

Plant composition of a pasture as a predictor of soil salinity

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Abstract: The present vegetation of a 1100x2000m saline pasture in Oriente, Cuba, has been formed mostly under human influence. There are few native grasses surviving in the area and most of these are halotolerant species that live on marginal areas where the introduced fodder species cannot tolerate the high salinity. Authors found a close correlation between the electrical conductivity of the soil saturation extract and the plant composition of 252 sampling quadrats. Among the commonest grass species, the order of halotolerance from the least to the most halotolerant species was *Bothriochloa pertusa*, *Dicanthium caricosum*, *C. plectostachyon* and *C. nlemfuensis*, *Cynodon dactylon* and *Sporobolus pyramidatus*.

As a result of the limited number of plant species occurring, the strong abiotic stress caused by salinity, and the occasional waterlogging, the vegetation predicts the soil salinity status with acceptable precision. Both in discriminant analysis and through the use of arbitrary vegetation categories, the salinity category (<4, 4-8 or >8 mS/cm) of the soil was predicted with a precision of about 75%. The lowest salinity category (<4 mS/cm) coincided with the dominance of *Bothriochloa pertusa*, *Dicanthium caricosum*, *Cynodon nlemfuensis* and *C. plectostachyon*. The high cover of halotolerant species such as *Sporobolus pyramidatus*, *Sesuvium portulacastrum* and other halophytes coincided mostly with the highest salinity category (>8 mS/cm).

Because of the ease of distinguishing the vegetation categories and the straightforwardness of the technique, which does not require any specific statistical preconditions, authors suggest the use of the occurrence of halotolerant plant species to judge the salinity status of the pasture.

Key words: plant indication, halotolerance, soil salinity, electrical conductivity, discriminant analysis

The accumulation of salts in soils is a common natural process and several plants have developed mechanisms to resist high soil salinity. Inside one specific area the stresses caused by salts are often modified by the differences in water regime of the habitats, since the most influential factor in soil salinization is the water transport, as it carries the soluble salts. Therefore, on a slope inside an undulating saline area, at the bottom of the slope higher salinity and more abundant moisture is found, compared to the increasing scarcity of these two factors at higher positions on the slope. This kind of pattern in the abiotic ecological conditions has severe consequences for the occurrence of plants in saline grasslands, and

under natural conditions at specific salinity levels the plant composition is in a probabilistic relationship with the soil properties, most importantly soil salt concentration. Consequently, several attempts have been made to use the vegetation for predicting soil properties in saline areas (Kearney et al. 1914, Shantz and Piemeisel 1924, Magyar 1928, Ballenegger 1929 and Bodrogközy 1965).

In the present saline savannahs of Cuba the occurrence of grasses is largely determined by the introduction of forage species. After the colonization of Cuba cattle breeding became the most important agricultural activity of the Spaniards (Marrero 1951), and much of the widespread forests was cut. The original area of

savannahs estimated at 5-26% (Borhidi and Herrera 1977), has tripled over the centuries. Since before the arrival of the Spaniards there were no large herbivores living in Cuba the native grasses could not tolerate the newly imposed grazing pressure. The meat producers introduced grasses to improve forage growth, and in consequence, the plant species composition of the grasslands has been transformed. The salinised grasslands are now composed of salt-tolerant introduced grasses and of native grasses, partly originating from coastal areas, which can tolerate the stresses caused by grazing. Up to now no attempts have been made to use the plants of Cuban pastures to predict salinity levels in quantitative terms. Instead, the indicator significance of the plants was considered qualitatively and the opportunities afforded by the quantitative estimation of soil properties, as shown by Tóth and Rajkai (1994), Tóth et al. (1994, 1995), Kertész and Tóth (1994), Tóth and Kertész (1996), were not utilised. The purpose of this paper was to describe the vegetation of a saline pasture and to test simple techniques for predicting soil salinity from plant cover data.

MATERIAL AND METHODS

The study area: The study area is in the Llanura del Cauto-Alto Cedro, in the central eastern zone of the largest plain of the biggest river in the country, the River Cauto, at 20°23' N, 76°27' W. The climate in this region (see Fig. 1., after Borhidi 1991) is thermobixeric, i.e. during the year there are two dry periods, with a total of 5-6 dry months.

The area surrounding Bayamo is known to be one of the oldest and most important pastures of Cuba (Ribera 1757). The history of the study area includes periods of cropping alternating with grazing. Nowadays, the area is covered by grassland with some scattered trees, so it is representative of the most wide-spread artificial grasslands, where the previous vegetation has been intentionally and almost completely destroyed. Some plants, such as *Cynodon dactylon* and *Dicanthium caricosum*, are species typical of artificial monocultural pastures. From among the grasses introduced, the species *Pennisetum purpureum* (this is the most abundant), *Cynodon nlemfuensis* and *C. plectostachyon* can still be found.

Field and laboratory techniques: The study site is a 1100 by 2000 m rectangle in a large pasture (a fenced plot managed and utilized only for cattle grazing) with some farmhouses and sparse groups of trees. The area slopes towards the River Jiguani. The study site is too large to fit inside one management unit, but crosses several fences, and this increases

the complexity of the vegetation. The field measurements were carried out in January 1995 on six days of field work during a period of eleven days. The 252 sampling points were placed in a 100 by 100 m grid. The elevation of the sampling points (between 77 and 87 m) was read from a 1:10,000 scale topographic map.

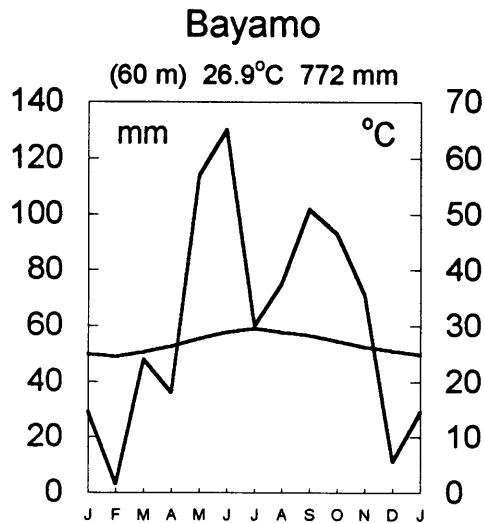


Fig 1. The climate diagram of a nearby meteorological station at Bayamo

The electrical conductivity (EC) measurements were carried out with a portable, direct current 4-electrode field conductivity meter, arranged in fixed array (Rhoades and Miyamoto 1990). At the sampling points EC was measured in three replicates inside one square metre by inserting the electrodes to a depth of 13 cm (to measure EC 0-40 cm) in the soil. Plant cover percentages were estimated for all species found in 0.5 x 0.5 m quadrats located in the centre of the surveyed 1 square metre at each grid point. This small quadrat size was chosen because inside the large patches of the pasture the vegetation was fairly homogeneous. Besides the quadrat records, all species found across the pasture were listed. Saturated soil paste was prepared according to Richards (1954), then centrifuged and decanted to give a saturation extract. The EC of the saturation extract was measured with a pocket EC meter. Based on the EC measured in the saturation extract and the EC measured with the field meter a calibration regression equation was calculated ($R=0.91$), with which the field values were transformed; therefore, all the EC values reported are expressed as the EC of the saturation extract for a soil depth of 0-40 cm.

Prediction of soil salinity based on vegetation data: Discriminant analysis and arbitrary categorisation of the quadrats was applied to predict soil salinity categories based on plant species coverage data. Discriminant analysis (DA) is a technique closely related to multiple regression analysis, which provides information on the predictability of which class individual cases belong to. DA quantifies the degree of separability of the established categories when the

categorisation is made with the linear combination of variables. The prediction performance is expressed in terms of classification precision, i.e. the ratio of diagonal frequencies of the classification matrices to the total frequency. This ratio is also reported in the case of homogeneous matrices with the same marginal frequencies, i.e. when there is no prediction, and the χ^2 measure of homogeneity is used, which is a more sensitive indicator of the prediction performance.

RESULTS & DISCUSSION

The composition of the vegetation of the pasture

Main grass species

Bothriochloa pertusa (L.) A. Camus is a native grass in Central and Southern Asia and India (Maheshwari 1963, Nair 1978, Bhandari 1978), and is widespread in tropical Africa, and in Arabia. In soils degraded by erosion it is very useful for revegetation (Whyte *et al.* 1967). It shows high adaptability to dry areas and many kinds of soils (Funes 1979) and can be established very easily. It was introduced into the southern part of North America and the West Indies (Pohl 1980). In Cuba it grows among the ruderal vegetation; it is an aggressive plant and tolerates a certain degree of soil salinity. It is useful as a ley species and also in pastures.

Dicanthium caricosum (L.) A. Camus has an optimum pH range of 6-7.5 and grows well in all kinds of savannah soils (Pastos y forrajes 1964). It originates from India, Burma and other regions of Southeast Asia and spread to Cuba in a period not known. This plant is aggressive, and endures drought and overgrazing. It is a useful plant in soil conservation (Pastos y forrajes 1964) and is esteemed as a good forage plant (Havard-Duclos 1968, Whyte *et al.* 1967), though Funes (1979) emphasises its poor growth in dry periods. In Cuba it grows spontaneously among other ruderal species.

Cynodon nlemfuensis Vander and *C. plectostachyon* (Schum.) are species which originate from South Africa. In the research plot they occurred on disturbed spots, such as shaded areas under trees where the cattle rest, and they have also been planted. Later in the text the term *Cynodon nleumfesis* is used to include *C. plectostachyon*, since the ecological requirements of the two species are similar.

Cynodon dactylon (L.) Pers probably originates from Africa. It is now cosmopolitan and there are several varieties distributed in Cuba (Funes 1979). It has a relatively profound root system, and is capable of resisting both moderate soil moisture deficit (Havard-Duclos 1968) and inundations (Pastos y forrajes 1964). The reported avoidance of acidic soils by this plant is controversial (Pastos y forrajes 1964, Havard-Duclos 1968), but there is a consensus regarding its resistance to medium or slight salinity (Havard-Duclos 1968).

Chloris barbata (L.) Sw resists medium or slight salinity (Havard-Duclos 1968) and grows on lower lying areas. It is esteemed as a suitable forage plant in Brazil (Havard-Duclos 1968), but Roshevits (1980) cites it among the important fodder grasses. From Mexico and the West Indies to Argentina it is a common weed (Hitchcock 1936). It is also found in Africa, Asia (Maheshwari 1963, Bhandari 1978), Australia and the Pacific Islands (Hafliger and Scholz 1980). According to Ricardo *et al.* (1990) and Pouyú *et al.* (1992) this species originates from tropical America, and has pioneer intraprophyte

characteristics in plant succession, i. e. it is a species which shows an explosive increase in individual plant number when there is an ecological change.

Sporobolus pyramidatus (L.) Konth is spread from the southwestern part of the USA to Argentina, West Indies and the Bahama islands in sodic or sandy soils close to the sea coast (Hitchcock 1936, Howard 1979). This genus is known for its resistance to high salinity (Havard-Duclos 1968), sodicity and inundation (Gay and Dwyer 1980). In Cuba it was collected in halophilic plant communities (León 1946).

Paspalum distachyon Poit lives in dry or wet saline or sodic soil, typically close to the sea coast (Hitchcock 1936). This is a native plant species in the West Indies from the island of Cuba to the island of Dominica (Howard 1979).

Main non-gramineous plant species

Spilanthes urens Jacq. (Asteraceae) is an indigenous plant of America (Mexico, Colombia, Brazil, Cuba, Jamaica, Hispaniola and Cayman Islands). It prefers moist areas (Liogier 1964). It is locally used as anodyne for toothache (Roig 1988).

Desmanthus virgatus (L.) Willd. (Mimosaceae) is a native plant in tropical and subtropical regions of the New World from Florida to Argentina. It was also reported from Punjab, India (Nair 1978). It is a palatable fodder species, is aggressive, persistent, tolerates heavy grazing and shows fast regrowth (National Academy of Science 1979).

Sesuvium portulacastrum L. (Aizoaceae) is found on sandy and rocky beaches in the West Indies, the Southeastern part of the USA, and the tropical regions of both hemispheres. It is edible and is sold in the markets of India and China (Sauget and Liogier 1951). Bhandari (1978) did not find it in North-Western Rajasthan, where it was reported earlier, but it is wide spread in other areas of India.

Trianthema portulacastrum L. (Portulacaceae) was also reported from India (Maheshwari 1963, Nair 1978). Bhandari (1978) considers it to be a pantropical weed.

Heliotropium curassavicum L. (Boraginaceae) grows on the coasts of America, Africa, Australia and Southern Europe (Sauget and Liogier 1957).

Less frequent species

Other, less frequent herbaceous plants were *Achrydanthes aspera* L. (Amaranthaceae), *Chamaesyce berteriana* (Balbis) Millsp. (Euphorbiaceae), *Clitoria speciosa* Cav. (Fabaceae), *Crotalaria retusa* L. (Fabaceae), *Dactyloctenium aegyptium* (L.) Willd. (Poaceae), *Dicanthium annulatum* (Forsk.) Stapf. (Poaceae), *Echinochloa colona* (L.) Link. (Poaceae), *Hymenocallis arenicola* North. (Amaryllidaceae), *Melochis pyramidata* L. (Tiliaceae), *Sida espinosa* L. (Malvaceae) and *Wissadula periplocifolia* (L.) Presl. (Malvaceae).

Native woody plants were *Brosimum alicastrum* Sw. (Moraceae), the endemic *Bourreiria cuneifolia* Schulz (Boraginaceae), *Caesalpinia vesicaria* L. (Caesalpinaceae), *Canella winteriana* (L.) Guertn. (Canellaceae), *Copernicia yarey* Burret. (Arecaceae), *Guazuma tomentosa* H. B. K. (Sterculiaceae), *Harrisia eriophora* (Pfeiff.) Britt. (Cactaceae), *Melicocca bijuga* L. (Sapindaceae), *Pithecellobium saman* (Jacq.) Benth. (Mimosaceae) and *Switenia mahagoni* (L.) Jacq. (Meliaceae).

Introduced woody plants were *Barysylum inerme* (Roxb.) Pierre (Caesalpinaceae), *Delonix regia* (Bojer.) Raf. (Caesalpinaceae), *Ficus* sp. (Moraceae), *Gliricida sepium* (Jacq.) Steud. (Fabaceae), *Leucaena leucocephala* (Lam.) de

Wit (Mimosaceae), *Pithecellobium dulce* Benth. (Mimosaceae), *Tabebuia crassifolia* Britton (Bignoniaceae), *Tabebuia angustata* Britt. (Bignoniaceae) and *Terminalia catappa* L. (Combretaceae).

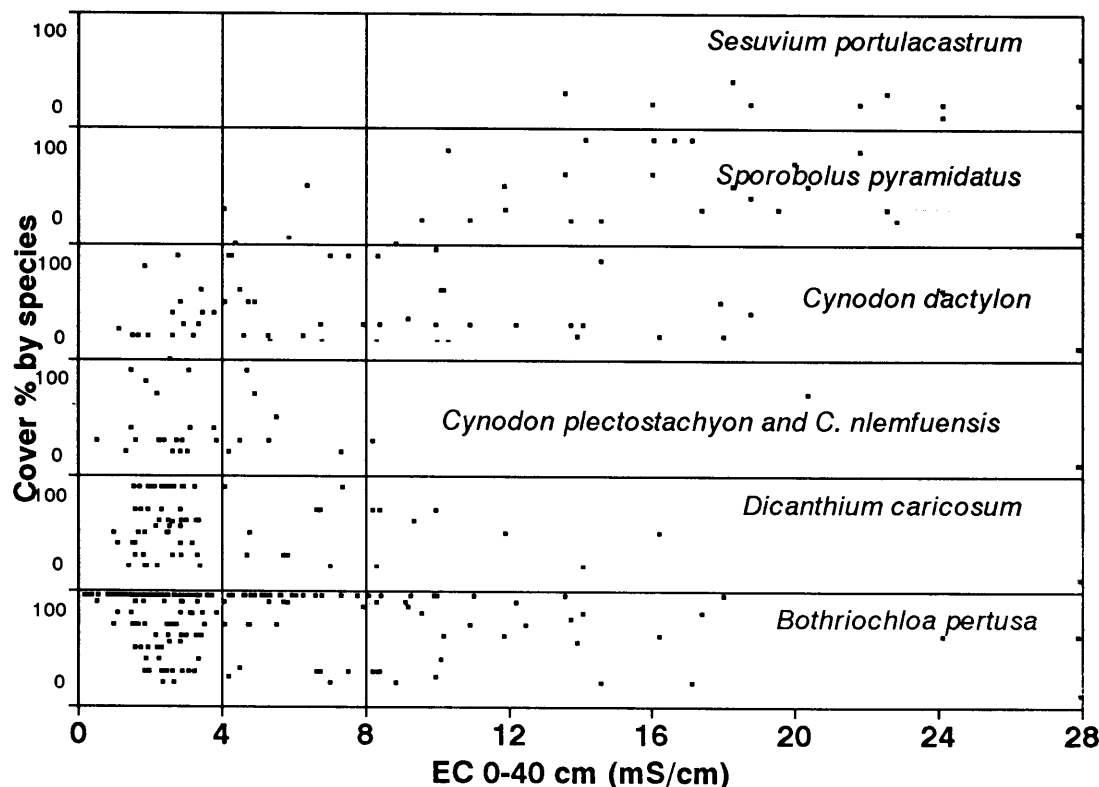


Fig. 2. Occurrence of the most important plants in relation to the soil salinity of the quadrats

Introduced poisonous or spiny species were *Acacia farnesiana* (L.) Willd. (Mimosaceae), *Calotropis procera* (Ait.) Ait. (Asclepiadaceae), *Cryptostegia grandiflora* R. Br. (Asclepiadaceae), *Dichrostachys cinerea* Wight and Arm. (Mimosaceae), *Jatropha gossypifolia* L. (Euphorbiaceae), *Malpighia cnide* Spreng. (Malpighiaceae), *Mimosa pudica* L. (Mimosaceae), *Pisonia aculeata* L. (Nictagiaceae) and *Urechites lutea* (L.) Britt. (Apocynaceae).

Representatives of the rapidly vanishing vegetation of the area, found sparsely at the time of the survey, were *Bucida buceras* L. (Combretaceae), *Bursera simaruba* (L.) Sarg. (Burseraceae), *Cordia collococa* L. (Boraginaceae), *Crescencia cujete* L. (Bignoniaceae), *Ehretia tinifolia* L. (Boraginaceae), *Prosopis juliflora* (Sw.) P. D. C. (Mimosaceae), which is one of the most popular fuel trees in the afforestation of sodic and saline soils in India according to Singh et al. (1994), and *Zantoxylum fagara* (L.) Sarg. (Rutaceae).

In brief, the list of species shows that the present vegetation is secondary, resulting from various processes, such as clear-cutting, ploughing and pasturing. Some plants are reminiscent of the original vegetation type.

Origin of the plant species found in different soil salinity ranges

The salinity range of 252 observations was divided according to the classes suggested by Richards (1954) as shown in Table 1 and Fig. 2. In the case of the first class, when EC is less than 4 mS/cm, yields of very sensitive crops may be restricted. When the EC of the saturation extract is between 4 and 8 mS/cm the yields of many crops are restricted. When EC is greater than 8 mS/cm only tolerant crops yield satisfactorily. Table 1 shows the origin of the most common plants found in the pasture.

TABLE 1

The most frequent plant species in the studied pasture and their occurrence in sampling quadrats according to soil salinity categories

Species	Origin [#]	Habitat [§]	Soil salinity category (mS/cm)		
			<4	4-8	>8
Gramineaceae					
<i>Bothriochloa pertusa</i>	I	h	127	36	31
<i>Dicanthium caricosum</i>	I		59	9	10
<i>Cynodon nlemfuensis</i>	I		21	7	2
<i>Cynodon dactylon</i>	I	h	17	16	23
<i>Chloris barbata</i>	N	H	2	1	11
<i>Sporobolus pyramidatus</i>	N	H	0	1	9
<i>Paspalum distachyon</i>	N	H	0	0	6
Other species					
<i>Spilanthes urens</i> (Asteraceae)	N	hw	0	0	10
<i>Desmanthus virgatus</i> (Mimosaceae)	N		21	7	2
<i>Sesuvium portulacastrum</i> (Aizoaceae)	N	H	0	1	9
<i>Trianthema portulacastrum</i> (Portulacaceae)	N	H	0	0	5

[#] I - Introduced; N - Native.

[§] h - Halotolerant; H - Halofrequent; w - Hygrofrequent.

Table 1 shows the distribution of the most common plant species between the different soil salinity categories. Among the plants shown in the table there were records of only one planted species in the area, *Cynodon nlemfuensis*. It is certain that *Cynodon dactylon*, *Bothriochloa pertusa* and *Dicanthium caricosum* were introduced into Cuba on purpose. The origin of *Chloris barbata*, *Paspalum distachyon*, *Desmanthus virgatus*, *Sesuvium portulacastrum* and *Trianthema portulacastrum* is not certain, because all these were also reported from Asia. The introduced grass species were dominant in the less saline categories. Based on the relative abundance of these species in the quadrats, the following order of occurrence in the salinity categories was found from the smallest to the highest salinity: *Dicanthium caricosum*, *Bothriochloa pertusa*, *Cynodon nlemfuensis*, *Desmanthus virgatus*, *Cynodon dactylon*, *Chloris barbata*, *Paspalum distachyon*, *Spilanthes urens* and *Sporobolus pyramidatus*.

The species found to be halofrequent are not necessarily halophytes. It should be emphasised that the use of plants for soil salinity mapping does not require that these plants should be true

halophytes. It is only assumed that they are in equilibrium with the soil properties and show a close statistical correlation with the values of the soil properties which are intended to map.

Electrical conductivity ranges of plant species

Fig. 2 shows the ranges in which several frequent plant species were recorded during the survey. The limits of the salinity categories have been marked for ease of orientation.

Only the seeded species *Cynodon plectostachyon* and *C. nlemfuensis* were limited to the low salinity quadrats. *Sesuvium portulacastrum* and *Sporobolus pyramidatus* did not show up in low salinity quadrats; these were typical of the highest salinity range. In the transitional area towards the meadows along the River Jiguani these plants formed scarcely vegetated patches, often with obvious marks of occasional surface runoff. The three introduced, but not sown species in the figure (*Cynodon dactylon*, *Dicanthium caricosum* and *Bothriochloa pertusa*) showed tolerance of low and intermediate salinity levels. The distribution of the elevation and plant coverage data among the EC classes is shown in Table 2.

TABLE 2

The means and standard deviations (StD) of elevation and the cover of the most important plant species in the soil salinity categories

Soil salinity category (mS/cm)	<4		4-8		>8	
	Mean	StD	Mean	StD	Mean	StD
Elevation (m)	81.8	2.2	80.2	2.1	77.6	2.1
Cover %						
<i>Bothriochloa pertusa</i>	65.6	38.1	65.1	39.6	31.4	36.8
<i>Dicanthium caricosum</i>	23.2	34.9	7.8	20.4	5.9	16.1
<i>Cynodon dactylon</i>	3.8	13.9	16.6	30.0	14.5	26.0
<i>Chloris barbata</i>	0.3	3.3	0.1	0.8	1.6	3.9
<i>Sporobolus pyramidatus</i>	0.1	1.6	0.9	6.1	15.9	26.7
<i>Paspalum distachyon</i>	0.0	0.0	0.0	0.0	1.6	5.6
<i>Spilanthes urens</i>	0.0	0.0	0.0	0.0	2.4	7.2
<i>Desmanthus virgatus</i>	0.8	2.7	2.2	4.8	0.3	1.6
<i>Sesuvium portulacastrum</i>	0.0	0.0	0.0	0.2	2.9	8.6
<i>Trianthema portulacastrum</i>	0.0	0.0	0.0	0.0	1.3	5.0

Only four plant species had mean coverages greater than 10 %. *Bothriochloa pertusa* and *Dicanthium caricosum* behaved similarly, both had a rough tendency of decreasing cover percentage as the salinity increased. *Bothriochloa pertusa* had a much higher cover percentage than *Dicanthium caricosum*. The halofrequent species *Sesuvium portulacastrum*, *Trianthema portulacastrum*, *Sporobolus pyramidatus* and *Chloris barbata* had their maximum cover in the highest category of salinity. All the other plants in Table 2 had their maximum cover in the intermediate category of salinity.

Discriminant analysis for the prediction of the range of soil salinity based on plant composition

In discriminant analysis (DA) the classes of electrical conductivity (EC) were predicted by elevation and non-transformed percentages of plant cover. Table 3 shows the classification matrix of DA for the EC classes. The good matches are shown on the upper left - lower right diagonal, that is, out of 151 cases with EC lower than 4 mS/cm, the discriminant functions, calculated using elevation and plant cover data, classified 120 cases as being such; 27 out of 43 cases were properly classified for the 4-8 mS/cm class and 38 out of 58 for the class with >8

mS/cm values, giving a total of 185 on the diagonal, representing an $185/252=73\%$ correct classification. This is much higher than the random distribution would be (42%).

TABLE 3

Results of discriminant analysis, using plant cover and elevation data as predictor variables, to classify quadrats into soil salinity categories

Actual group	No. of Cases	Predicted classification (mS/cm)		
		<4	4-8	>8
<4 mS/cm	151	120	30	1
4-8 mS/cm	43	14	27	2
>8 mS/cm	58	4	16	38

Percent of cases correctly classified: 73%
(in the case of homogeneous distribution: 42%;
 χ^2 measure of homogeneity: 178.9)

The precision of prediction ranged from $27/43=63\%$ for the intermediate salinity category, to $120/151=79\%$ for the lowest salinity category, that is, the precision was better in the extreme (low and high salinity) categories.

Use of arbitrary vegetation categories for the prediction of ranges of soil EC

In DA the individual cover percentage data of each plant and the elevation data were entered into the discriminant functions to

predict the salinity category membership of the quadrats. The precision is the best which can be achieved with these data. A much simpler approach is to classify the vegetation into categories depending on the plant species present and to use these as predictors of soil salinity status. The aim was thus to create plant categories that comprise the plant species on the basis of their salt tolerance.

The following categories were created based on the relative percentage cover of selected species compared to the total plant cover found, listed in increasing order of halotolerance:

Bot-Dic = 100% *Bothriochloa pertusa*, or 100% *Dicanthium caricosum*, or *B. pertusa* and *D. caricosum* > 50% or *Cynodon nlemfuensis* > 0 % with (*B. + D. caricosum*) < 50 %

Cynod = *Cynodon dactylon* > 50%

Spo-Ses = *Sporobolus pyramidatus* and *Sesuvium portulacastrum* > 0 %, and all other cases

The correspondance between the soil salinity categories and the arbitrary vegetation categories is shown in Table 4.

TABLE 4

Classification results for arbitrary vegetation categories as classifiers of quadrats into 3 soil salinity categories

Soil salinity	No. of Cases	Vegetation category		
		Bot-Dic	Cynod	Spo-Ses
<4 mS/cm	151	46	3	2
4-8 mS/cm	43	35	6	2
>8 mS/cm	58	15	4	39

Percentage of cases correctly classified: 76 %
(in the case of homogeneous distribution: 51 %, χ^2 measure of homogeneity: 148.2)

When compiling this table it was assumed that the lowest soil salinity category could be matched with the vegetation category which had no halotolerant species (**Bot-Dic**), the intermediate salinity category with the **Cynod** vegetation category and the highest soil salinity category with the vegetation category comprising the halophilic species (**Spo-Ses**). Therefore, by simply categorising the vegetation of a quadrat, assumptions can be made on the

salinity of the soil. The precision of this match is even higher than that shown in Table 3 (76% vs. 73%), but the precision of the match with the corresponding homogeneous matrix is also higher (51% vs. 47%), and the χ^2 measure of homogeneity is lower (148.2 vs. 178.9). In spite of its overall poorer performance, indicated by the χ^2 measure, the arbitrary categorisation of quadrats can also provide an algorithm for the quick prediction of salinity categories. Predictions that the soil salinity was low were much more precise (146/151=97%) than predictions of the high salinity class (39/58=67%), while the most difficult to predict was the intermediate salinity category (6/43=14%). There were 17 cases when the arbitrary vegetation categories put the quadrats 2 classes away, that is, into the >8 mS/cm category instead of the <4 mS/cm category or vice versa. DA gave only 5 such misclassifications (see Table 3).

Multivariate statistical tests, such as discriminant analysis, are suitable for the prediction of salinity when the preconditions of these tests are fulfilled. The most important precondition is that the samples should be drawn from a population with multivariate normal distribution. Due to the nature of botanical data this condition is rarely met. On the other hand, these tests are fairly robust against minor violations of their assumptions and there are several alternative parameters for expressing the precision of the estimation; consequently the fitting procedure can be separated from its statistical significance tests.

It is better, however, if methods can be used which do not have any preconditions for the nature of the variables. Cross-tabulation based on the presence of vegetation categories is such a method; and if the vegetation categories are well defined, its use is straightforward. In the present case the precision provided by the cross-tabulation was practically equal to that of discriminant analysis, but the latter gave smaller deviations in the misclassified cases.

Cross-tabulation was very useful, because it put two grass species, *Bothriochloa pertusa* and *Dicanthium caricosum*, whose separation was rather tiresome during the botanical survey, into one category. The resulting three categories (Table 4) are very easy for pasture managers to distinguish.

The use of vegetation demonstrated here, provides an economic, fast means of mapping the salinity of pastures and the resulting maps are precise enough for the management of pastures. This use of vegetation for predicting soil salinity should be considered as an example and not valid for different times and places. The relationship between plant composition and soil salinity often changes in time due to the temporal dynamism of soil salt concentration, and there are differences between the areas as well, since other factors besides soil salinity and water regime also influence plant composition.

In a realistic mapping situation the study quadrats, on which the classification and cross-tabulation are calculated, must represent the range and relative frequency of plant composition types and soil salinity values and also most of the localities inside the area.

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RESUMEN

En la vegetación de un pasto salinizado del Oriente de Cuba, en un área de 1000x2000m formada bajo influencias antropogénicas existen pocas gramíneas nativas y la mayoría de éstas viven en áreas marginales, donde las especies forrajeras introducidas no pueden tolerar la alta salinidad. Se encontró una correlación estrecha entre la composición vegetal de 252 cuadrantes de muestreo y la conductividad eléctrica del extracto de saturación del suelo. El orden de

tolerancia a la salinidad de las especies más frecuentes, desde las menos tolerantes hasta a las más tolerantes fue el siguiente: *Bothriochloa pertusa*, *Dicanthium caricosum*, *C. plectostachyon* y *C. nlemfuensis*, *Cynodon dactylon* y *Sporobolus pyramidatus*.

El pequeño número de especies encontradas, el fuerte estrés abiótico causado por la salinidad del suelo y el encharcamiento ocasional de la superficie de éste permiten, que la vegetación se pueda utilizar para predecir la salinidad del suelo con precisión aceptable. La categoría de salinidad del suelo (<4, 4-8 o >8 mS/cm) fue predicha con la precisión aproximada de 75% en el análisis de discriminancia y también a través del uso de categorías arbitrarias de vegetación. La categoría de menor salinidad coincidió con la mayor cobertura de *Bothriochloa pertusa*, *Dicanthium caricosum*, *Cynodon nlemfuensis* and *C. plectostachyon*. La categoría de mayor salinidad (>8 mS/cm), en la mayoría de los casos coincidió con la mayor cobertura de especies tolerantes a la salinidad como: *Sporobolus pyramidatus*, *Sesuvium portulacastrum* y otras halofitas.

Como las categorías de vegetación son fáciles de distinguir y la técnica de su clasificación es simple y no requiere ninguna condición estadística se sugiere el uso de la ocurrencia de especies vegetales halotolerantes para evaluar el estado de salinidad de pastos.

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