitude between 1 m and 3 m (on ground 20 and 60 cm in diameter).

Measurements are realized in front of the sun direction and we do not observe significant variations at 120° here and there of sun direction.

The experiment was conducted in april 1986 (end of dry season) on soils of a small valley (Koubalan in Casamance), partially flooded by sea-water. We have defined 3 main topics and 6 principal groups of surface states :

A - Soils partially or entirely covered by natural or cultivated vegetation :
1. active and 2. no active.

B - Bare soils (salt and acid or not) : 3. moist 4. dark, 5. clear.

C - Water : concentred sea-water - 6.

For each surface state, except water, (19, in all) we have delimited a representative plot of 20 m x 20 m (equivalent to the pixel of the SPOT Satellite) where we realize 20 measures with radiometer and 20 sampling of the surface horizon (0-5 cm). Surface state (0-0,5 cm) is described : vegetation coverage, soil color, roughness and moisture. We analyse samples at laboratory : moisture and, on soils extracts pH and electric conductivity (texture analysis is not ended). Soils and water-table are quickly caracterised with one sampling in the center of each parcel. Elementary statistic processing are used in this first analysis.

3 - RESULTS

The coefficient of variation (X) of reflectance measures is not very high on each plot : 10 and 2 % for natural vegetation and bare soils. So, average values of reflectance is used to characterize a surface state. The choice of homogeneous plot can explain that. Irregular repartition of rice straw involves a greater coefficient of variation (10 to 20 %). Surface states repartition on valley is showed on the figure 1.

On the figure 2 and 3 are plotted average reflectance (%) of each surface state characterizing a plot. The connection with some soils and water table parameters are on table 1, 2 and 3.

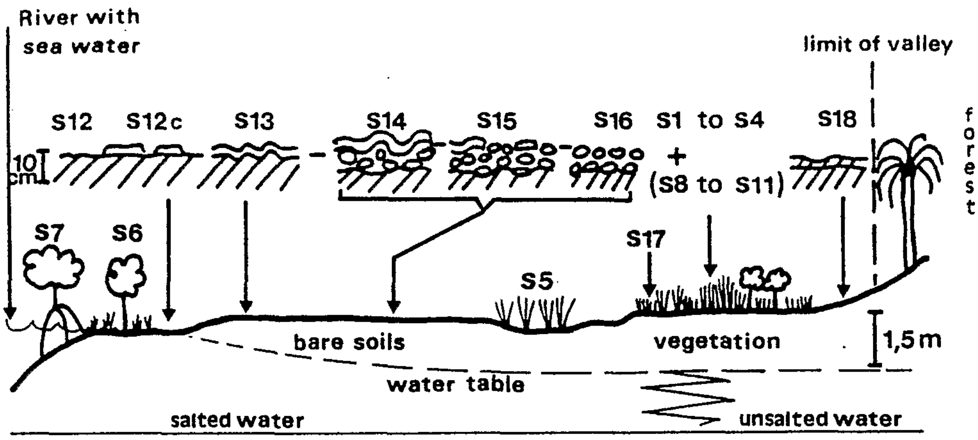


Fig. 1 - Transversal surface states repartition on valley.

1. Vegetation (Fig. 1,2 - Tab. 1).

Active and no active vegetation have a low response on the channel XS1. It increases a little on the channel XS2 and more on the channel XS3. This increasing is higher for active vegetation (surfaces : S1, S2, S3, S6, S7) corresponding to near infrared. Increasing of color, hue and chroma, makes decrease reflectance on the three channels (S5A, S5b). The coverage rate according to the characteristics of the bare surface can modulate these responses (S4, S5a). It is observed on rice fields with a low straw coverage (< 15 to 25 %). Hidging has not a great influence on reflectance (no shadow).

A rate coverage equals to about 25 % can be suffisant in our case to give specific response for dry vegetation. The color that reflects chlorophyllian activity seems the most important parameter acting on spectral response.

The relationships with soils chemical parameters are often very good : intensity of salinity, sometimes acidity. Active vegetation is only observed on unsalted soils with a shallow water-table, a little or not salted ; but a covering dry vegetation hide on interesting soil characteristics as moisture (S5b). Mangrove vegetation reflects specific soil environment : soil salinity equal to the one of sea water for Rhizophora flooded by daily tides, and salinity upper than sea water for Avicennia flooded only by highest tides. A lowering of water table induces irreversible decreasing of pH (< 4) and the formation of bare salt affected and acid sulfat soils (Fig. 1).

Figure 2. Average reflectance (%) of vegetation (● : active vegetation, +, ♦:no active vegetation)

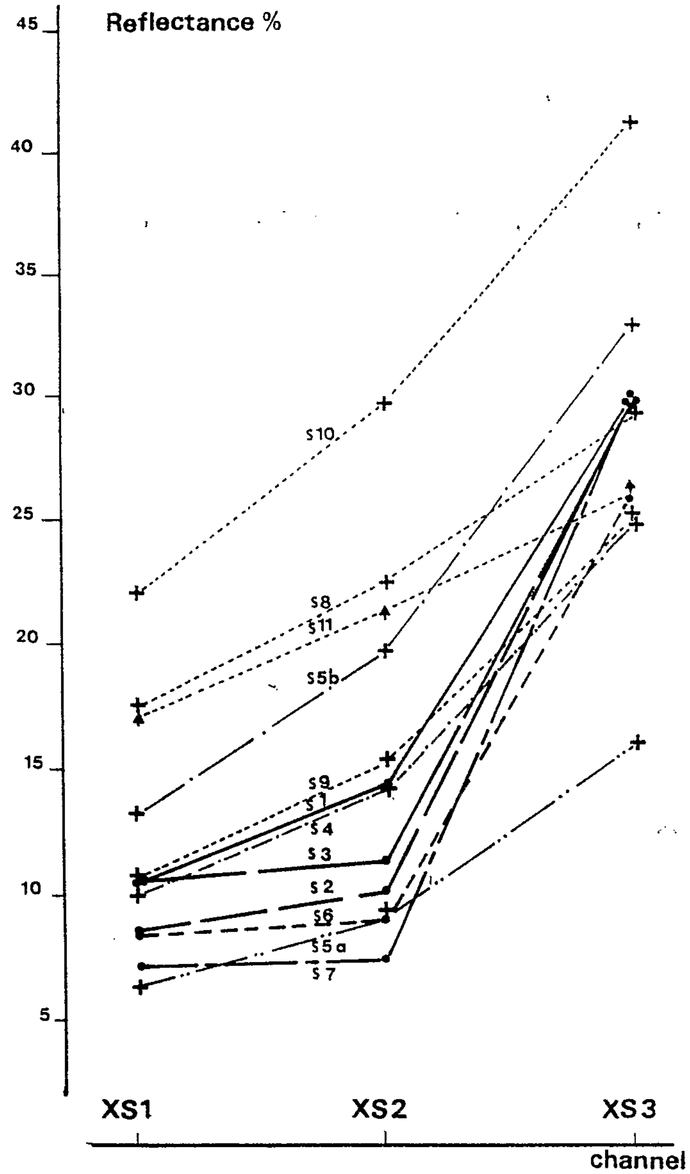


Table 1. Main relations between vegetation parameters and some average chemical characteristics of soils and water-table.

Vegetation

N° (group)	Surface states	Cove-rage %	Color (dominant)	Moisture 1	Soil* extract 1/5 2 (3)	Water table depth in m 2
S1 (●)	Bush	50	Green	1	1	< 1,5; 1
S2 (●)	Graminaceae (high)	60	Green	2	1 (2)	< 1,5; 1
S3 (●)	Graminaceae (low)	60	Green	2	1 (2)	< 1,5; 1
S4 (+)	Dry graminaceae	50	Brown	1	3 (2)	< 1,5; 2
S5a(+)	Cyperacene	80	Pale brown	1	3	> 1; 4
S5b(+)	Cyperaceae	95	Yellow	2	3	> 1; 4
S6 (●)	Avicennia (Mangrove)	70	Dark green	4	5 (2/1)	< 1; 5
S7 (●)	Rhizophora (Mangrove)	80	Light green	5	4 (1)	< 0,2; 4
S8 (+)	Rice straw on hidging Field	25	Palebrown,yellow	1	3	> 1; 4
S9 (+)	Fallow paddy-Field	95	Brown and Yellow	1	2	> 1; 3
S10(+)	Rice straw on Flat Field	95	Yellow and brown	1	2	> 1; 3
S11(♦)	Rice straw on Flat Field	15	Grown and yellow	1	2	> 1; 3

* Average on 0-150 cm

1 Moisture % (0-0-5 cm) ; 1 : < 5, 2:5-20, 3: > 20, 4: saturated, (5: Seo-water).

2 Electric conductivity mS.cm-1 ; 1: < 1, 2:1,-5, 3:5-10, 4:10-60, 5: >60

3 Soil acidity ; 1:potential acidity, 2:very low acidity (pH < 3,5)

2. Bare soils (Fig. 1, 3 - Tab. 2)

The muddy surfaces of the mangrove environment (S12 a,b) have low reflectances on the three channels due to its dark color and free water. A white saline crust appears when the surface is drying and makes reflectance increase. Moisture caracteristic is still observed on S3 (decreasing of reflectance).

The surfaces S13 to S16, are three examples of salted surfaces, saline crusts (sodium chloride) pure (S13) or mixed with soil are induced by successives cycles of moistering (rain or tide) and drying on bare soils with a salt shallow water-table. Saline crusts can be preserved during the dry season, entirely (S13, S14), or partially (S15). Salt crystallizations in surface horizon can induce a micro-aggregation (aggregates of 0,1 to 0,5 cm in diameter), from 1 to 10 cm in depth. On the third channel the presence of saline crust increases reflectance. The development of microaggregated horizon (more darkness and roughness) decreases it.

Brown eolian dust deposits can decrease (S19b) or increase (S14a) reflectance on the three channels according to the initial surface state color - "Acid sulphates" (S17) and "saline crust" (S13) surfaces have similar reflectance.

These elements can give some difficulties to understand relation between reflectance surface states and soils. Roughness is never very important, (it is rather micro-roughness). Data spectral reflectance on bare soils are influenced at first by color and moisture parameters.

About relation with soils and water-table (tab. 2) we remark :

* Bare soils, always moist, are potential acid sulfat soils but too salted for adapted vegetation of mangrove.

* Saline crust surface without micro-aggregates means that soils often sandy, are moist, even if saline crust is dry (S5) and water-table is shallow (1 m) and salted

* Micro-aggregated surfaces mean that the horizon surface is dry (on 20 cm), soil texture more clayed and water table often more depth and always more salted.

* Acid sulphates surfaces are an extrem expression of acidity in soils and water-table. It can give informations on moving of acidity along the valley. Vegetation disappears quickly.

3. Water

The reflectances (%) are the lowest of all studied surfaces. The sea-water is concentrated by evaporation, (E.C. 80 mS.cm^{-1}). A visible bottom increases reflectance on the three channels. Turbid water induces a falling on XS3.

N° (group)	Quality	Depth of bottom
S19a (■)	Clear	10cm
S19b (■)	Clear	50cm
S19c (■)	Clear	>100cm no visible
S19d (■)	Turbid	no visible

Table 3. Quality of sea-water.

Figure 3, Average reflectance (%) of bare soils (× : moist, ▲ : dark, o : clear) and sea water (■).

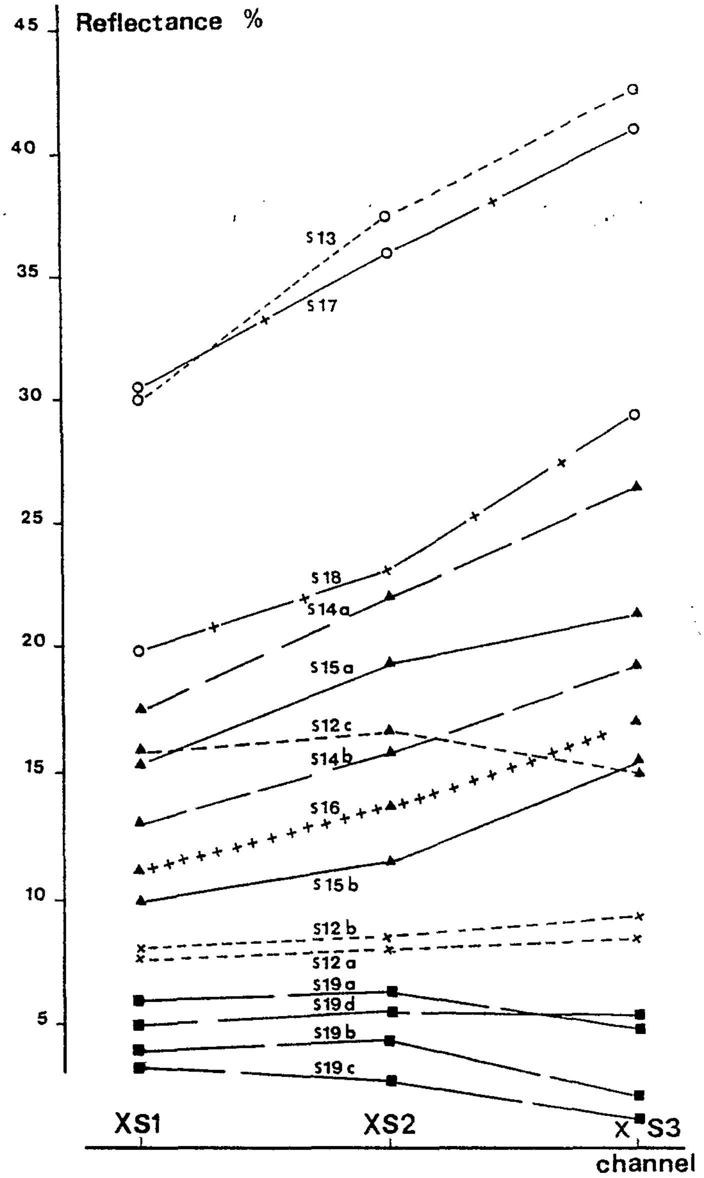


Table 2. Main relations between bare soils parameters and some average chemical characteristics of soils and water-table.

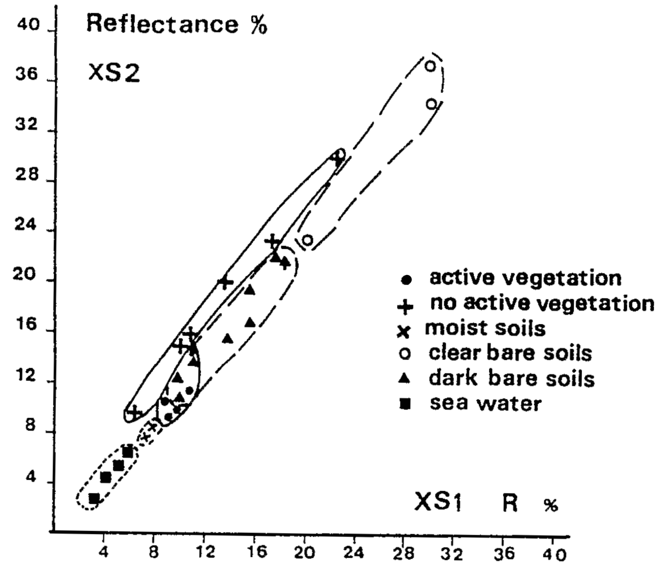
Bare Soils

N° (group)	Surface state	Color	Roughness 4	Moisture 1	Soil extract 1/5 2 (3)	Water-table depth in m; 2
S12a (×)	mud (Mangrove)	Dark grey brown	1	4	4(1)	0 ;4
S12b (×)	mud (Mangrove)	Dark grey	1	4	4(1)	<0,2;4
S12c (▲)	Saline crust (20%) on Sludge (Mangrove)	White and grey brown	1	3	4(1)	<0,3;4
S13 (o)	Saline crust	White	1	1	4	<1;4
S14a (▲)	Clear saline crust on micro-aggregates	Pale brown	2	1	4	>1;5
S14b (▲)	Dark saline crust on micro-aggregates	Brown	2	1	4	>1;5
S15a (▲)	Clear saline crust (60%) and micro-aggregates	Pale brown brown	2	1	4	>1;5
S15b (▲)	Dark saline crust (50%) and micro-aggregates	Dark grey brown	2	1	4	>1;5
S16 (▲)	Micro-aggregates	Dark grey	3	1	4	>1;5
S17 (o)	Acid sulphates	White and yellow	1	1	1(2)	>1;2
S18 (o)	Soil crust	Pale brown	1	1	1	>1;2

4 Roughness; 1: Low, 2: medium, 3: high

The figure 4 represents the six groups of surface states. They are compared on channels XS1, XS2, and XS2, XS3 graphs. The point "+" represents the rice-field with a low coverage of straw (S11), included in bare soils. They are better linearly correlated on XS1, XS2 than on XS2, XS3. These results are similar to spectral satellite data obtained with landsat satellite on similar channels (ESCADAFAL,1985) Active vegetation, mistaken with dark soils on XS1, XS2, defines on XS2, XS3 a perpendicular axis, often described by authors.

The points of the "no-active vegetation" group define a specific linear correlation on the two graphs.



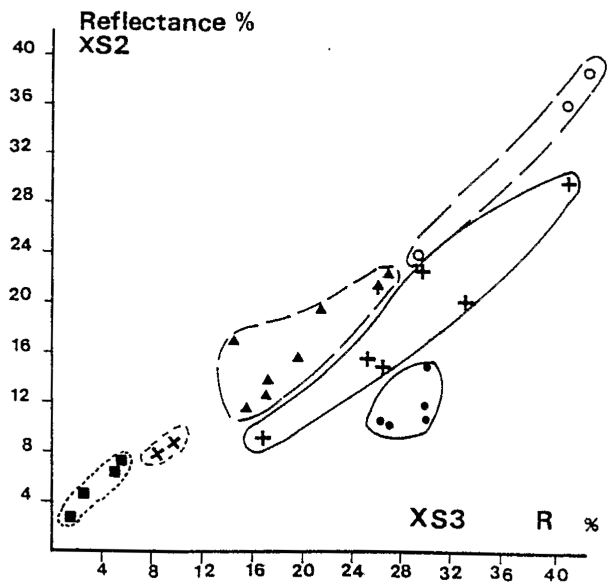


Figure 4. Repartition of reflectances on XS1, XS2 and XS2, XS3.

These six groups do not take into account important soils parameters as salinity, and can gather surfaces representative of soils affected or not by salt (for example, S13 and S17 in "clear bare soils"). More extended measurements will be necessary to improve the quality of this classification in relation with soils.

4 - CONCLUSION

A few reflectance (%) measurements (2 or 3) are only necessary to characterize an homogeneous plot. On complexe surface, frequent in nature, a balance between the different elementary surface, giving good results on hidging fields, must be tested.

Near infrared and visible spectral data are necessary to separate all surface states. Color, moisture and roughness secondary, are the surface states factors acting on reflectance. The most important chemical soils parameters for the region as salinity and acidity can be only studied and followed by theirs effects on surface states ; surfaces evolutions and reflectance variations consequently, due to external factors (rain, eolian dust) will need seasonnal and repetitive studies with radiometer and satellite.

These first results will be also continued on stability of spectral measurements with time and spectral correlation in several similar valleys of Casamance to obtain understanding keys about reflectance, surface states and soils relations with simultaneous radiometer and satellite measurements.

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