Land Suitability Assessment for Sugarcane Cultivation in "Herois de Caxito" (Angola)

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Summary

The suitability of the soils surrounding the sugarcane plantation at "Herois de Caxito" (7068 ha) is assessed. The main goal is to identify land suitability for the enlargement of the present plantation, using FAO land evaluation models (modified to suit Herois de Caxito conditions) and GIS. Calculations of the radiation-thermal production potential (RPP), land production potential (LPP), irrigation suitability index, and evaluation of the irrigation water quality are done. The water-limited production potential (WPP) is found equal to the RPP, because water needs were fully met under irrigation. Maps showing the spatial distribution of the LPP and the suitability for irrigation are generated. The matching of irrigation and fertility indices has shown that, about 40% of the soils with good fertility for sugarcane production present low suitability for irrigation, the main limitations being the very fine texture and the drainage. The available surface water at Herois de Caxito (Dande river) is of very good quality for irrigation of sugarcane.

Résumé

Evaluation de l'aptitude pour la culture de la canne à sucre à "Herois de Caxito" (Angola)

L'aptitude des sols aux alentours de la plantation de canne à sucre à "Herois de Caxito" (7068 ha) est évaluée dans le but principal d'augmenter la superficie de la plantation actuelle, utilisant des modèles d'évaluation des terres de la FAO (adaptés aux conditions de Herois de Caxito) et du SIG. La production potentielle radiation-thermique (RPP), la production potentielle de la terre (LPP) et l'indice d'aptitude pour l'irrigation furent calculés, tandis que la qualité de l'eau pour l'irrigation fut évaluée. La production potentielle tenant compte de la disponibilité en eau (WPP) est comparable à la RPP, les besoins en eau étant complètement satisfaits par l'irrigation. Des cartes reflétant la distribution spatiale de la LPP et l'aptitude pour irrigation sont générées par le logiciel SIG. La comparaison des indices d'irrigation et de fertilité a montré qu'environ 40% des sols ayant une bonne fertilité pour la production de la canne à sucre ne sont que peu aptes pour l'irrigation. Les principales limitations sont la texture très fine et le drainage insuffisant. L'eau de surface disponible à Herois de Caxito (rivière Dande) est d'une très bonne qualité pour l'irrigation de la canne à sucre.

Introduction

Sugarcane (*Saccharum officinarum* L.) is a C4 perennial crop with a metabolism leading to the accumulation of sucrose. The plant grows 2.5 to 4.25 metres tall (10). Higher yields are obtained with increasing incident solar radiation. Cane production is directly proportional to the water transpired (2). Therefore, good yields are obtained under adequate supply of water and sunshine in a climate which ensures sprouting of stem cuttings at mean daily temperatures of 32 to 38 °C, and which allows cane growth at mean daily temperatures of 22 to 30 °C (15). At maturation, the ratio of the difference between maximum and minimum temperatures to the mean temperature values should be above 0.5 for optimal conditions, while values below 0.35 are considered marginal. During ripening weather should be clear (high insolation), dry, cool with temperatures around 10-20 °C, as this stimulates the accumulation of sucrose (12). More than 2 000 hours of sunshine per year are required for a successful growth of sugarcane. When sunlight period is halved, sugarcane production is reduced by 50% (9). The rainfall is of capital importance in the sugarcane production areas. An effective rainfall of 1 500 mm, equivalent to a total of 2 255 mm during the growing period is required to attain good yields, otherwise irrigation is needed (8).
The "Herois de Caxito" sugarcane plantation is located in the region of Caxito (Figure 1) between 8° 30' to 8° 37' southern latitude and 13° 30' to 13° 45' eastern longitude, at about 50 km from Luanda (1).

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Figure 1: Location of Caxito .

A land evaluation study is presented for determination of both the land suitability for sugarcane cultivation (FAO-models) and for irrigation. As Angola is not self-supporting in sugar, extension of the sugar production is of great importance. Moreover, several plantations were destroyed during recent years. The methodology used in this paper is applicable to other parts of Angola, as well as in other countries, for land evaluation for sugarcane cultivation.

Materials and methods

Materials

Climatic data

The climate of Caxito, influenced by the cold current of Benguela, is semi-arid with a well-marked dry season. The maximum precipitation occurs during the months of March to April and November to December. A long dry season is noticed during the months of June to September (6). Climatic characteristics based on records of 20 years are given in table 1.

Soil data

The study area covers about 7 068 ha of fluvial lowlands, characterized by a temporary or permanent groundwater table, low content of soluble salts and sulphides, presence of illites and smectites, relatively good fertility and the development of a B-horizon in a few cases. A regional soil classification based on (i) dominant texture within 120 cm, (ii) drainage indicated by the intensity and deepness of redoximorphic features and, (iii) topographic position and duration of flooding as main keys, distinguishes 14 soil series (3) as shown in table 2.

According to WRB soil classification (5), the dominant soils are fluvisols and gleysols, with also important areas of vertisols and histosols. Soil classification and major chemical properties of the soil series are given in table 3. The CEC ranges from 25 to 70 cmol (+).kg^{-1}clay, the highest values being observed in the vertisols (3). Most soils have a slightly to neutral soil reaction (pH 6-7), apart from the histosols (pH 3-3.5) and those bordering the histosol area (pH 4-5). The

Table 1
Climatic characteristics of Caxito –Angola (6)

Station: Tentativa – Caxito* Latitude: 8° 33' S; longitude: 13° 40' E; altitude: 20 m asl

Months/ Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (°C)													
Maximum	32.9	33.8	33.2	32.9	31.7	28.7	26.2	26.9	28.4	30.3	31.8	32.1	30.7
Minimum	21.9	22.1	22.3	22.6	21.4	18.4	17.2	17.9	20.	20.5	21.9	21.8	20.7
Average	27.4	28	27.8	27.8	26.5	23.6	21.7	22.4	24.2	25.4	26.9	27	25.7
Relative humidity (%)	77	76	79	82	81	80	83	84	81	80	79	78	80.0
Sunshine hours	212	205	197	189	221	196	156	142	148	151	178	200	2195
N/N **	0.54	0.59	0.53	0.53	0.61	0.57	0.43	0.39	0.41	0.41	0.45	0.53	0.50
Rainfall (mm)	27.5	56.8	154.3	185.7	40.2	0	0	1.1	1	8.7	54.3	40.1	568.8
Rainfall days	4	2	5	12	1	0	0	0	0	3	5	4	36.0
Eto (Penman method) (mm)	191	183	187	162	152	121	111	119	137	159	172	184	1878
Mean wind speed ($m.s^{-1}$)	5.7	6.3	6.2	5.6	5.5	5.4	5	4.8	5.4	6.6	6.4	5.7	5.7

* average data over period of 20 years ** actual insolation / theoretical possible insolation

Table 2
Soil series of the extension of the sugarcane plantation (3)

Drainage and inundation	Temporarily imperfectly drained	Imperfectly to poorly drained		
		Inundated per year		
Dominant texture under mineral soils Heavy clay	*No inundation*	*< than 2 months*	*2 to 4 months*	*> than 4 months*
	Buya	Ube	Quijanda	Sungue
Clay and sandy clay	Cume	Sassa	Ibendua	-
Sandy loam and loam	Dande	Caxito	-	-
Sand and sandy loam	Paranhos	Pinto	Icau	Tolola
Organic matter- hemic	-	-	-	Morima (permanent inundation)

Table 3
Soil classification (5) of and chemical properties of the soil series in Herois de Caxito

Series	Soil classification	ACEC $cmol(+).kg^{-1}$ soil	Base cations $cmol(+).kg^{-1}$ soil	pH	OC %	EC dS.cm	ESP %
Buya	Calcic vertisol	60-70	30-40	7-7.5	1.5-2	05-1.5	< 1
Ube	Eutric vertisol – Vertic cambisol	40-70	15-40	5-5.5	1.5-2	< 0.5	< 1
Quijanda	Humic gleysol	30-40	20-30	4-4.5	2-7	5-7	5-10
Sungue	Humic gleysol	40-50	30-50	4-5	2-6	1-2	1-3
Cume	Humic - Eutric fluvisol	50-70	25-35	6-7	1-2	< 0.5	< 1
Sassa	Gleyic fluvisol	30-40	20-30	5-7	1-2	< 0.5	0.5-2
Ibendua	Humic dystric gleysol	25-35	8-15	4-4.5	1-2.5	0.5-1	< 1
Dande	Arenic eutric fluvisol	35-40	4-6	6.5-7	0.5-1.5	< 0.5	< 1
Caxito	Gleyic humic fluvisol	40-60	15-20	6-7	1.5-4.5	< 0.5	< 1
Paranhos	Eutric fluvisol	60-70	20-30	6-6.5	1-2	< 0.5	< 1
Pinto	Eutric gleysol	60-70	5-10	5-5.5	1-1.5	< 0.5	1-2
Icau	Humic abruptic gleysol	30-40	5-10	4-4.5	2-4.5	1-1.5	2-4
Morima	Thionic histosol	-	15-50	3-3.5	> 20	10	-

latter, mostly humic gleysols, generally have a higher O.C content (2-7%) than the better drained fluvisols (1-2%). The heavy textured soils contain high amounts of exchangeable basic cations (15-50 cmol (+). kg^{-1} soil) compared to the sandy soils (series Pinto, Icau, Dande; < 10 cmol (+) basic cations. kg^{-1} soil). The exchangeable sodium percentage (ESP) is low in all soils. Also soil salinity (EC) is very low, apart for the organic soils (soil series Morima). The available water varies between 20 and 150 $mm.m^{-1}$ of soil with an infiltration rate which is texture dependent, ranging from 0.5 $mm.h^{-1}$ in the clay soils to 25 $mm.h^{-1}$ in the sandy soils (3).

Methods

Radiation-thermal Production Potential (RPP)
Sugarcane crop growth is simulated with the FAO-crop growth model. This model allows to estimate, from radiation and temperature data, the net biomass production (Bn) and yield of a high-yielding crop that is optimally supplied with water and nutrients and grown in the absence of pests and diseases (12). The RPP is calculated as the product of the economically useful part of the crop, in this case sugar (harvest index Hi), defined as a fraction of the net biomass of the crop (Bn), as follow: RPP= Bn x Hi.

Water-limited Production Potential (WPP)
WPP is defined as the reduction of RPP due to soil water deficit resulting in a decreased evapotranspiration (Eta < ETm) (7). Thus the WPP was quantified as follow:
WPP= RPP x [1-Ky x (1-ETa/ETm)]
where Ky: yield response factor;
ETa: actual evapotranspiration;
ETm: maximum evapotranspiration.
ETm refers to conditions when water is adequate for unrestricted growth and development. To determine ETa, the level of the available soil water must be considered. ETa equals ETm when available soil water to the crop is adequate. The response of yield to water supply is quantified through the yield response factor 'ky', which relates relative yield decrease to relative evapotranspiration deficit (1- ETa/ETm). It is evident that under optimal irrigation (Eta = Etm), WPP will equal RPP.

Land Production Potential (LPP)
The LPP is calculated from the water-limited production potential, a soil index (Sy) and a management index (My):
LPP= WPP x Sy x My
The soil index is based on the parameters with direct impact on the yield, such as the sum of basic exchangeable nutrients or pH, organic carbon, electric conductivity and exchangeable sodium percentage. The evaluation of those chemical soil parameters is based on the FAO approach for irrigated agriculture (4). These land characteristics of each soil unit are matched with the requirements of sugarcane using the parametric approach. This consists in the allocation of numerical ratings (R) from a maximum of 100 (optimal) to a minimum value (less optimal) for each characteristic (14). The soil index is then computed from the individual ratings using the square root method (11) as follow:

$Sy= Rmin \times (R1/100 \times R2/100 \times R3/100 \times \ldots)^{1/2}$
where Rmin: lowest rating attibuted;
R1, R2, R3 ….: ratings of the other chemical land characteristics (with the exception of the lowest rating).

For the determination of LPP, a high management has been considered (My= 0.8).

Evaluation for irrigation
The soils were evaluated for basin furrow irrigation by calculating an irrigation capability (11) index as follow:
Ci= A x B/100 x C/100 x D/100 x E/100 x F/100 x G/100
where Ci is the capability index and A, B, C, D, E, F and G are ratings for soil texture, soil depth, $CaCO_3$ status, gypsum status, soil salinity/ alkalinity, drainage and slope, respectively.
The capability classes were defined considering the capability indices as excellent (> 80), suitable (60-80), slightly suitable (45-60), almost suitable (30-45) and unsuitable (< 30).

Quality of irrigation water
The irrigation water was evaluated on salinity, sodicity and element toxicities according to the USDA diagram for classification of irrigation water (13). The chemical composition of the irrigation water is given in table 4.

Table 4
Chemical composition of the irrigation water in Herois de Caxito

Sample	A	B	C
pH	7.5	7.2	7.1
EC (µS/cm)	186	188	195
Cations		meq/l	
Na^+	0.126	0.107	0.116
K^+	0.075	0.035	0.082
Mg^{2+}	0.798	0.798	0.790
Ca^{2+}	1.267	1.262	1.307
Sum	2.266	2.242	2.295
Anions		meq/l	
Cl^-	0.023	0.023	0.056
SO_4^{2-}	0.159	0.229	0.157
NO_3^-	0.018	0.017	0.006
HCO_3^-	2.038	1.967	2.032
CO_3^{2-}	0.000	0.000	0.000
Sum	2.232	2.236	2.261
SAR	0.12	0.11	0.11
Boron (mg/l)	0.025	0.025	0.027

A: river dam; B: start of main irrigation channel; C: end of main irrigation channel

Results and discussion

Applying the FAO growing period concept it was found that planting in August, September and October is ideal for short cycle cane whereas for cane longer than 12 months January, February and March is the optimal planting period. In both cases the ripening will coincide with a period of relatively low temperatures and low relative humidity which are ideal for sucrose concentration. Cane grown in these conditions may yield a total net biomass production of 55.41×10^3 kg CH_2O/ha/day resulting in a RPP of 13.85 tonnes/ha/year (sugar) considering a harvest index of 0.25. The water-limited production potential (WPP) is found equal to the RPP, because water needs were fully met under irrigation.

Land Production Potential

Land suitability classification indicates the nature of constraints and allows attention to the land improvement activities and potential yields. Table 5 gives the suitability of the different soil series at Herois de Caxito in terms of land production potential. The results of the evaluation demonstrate that the only factor to be considered limiting is the pH. It was found that all other factors being equal, an increase in the amount of the sum of basic cations leads to an increase in LPP as the soil become less acid. Figure 2 shows the distribution of the LPP (tonnes sucrose.ha^{-1}) in the studied area. By using GIS tools (ArcInfo and ArcView) it was found that 2 050 ha, representing 40% of the surveyed area, yields the highest LPP class (8-12 tonnes.ha^{-1}), i.e. a value greater than the average yields at Herois de Caxito (7.8 tonnes.ha^{-1}). About 40% (an area with permanent inundation as main limitation) gives yields lower than 4 tonnes.ha^{-1}. Yields higher than those observed in the present plantation can be obtained by improving the infrastructure, traffic systems and farm size, and by improving the drainage systems and controlling the inundation and flooding.

Table 5

Evaluation of soil parameters and for sugarcane production and LPP in Herois de Caxito

Series	ACEC	Base cations	pH	OC	EC	ESP	Soil index	LPP tonnes.ha^{-1}
Buya	++	++	++	++	++	++	0.86	9.53
Ube	++	++	+	++	++	++	0.71	7.86
Quijanda	++	++	-	++	++	++	0.36	4.00
Sungue	++	++	-	++	++	++	0.39	4.32
Cume	++	++	++	++	++	++	0.96	10.65
Sassa	++	++	++	++	++	++	0.97	10.74
Ibendua	++	++	-	++	++	++	0.38	4.32
Dande	++	++	++	++	++	++	0.81	9.00
Caxito	++	++	++	++	++	++	0.96	10.5
Paranhos	++	++	++	++	++	++	0.96	10.5
Pinto	++	++	+	++	++	++	0.69	7.65
Icau	++	++	-	++	++	++	0.39	4.33
Morima	++	++	-	++	-	++	0.27	2.99

- : marginally suitable, rating 40-60; **+** : moderately suitable, rating 60-85; **++** : suitable, rating 85-100

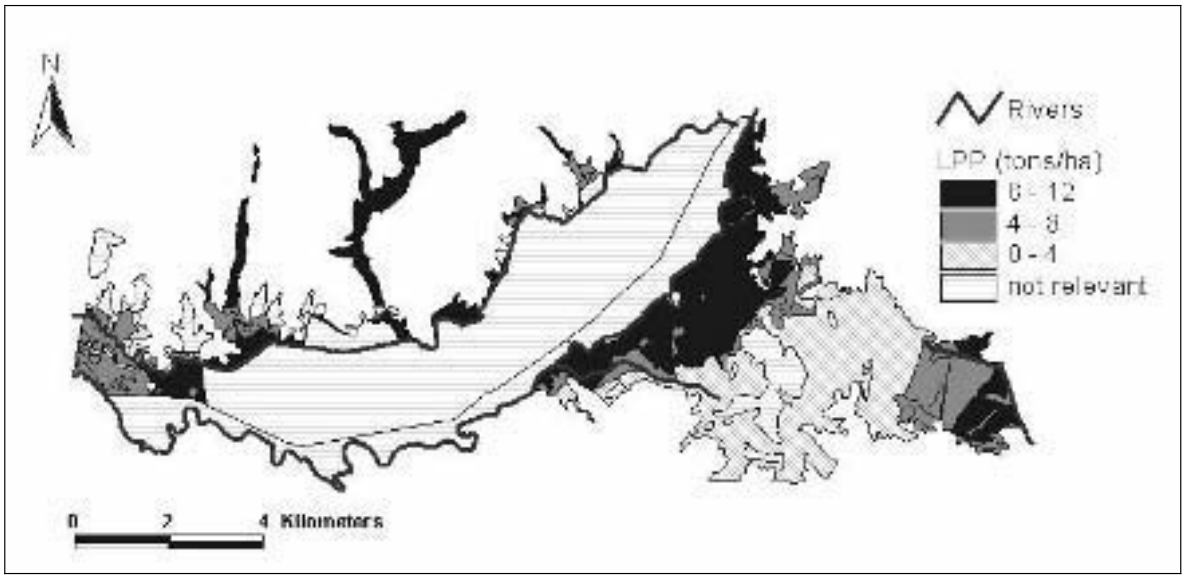

Figure 2: Distribution of LPP in Herois de Caxito.

Evaluation for irrigation

Surface furrow irrigation provides a mean for controlling and guiding water on steep, undulating and on very level land (16). The evaluation, presented in table 6 and figure 3, shows that in the study area 61% of the soil series presents drainage limitation. This is due to the high clay content of the A–C soil profiles in Caxito, totalling 92% in some horizons (3).

Values of both salinity and alkalinity are viable and do not constitute a limitation in the majority of the soil series. Exception constitutes the Morima series with high salinity that acts harmfully on the sugarcane growth.

Table 7 gives the areas of the different irrigation capability classes calculated by using ArcView tools. From this follows that out of 6 220 ha of mineral and organic soils surveyed, about 65% presents limitation ranging from moderate to slight and can be used for irrigation. Around 35% is unsuitable for irrigation and can be only irrigated if drainage operations are performed prior to cane plantation.

The irrigation water if of very good quality as expressed by its low salinity (EC) and sodium hazard. Also the boron concentration in the irrigation water, with values

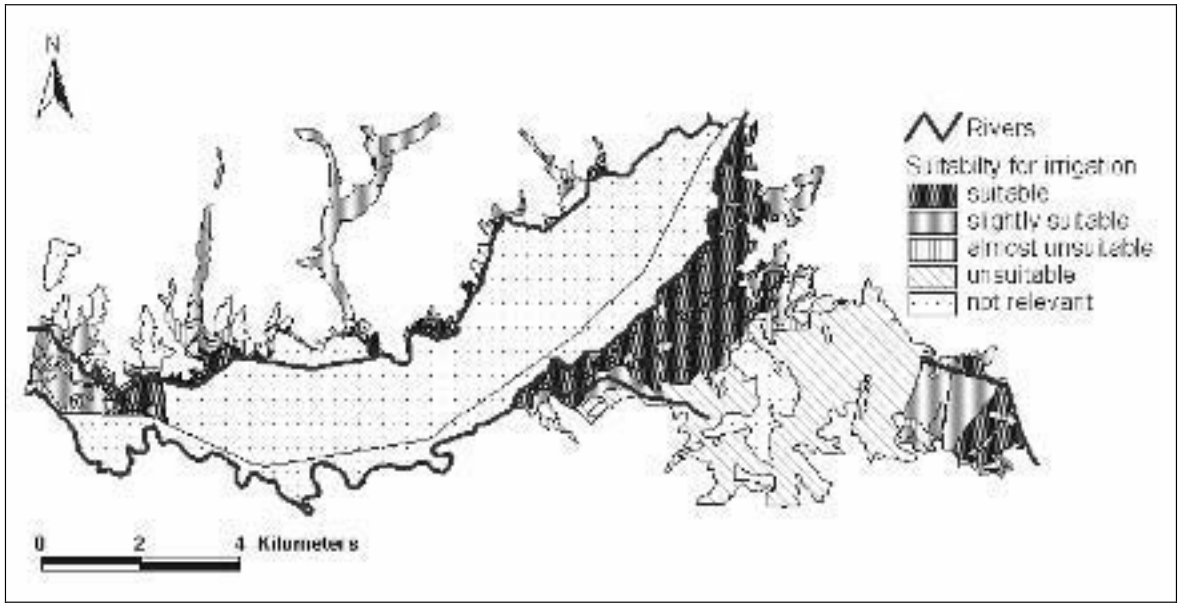

Figure 3: Irrigation capability classes in Herois de Caxito.

Table 6

Soil suitability for surface irrigation after flooding and artificial drainage control

Soil characte-ristics / Series	Topography (t)	Soil depth	Drainage /GWT depth saline,(w)	Soil physical condition (s)				Salinity and alkalinity (n)	Suitability for irrigation	
				Texture (0-1m)	Texture (1-2 m)	Carbonate	Gypsum		Rating (Ci)	Class and limitation
Buya	100	100	100	65	70	100	90	100	52	III, s
Ube	100	100	82	60	100	80	90	100	46	III, s
Quijanda	100	100	82	70	70	85	90	95	45	II, s, w
Sungue	100	100	70	80	70	80	90	100	44	III, s, w
Cume	75	100	100	80	100	80	90	100	57	III, t
Sassa	100	100	82	85	80	90	90	100	60	II, w
Ibendua	100	100	80	80	70	90	90	95	51	III, w, s
Dande	100	100	85	80	80	90	100	100	62	II, s
Caxito	100	100	85	100	80	90	100	100	70	II, s
Paranhos	100	100	100	70	60	90	100	100	48	III, s
Pinto	100	100	85	50	60	90	100	100	34	IV, s, w
Icau	100	100	85	50	60	90	100	100	34	IV, s, w
Morima	60	100	70	80	60	90	90	60	26	V, s, w, n

II: suitable; III: slightly suitable; IV: almost unsuitable; V: unsuitable; Ci: irrigation index

Table 7
Areas of irrigation capability classes in Herois de Caxito

Classes	Area (ha)	%
Moderately suitable (II)	2 534	40.7
Slightly suitable (III)	1 119	18.0
Almost unsuitable (IV)	369	5.9
Unsuitable (V)	2 198	35.4

clearly demonstrated in the series Buya, Cume, Sassa, Caxito, Paranhos, Quijanda and Ibendua.
The analysis of the soil fertility index and the irrigation index has demonstrated that the clayey texture and drainage are the main limiting factors in the majority of the surveyed soil units. About 40% of the soil units with good fertility for sugarcane production presents

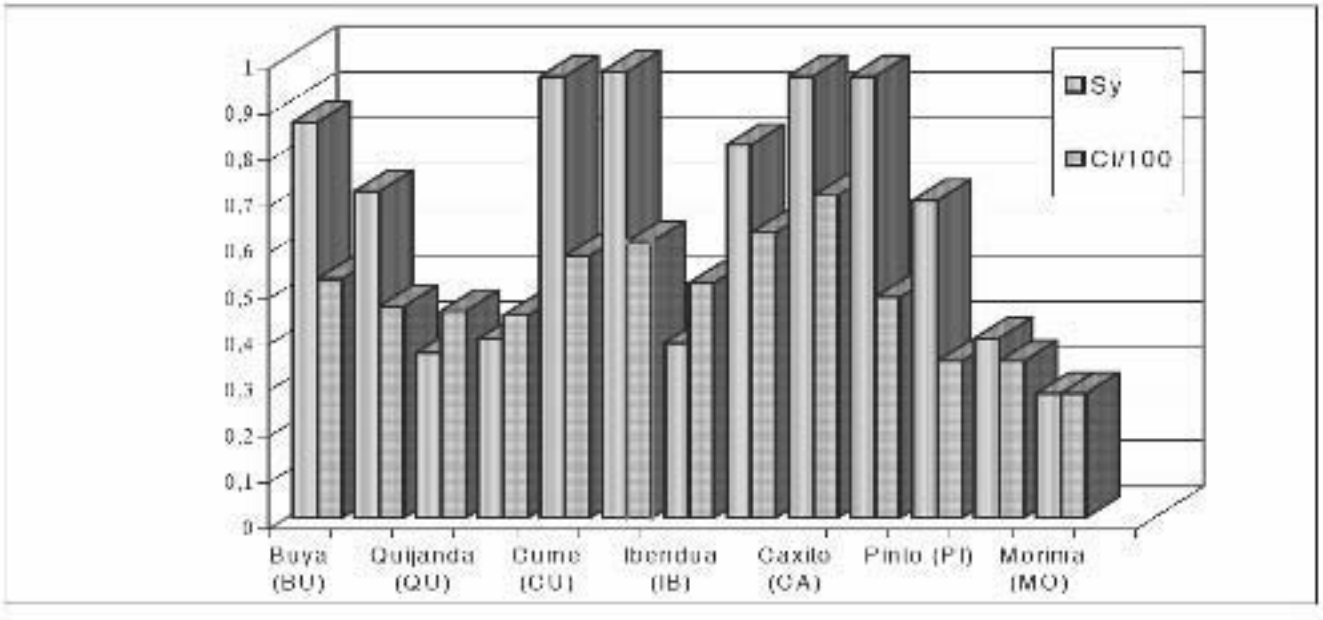

Figure 4: Combination of the soil index (Sy) and the irrigation capability index (Ci/100).

around 0.025 mg/l, does not constitute a constraint in the use of the water for irrigation of sugarcane.

Combination of the soil index and the irrigation capability index

The suitability for soils for cultivation and the suitability of soils for irrigation were combined in every soil unit to know whether a soil unit suitable for sugarcane cultivation is also suitable for irrigation. The results of the evaluation (Figure 4) indicate that soils with good fertility qualities present in many cases bad irrigable characteristics and vice versa, making the suitability for irrigation not ideal without reclamation. This is low suitability for irrigation. Dande and Caxito series are the best soils both for irrigation and sugarcane plantation and so 55% of the surveyed soils can be used directly for sugarcane plantation.

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AVIS

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Nous pensons ainsi, grâce à votre aide, pouvoir rendre un grand service à la communauté pour laquelle vous travaillez.

Merci.

BERICHT

Wij herrineren al onze lezers eraan, vooral diegenen in de ontwikkelingslanden ,
dat TROPICULTURA bestemd is voor ieder die werk verricht op het gebied van het platteland en dit in de meest ruime zin van het woord.

Daarom zou het nuttig zijn dat u ons de adressen zou geven van de Instellingen, Scholen, Faculteiten, Centra of Stations voor landbouwonderzoekvan het land of de streek waar U zich bevindt. Wij zouden ze kunnen abonneren, zo dit niet reeds gebeurd is.

Met uw hulp denken we dus een grote dienst te kunnen bewijzen aan de gemeenschap waarvoor u werkt.

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