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Cacao was one of the most important crops of the lowland Maya. Ethnohistoric sources document that the Postclassic-Colonial Period Maya settlement of Tipu in western Belize was an important cacao-growing center, yet evidence of where the cacao was grown is not apparent. We analysed the suitability of floodplain, terrace, and bedrock soils for cacao cultivation. Our results indicate that the soils most likely to have been used for cacao growth were those on the modern floodplain of the Macal River, based on their suitable physical and chemical properties. In addition, buried stone walls of Late Classic or Postclassic age that may have been used for field demarcation were found on the floodplain, suggesting that this geomorphic surface was also utilized well before the time of Spanish contact, possibly for intensive agriculture.

Keywords: CACAO, SOILS, FIELD WALLS, MAYA, BELIZE, AGRICULTURE.

Introduction

Cacao (*Theobroma* sp.) was one of the most important crops of the lowland Maya during the Classic, Postclassic, and Colonial Periods. Cacao served important functions as a medicinal and ritual material, as a prestige beverage, and as currency throughout Mesoamerica (Millon, 1955; Thompson, 1956, 1966; Bergmann, 1969; Dahlin, 1979). The high value of cacao may have been in part responsible for the rise of a wealthy merchant class among the Maya.

Although the importance of cacao has not been debated by Mesoamerican researchers, there is little direct evidence for cacao growth in the archaeological record. Although some macrofossils in the form of wood fragments have been obtained by flotation at Cuello, Pulltrouser Swamp, and Copan (Turner & Harrison, 1981; Turner & Miksicek, 1984), these kinds of occurrences seem to be rare. This could be because macrofossils are often not well preserved in the hot, humid environments where cacao-growing centers likely existed or because little effort has been spent thus far on flotation at most sites (Turner & Miksicek, 1984). The problem is compounded by the fact that cacao apparently sheds little or no pollen (Hammond, 1978).

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Thus, to date most workers have tended to rely on indirect evidence to identify centers of cacao growth. This category of evidence includes representation in sculptural art (Thompson, 1948; Parsons, 1967–69) or ceramics and murals (Millon, 1981), cacao-drying floors (Ekholm, 1969), or references in ethnohistoric sources (Jones, 1982). Even when cacao can be identified as having been an important crop at a given site, however, indirect forms of evidence can rarely, if ever, provide clues as to where the crop was grown at that site.

In this paper, we have attempted to identify the probable location of Maya cacao cultivation at an ethnohistorically documented Colonial Period cacao-growing centre in western Belize. The methodology is based on detailed field and laboratory studies of soils at various locations around the site with the aim of determining which soils would be most suitable for cacao cultivation. Thus, our methodology falls into the category of argument by ecological analogy as outlined by Turner and Miksicek (1984: 180). A second purpose of our investigation was to see if there was archaeological evidence for pre-Hispanic cultivation at the site.

Study area

The study area is located at the present settlement of Negroman, south of San Ignacio in western Belize (Figure 1). The Postclassic-Colonial Period site of Tipu has been

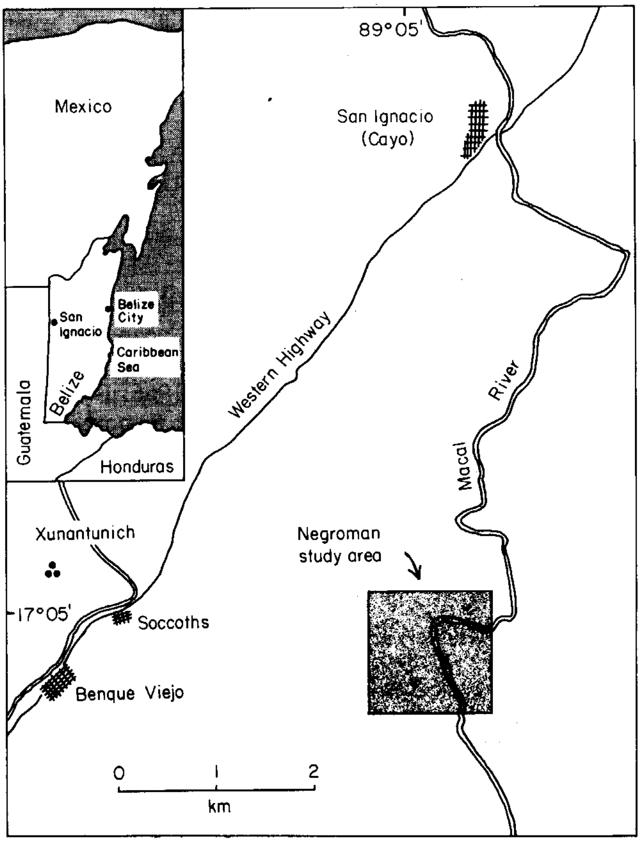

Figure 1. Location of the study area and localities referred to in the text.

hypothesized to be located at or near Negroman (Scholes & Thompson, 1977; Jones, 1982). Recently, excavations at Negroman have revealed the presence of a Spanish Church, strongly suggesting that Tipu was located there (Graham *et al.*, 1985).

Tipu was the most important of the colonial frontier towns in what is now western Belize because of its organizational role in the regional rebellion of the 1630s and its importance as a regional centre of control for commerce and agriculture (Jones, 1982). Jones (1982) has summarized the visits of two evangelizing Franciscan priests to the western Belize region, based on accounts by Lopez de Cogolludo (1688, in Jones, 1982). These two priests visited Tipu early in the 17th century, and found an orchard of 8000 cacao trees grown by the *maestro de capilla,* who was apparently an immigrant from Hekelchacan, a trading town north of Campeche (Lopez de Cogolludo, 1688, in Jones, 1982). The priests noted in particular the wealth of certain members of the Tipu community as a result of cacao cultivation.

The location of the Colonial Period cacao orchards at Negroman is not immediately obvious. The physical landscape consists of the modern floodplain, a river terrace, and limestone bedrock uplands. We hypothesized that the upland soils might be too thin or calcareous to support cacao. In addition, upland slopes may be too steep and thus too dry unless irrigated terraces were used. The river terrace and floodplain contain sediments derived from the acid soils (Ultisols) of the Maya Mountains; thus, we thought these soils might have pHs that were too low or insufficient quantities of basic cations for cacao growth. In addition, Colonial Period residential structures are located on the terrace, based on both ethnohistoric sources and archaeological testing (Graham *et al.*, 1985). The number of cacao trees reported for Tipu seems rather large to have shared space with the structures at the site on the terrace alone, unless the trees were placed on river terraces up and downstream from the central site. Finally, we thought that the modern floodplain might have soils that were too wet or were flooded too frequently for successful cacao cultivation.

Methods

Geomorphic surfaces and soils were first mapped on 1:10,000 Royal Air Force air photos in the field. Four major geomorphic surfaces were delimited and representative soils were then described and sampled from hand-dug pits on each of the surfaces. Horizons were described using the new terminology of the U.S. Soil Conservation Service (Guthrie & Witty, 1982; Bettis, 1984) and soils were classified according to the U.S. Soil Taxonomy (Soil Survey Staff, 1975).

Laboratory analyses of representative soil profiles followed standard procedures. Total nitrogen was determined by the Kjeldahl method (Bremner, 1965). Organic matter was extracted with potassium dichromate and sulfuric acid; quantities were determined colorimetrically. Available phosphorus (P) was determined using the Bray No. 1 method. Cations were extracted with ammonium acetate and quantities were determined by flame photometry. Cation exchange capacity was determined for some of the soils by the sum-of-cations method; for soils that have free carbonates, no estimate of cation exchange capacity was made since the ammonium acetate extraction procedure removes the calcium in free carbonates as well as exchangeable calcium. Calcium carbonate content was determined with a chittick apparatus following the method of Dreimanis (1962). Soil pH was measured on 1:1 soil-water pastes using a glass electrode. Particle size analysis for selected profiles was done using the pipette method (Day, 1965); in addition, the clay fractions of certain horizons in these soils were analysed for mineralogy. Clay samples were analysed using oriented particles on glass slides that had been glycolated and heat-treated (550°C for 2h); X-ray diffraction methods were employed for identification.

We compared the field and laboratory data derived from the Negroman area with published data on desirable soil characteristics for cacao growth. It should be noted that published soil data of which we are aware are for *Theobroma cacao*. Another species, *Theobroma bicolor*, is also found in the Maya lowlands and was apparently gathered, although not cultivated, by the early Maya (C. H. Miksicek, pers. comm., 1984). Miksicek also believes, however, that the species cultivated by the Postclassic and Colonial Period Maya was *Theobroma cacao*; hence, we feel that we can compare our soils to the published data. Smyth (1975) has summarized the following soil characteristics as being of most importance for cacao growth:

(1) a solum depth of at least 1·5 m, based on data in Hardy (1958);
(2) a texture in the < 2 mm fraction of 30–40% clay, about 50% sand, and 10–20% silt, and no drastic textural changes with depth;
(3) good soil structure, particularly in surface horizons;
(4) adequate soil drainage during wet periods, as indicated by a lack of colors indicative of gleying or reducing conditions;
(5) a cation exchange capacity in the surface horizons of not appreciably less than about 12 mmol 100 g^{-1} and in lower horizons not less than 5 mmol 100 g^{-1};
(6) organic matter content of about 3% or more in the 0–15 cm depth range;
(7) base saturation not appreciably less than 35% in the subsurface horizons;
(8) pH of 6·0–7·5 in the surface and 4·0–8·0 within 1 m depth;
(9) exchangeable cations in the depth range of 0–15 cm in the following quantities: Ca^{++} not less than 4·0 mmol 100 g^{-1}, Mg^{++} not less than 1·0 mmol 100 g^{-1}, and K^{+} not less than 0·24 mmol 100 g^{-1}.

Soils that do not meet all of the above requirements may still be capable of growing cacao. In fact, a recent study in Liberia (West Africa) by Geiger & Nettleton (1979) indicated that soils with significantly lower quantities of exchangeable cations than the limits cited above were capable of growing cacao. Thus, the limits given are general ones, and will probably be modified as more data become available.

Results

Distribution, morphology, and physical properties of soils

Soils in the study area are conditioned by the age of the geomorphic surface and the nature of the parent material. Four geomorphic surfaces were mapped and include the modern floodplain of the Macal River, a terrace above this floodplain, alluvial fans originating in the upland limestone areas, and the bedrock uplands themselves (Figure 2). Based on our observations of the lithology of modern point bar deposits of the Macal River and stream-cut exposures of the floodplain sediments, the deposits of the floodplain and terrace are derived mainly from the granitic and metamorphic rocks of the Maya Mountains, rather than the local limestone (see Kesler *et al.*, 1974 for a discussion of the lithology of the Maya Mountains).

Soils on the modern floodplain are Typic Hapludolls and Typic Argiudolls. The floodplain soils that are characterized by argillic horizons (Typic Argiudolls) appear to be located mainly at sites farther away from the river and thus are probably subjected less often to flooding and deposition of new parent material. Most areas of the floodplain that were examined, however, have soils with only cambic B horizons with well-developed soil structure and weak clay films on ped surfaces (Table 1). The present landowner (Mr J. S. Espat) has indicated to us that what we have mapped as the modern floodplain experiences flooding about once every 4 years. During our field work, we have noted that during storms of the rainy season, this surface also receives considerable runoff from the higher terrace. However, small gullies have dissected the floodplain surface (Figure 2) and much of the rainfall running onto the floodplain is carried into the

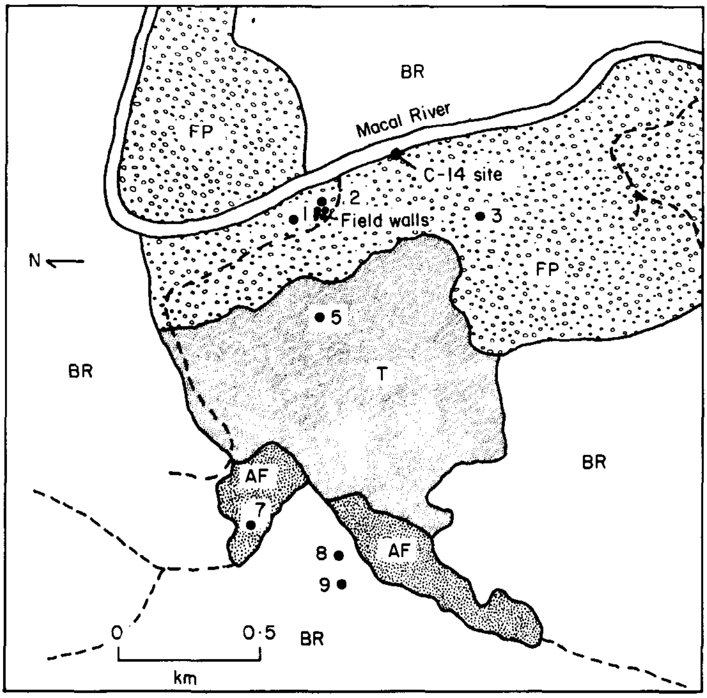

Figure 2. Geomorphic surfaces, soils, and soil pit localities in the Negroman study area. FP, floodplain (Typic, Hapludolls and Argiudolls); T, terrace (Aquic Tropudalfs); AF, alluvial fan (Typic Arguidolls); BR, limestone bedrock (Lithic Rendolls and Typic Argiaquolls) ●, soil pit location; – – –, gully.

Macal River from these gullies. As a result, soil horizon colors do not indicate poor drainage (Table 1). Gray colors that are indicative of gleying or reducing conditions are lacking in all floodplain soils that we examined. The soils, then, do not seem to have drainage problems that would adversely affect cacao growth. In addition, the well-developed angular blocky structure of the soils indicates no potential problems for cacao root penetration. The solum depth is greater than 1·5 m, which is the depth specified by Hardy (1958) for cacao growth. Finally, the texture of the floodplain soils is dominantly silt loam, a soil texture with one of the highest moisture-holding capacities. This beneficial texture would have the effect of mitigating some of the moisture deficit that occurs during the dry season which characterizes the study area (and much of the Maya lowlands) if irrigation techniques were not practiced. Detailed particle size distribution data (Figure 3) indicate little change in silt and clay content with depth, a condition which is ideal for cacao root penetration and moisture conditions (Smyth, 1975).

The soils on the terrace above the floodplain are Aquic Tropudalfs which exhibit a greater degree of profile development related to the greater age of the terrace (Table 1, Figure 3). These soils have well developed argillic B horizons with reddish (7·5 YR and 5 YR) hues and well expressed clay films on ped surfaces. As with the floodplain soils, the solum depths are greater than 1·5 m, which is ideal for cacao. Textures are also silt loam, which, as described above, is optimal for root penetration and moisture-holding capacity. The terrace soils do exhibit, however, some distinct mottling in the lower parts of their profiles (Table 1), which indicates seasonally wet conditions. The bright

Table 1. Morphological data for representative soils studied in the Negroman area

Profile Number	Geomorphic surface and classification	Horizon	Depth (cm)	Color (moist)	Texture*	Structure*	Consistence (moist)*	Boundary*	Other features
1	Floodplain; Typic Hapludoll	A	0–34	10 YR 3/2	sicl	2m, c abk	vfr	gs	Worm casts
		BAt	34–46	10 YR 4/3	sil	1m, c abk	fr	cs	10 YR 4/2 clay films; worm casts
		Bt1	46–85	10 YR 4/3	sil	1c abk	fr	cs	10 YR 4/2 clay films; worm casts
		Bt2	85–130	10 YR 4/4	sil	1c pr	fi	cs	10 YR 4/2 clay films; worm casts
		2Bt3	130–160	7·5 YR 4/4	sicl	1c abk	fr	gs	10 YR 4/2 clay films; worm casts
		2C	160+	7·5 YR 4/3	sil	1m sbk	vfr		Worm casts
5	Terrace; Aquic Tropudalf	A	0–13	10 YR 4/2	sil	3f, m abk	vfr	cs	Worm casts
		AB	13–21	7·5 YR 4/6	sil	3f, m abk	vfr	cw	Worm casts
		Bt1	21–41	7·5 YR 4/6	sil	2m, c abk	vfr	cw	7·5 YR 4/4 clay films; worm casts
		Bt2	41–92	7·5 YR 5/6	l	1,2 c pr	vfr	cw	7·5 YR 5/4 clay films; 5 Y 6/3 mottles; worm holes
		Bt3	92–126	7·5 YR 5/6	sil	1,2c pr, abk	vfr	cw	7·5 YR 5/4 clay films; 5 Y 5/2 mottles; worm holes

		Bt4	126–147	5 YR 5/8; 7·5 YR 5/6	sil	1c abk	vfr	cw	10 YR 6/4 clay films; 7·5 Y 6/2 mottles; worm holes
		C	147–168	7·5 YR 5/8	sil	m	vfr		7·5 Y 7/2 mottles; worm casts
7	Alluvial fan; Typic Argiudoll	A	0–18	10 YR 2/2	cl	2f, m abk	vfr	cs	
		Bt1	18–33	10 YR 3/2	cl	1f, m abk	vfr	gs	10 YR 3/3 clay films
		Bt2	33–52	10 YR 3/3	cl	1f abk	vfr	cw	10 YR 3/3 clay films
		C	52–80	10 YR 4/4	sl	sg	vfr		
8	Gentle bedrock slope; Typic Argiaquoll	A	0–15	10 YR 3/2	sicl	3f, m abk	fr	cs	Worm casts
		AB	15–26	10 YR 4/2	sicl	3f, m abk	fr	cs	Worm casts
		B	26–74	2·5 Y 6/6	sicl	2f, c, m abk	fr	cs	Worm casts; stress surfaces
		BCg	74–88	2·5 Y 6/1; 2·5 Y 6/6	c	2f, c, m abk	fr	cs	Slickensides
		Cg	88+	5 Y 6/1; 2·5 Y 6/6	c	3c abk	fr		Slickensides; rock fragments
9	Steep bedrock slope; Lithic Rendoll	A	0–10	10 YR 2/2	sil	2f, m gr	vfr	cs	
		AC	10–17	10 YR 3/2	cl	2f, m gr	vfr	ai	Rock fragments
		R	17+	limestone bedrock					

*Abbreviations: sicl = silty clay loam; sil = silt loam; l = loam; cl = clay loam; c (under texture) = clay; 1 = weak; 2 = moderate; 3 = strong; f = fine; m = medium; c (under structure) = coarse; abk = angular blocky; sbk = subangular blocky; pr = prismatic; gr = granular; m = massive; sg = single-grain; fi = firm; fr = friable; vfr = very friable; cs = clear smooth; gs = gradual smooth; cw = clear wavy; ai = abrupt irregular.

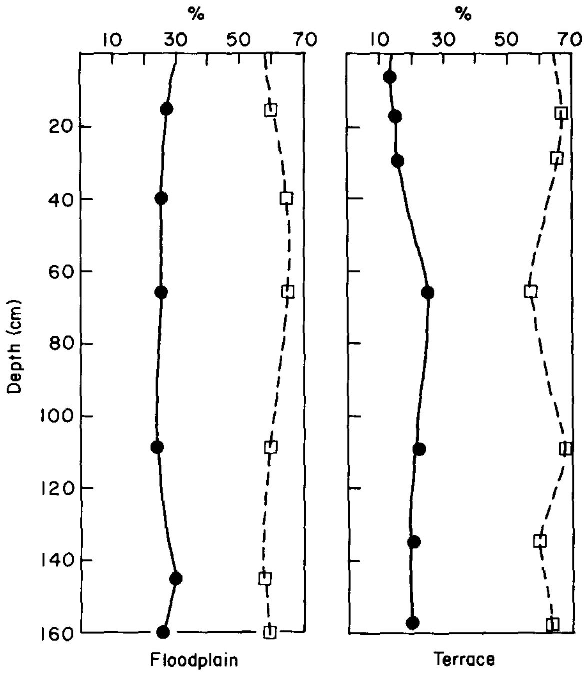

Figure 3. Clay and silt contents as functions of depth in the floodplain and terrace soils. ●——●, clay; □---□, silt.

reddish-brown colors which dominate the soil matrix indicate that the soils are probably not excessively wet for long, however. The terrace soils also have well developed structures that are satisfactory for root penetration. Although textural data indicate an argillic B horizon at depth (Figure 3), the increase in clay content is probably not high enough to seriously impede root growth or water movement.

In contrast to the floodplain and terrace soils which are derived largely from the granitic and metamorphic rocks of the Maya Mountains, small areas of alluvial fan deposits which partly overlie the terrace are derived from the local upland limestone bedrock. Profile 7 is representative of the Typic Argiudolls found on these deposits (Table 1). The solum is thin and is underlain by gravelly alluvial fan sediments with interbedded sands. Because the parent material is limestone-derived, calcium carbonate content is extremely high, ranging from 59 to 77%. Depite this, there is evidence of clay movement in the form of clay films (Table 1), and the soil has well developed structure. It is also well drained and the good structure would result in no serious problems for cacao root penetration in the upper part of the solum. However, the soil is thin and the gravelly texture of the C horizon would create serious problems for cacao roots.

On the upland limestone bedrock surfaces, soils vary with slope angle, as they do on other lithologies elsewhere in Belize (Furley, 1974*a*, *b*). Soils in the study area on flat or gently sloping bedrock surfaces are Typic Argiaquolls; steep slopes have Lithic Rendolls. The former soils have sola < 1 m deep, clayey textures in the lower B and C horizons, and show evidence of gleying as indicated by 2·5 Y and 5 Y hues (Table 1). In addition, the lower two horizons have slickensides which are indicative of intense swelling pressures resulting from seasonal wetting of smectitic clays. These features are common in Vertisols, but have also been reported in other soil types (e.g. Muhs, 1982); the swelling pressures exerted on roots in such soils can be severe. Thus, the solum depth, indications of poor internal drainage, and evidence of swelling pressures clearly indicate that these soils have serious physical limitations to cacao growth. The Lithic Rendolls found on more steeply sloping parts of the bedrock uplands are extremely shallow (Table 1) and it is unlikely that cacao could be grown on them, for that reason alone.

Soil chemical properties

The soils on the modern floodplain have very satisfactory chemical characteristics for cacao growth (Table 2). Organic matter decreases systematically with depth, and this is matched by a decrease in total nitrogen (N) with depth. However, organic matter content is high in the upper 0·3 m of the profile, which Smyth (1975) recommends for cacao growth. Cation exchange capacity is high in all horizons of the profile and the values (12–18 mmol 100 g^{-1}) are as high or higher than that recommended for cacao. The small variation in cation exchange capacity with depth is probably a reflection of the fairly constant clay content with depth (Figure 3). X-ray diffraction analyses of selected horizons indicate that the major clay minerals are kaolinite and mica. Soil pH is also fairly evenly distributed with depth and is surprisingly high considering that the main parent material for these soils is alluvium derived from the granitic and metamorphic Maya Mountains. Soils in the Maya Mountains themselves have quite low pHs and low quantities of exchangeable cations (Furley, 1974*a*, *b*). Romney (1962) reported pHs of less than 6·0 in all horizons of soils derived from young alluvium elsewhere in Belize. As a working hypothesis, we suggest that the high pHs found in the floodplain soils at Negroman may be a result of contributions of dissolved load from streams tributary to the Macal River which head in areas of limestone bedrock downstream of the Maya Mountains. This argument is supported by the high quantities of extractable Ca^{++} (Table 2). In any case, both pH values and extractable Ca^{++} are in the satisfactory range for cacao growth as specified by Smyth (1975). In addition, the pHs in this range indicate that all horizons are probably fully base-saturated (Buol *et al.*, 1980: 70). Extractable Mg^{++} and K^{+} are somewhat lower than the ideal values for cacao; however, they are not much lower and are fairly constant with depth (Table 2). We have included data on extractable P obtained by a method which is thought to be indicative of the quantities of this element available to plants. Smyth (1975) does not indicate any particular values of P that are limits for cacao growth. He does give some data on available P for soils that have been shown to support cacao satisfactorily. Our data indicate that the floodplain soils have values of P similar to those in some soils, and lower than those in other soils that support cacao. We feel that at this point in time too few data exist on available P necessary to support cacao to draw conclusions. In general, it appears that the floodplain soils have satisfactory chemical properties for cacao growth.

The Aquic Tropudalf on the terrace surface also appears to be generally satisfactory for cacao growth in terms of chemical properties, though perhaps somewhat less so than the floodplain soil (Table 2). Organic matter contents and total N contents are slightly lower in the surface horizons of this soil than in the floodplain soil, but are marginally satisfactory for cacao growth. The lower cation exchange capacities of this soil are apparently due to the lower organic matter and clay contents, because X-ray diffraction analysis indicates a clay mineralogy dominated by kaolinite and mica, similar to the floodplain soil. Soil pH is as high or higher (7·0–8·0) than the floodplain soil in all horizons. Although extractable K^{+} is higher than in the floodplain soil and extractable Mg^{++} is about the same, levels of extractable Ca^{++} are about half of what is present in the

Table 2. Chemical properties of representative soils studied in the Negroman area

Profile number	Horizon	Depth (cm)	Total N (%)	Organic matter (%)	Extractable P (ppm)	Extractable cations (mmol 100 g^{-1}) K^{+}	Ca^{2+}	Mg^{2+}	Na^{+}	CEC* (mmol 100 g^{-1})	pH
1	A	0–34	0·23	3·7	2·2	0·15	6·86	0·72	0·29	15·61	6·3
	BAt	34–36	0·14	1·7	1·6	0·11	5·86	0·62	0·27	13·35	7·1
	Bt1	46–85	0·12	1·3	1·5	0·09	6·17	0·64	0·31	14·01	7·4
	Bt2	85–130	0·09	0·9	2·0	0·09	5·46	0·68	0·32	12·67	7·2
	Bt3	130–160	0·08	0·7	1·5	0·18	8·00	0·88	0·40	18·33	6·8
	C	160+	0·07	0·7	3·0	0·12	6·53	0·66	0·35	14·86	7·0
5	A	0–13	0·19	2·9	124·2	0·98	3·49	0·81	0·27	9·85	7·0
	AB	13–21	0·15	1·9	98·7	0·74	3·58	0·77	0·28	9·71	7·3
	Bt1	21–41	0·09	0·9	49·2	0·74	2·60	0·54	0·23	7·26	7·5
	Bt2	41–92	0·07	0·4	1·5	1·03	2·47	0·98	0·25	8·20	7·9
	Bt3	92–126	0·07	0·5	1·9	0·70	2·71	0·81	0·25	7·99	8·0
	Bt4	126–147	0·06	0·4	4·3	0·34	3·48	0·77	0·27	9·10	8·0
	C	147–168	0·05	0·3	5·0	0·19	3·43	0·72	0·30	8·79	7·9
7	A	0–18	0·39	4·9	1·6	0·36	15·10	1·12	0·32	ND	8·0
	Bt1	18–33	0·19	2·0	<0·5	0·17	13·98	0·67	0·31	ND	8·0
	Bt2	33–52	0·12	1·2	<0·5	0·11	12·66	0·62	0·34	ND	8·3
	C	52–80	0·08	1·1	1·1	0·17	12·48	0·70	0·33	ND	8·3
8	A	0–15	0·26	6·0	2·2	0·33	12·22	1·07	0·35	ND	7·4
	AB	15–26	0·16	3·4	<0·5	0·24	16·33	0·87	0·37	ND	8·0
	B	26–74	0·08	1·0	1·0	0·12	13·16	0·54	0·33	ND	8·2
	BCg	74–88	0·04	0·5	<0·5	0·28	20·24	1·06	0·51	ND	8·0
	Cg	88+	0·03	0·3	<0·5	0·29	21·16	1·36	0·59	ND	8·0
9	A	0–10	0·63	7·5	1·3	0·54	17·83	1·22	0·37	ND	7·9
	AC	10–17	0·48	5·7	<0·5	0·17	13·60	0·68	0·32	ND	8·0

* By sum of cations in units of meq 100 g^{-1}; ND = not determined for soils with free calcium carbonate.

floodplain soil. The values of Ca^{++} range from about 2·5–3·5 mmol 100 g^{-1}, and the value in the surface horizon is slightly lower than the level recommended by Smyth (1975). These data suggest that the terrace is sufficiently old that significant quantities of Ca^{++} have been leached. Levels of extractable P in the upper horizons of the terrace soil are more than an order of magnitude higher than the levels found in the floodplain soil. We suspect that these high values of P are the result of manure accumulation (Proudfoot, 1976), since the terrace is presently being used for grazing cattle.

The chemical properties of the alluvial fan soil and the bedrock soils reflect the dominating influence of the limestone parent material. Organic matter content is high in all soils and decreases systematically with depth. Soil pH and extractable Ca^{++} values are all much higher than in either of the two soils discussed above (Table 2). Some pH values in the alluvial fan and gently sloping bedrock soils are significantly higher than those recommended for cacao. The presence of high amounts of Ca^{++} in soils has the effect of making P less available to plants and this is partly reflected in the lower values of extractable P in these soils (Table 2). Because there are free carbonates present in at least some horizons of all three of these soils, part of the Ca^{++} is not truly exchangeable, but is derived from the free calcium carbonate. Levels of extractable K^{+} and Mg^{++} are not significantly different from those found in the floodplain and terrace soils and are probably satisfactory for cacao growth.

Discussion

Cacao cultivation during the Colonial Period

On the basis of the field and laboratory data the best soils for cacao growth are the floodplain Hapludolls and Argiudolls. These soils are characterized by deep profiles, good structure, silt loam textures with minimally developed B horizons, and no evidence of saturated conditions. Soils on the floodplain also have high organic matter contents, near-neutral pHs, high cation exchange capacities, and high enough quantities of extractable Ca^{++}. Levels of extractable K^{+} and Mg^{++} are slightly lower than what is recommended for cacao, but are much higher than levels in some Liberian soils that are reported by Geiger & Nettleton (1979) to be satisfactory for cacao growth. Soils on the terrace above the modern floodplain also appear to be satisfactory for cacao growth in terms of physical properties, although there is evidence that they may be wet in the lower parts of their profiles for certain periods. In addition, the chemical properties of these latter soils are perhaps somewhat less than ideal. However, the soils on the alluvial fan and the upland bedrock areas have a number of undesirable physical properties and have excessive quantities of free carbonates that make them unlikely to support cacao. Finally, soils on the steeply sloping parts of the bedrock uplands are probably too dry during the dry season for year-round cacao growth, unless artificially terraced.

Soil considerations aside, the floodplain is the location of floods that could damage a cacao orchard. Normal low-magnitude floods should probably not affect cacao adversely since it is a deeply rooted tree. However, high-magnitude floods could be destructive. We examined analytical data from floodplain soils in order to assess the potential for this problem. In three soils sampled, organic matter content decreases systematically and gradually with depth (Figure 4). Floodplains that experience frequent floods with high quantities of suspended sediment often have soils that exhibit irregular changes in organic matter content with depth and are classified as Fluvents (Soil Survey Staff, 1975). In contrast, the floodplain soils in our study area demonstrate that a "normal" organic matter curve has been established, indicating that soil development can keep ahead of overbank sedimentation. Thus, high-magnitude floods

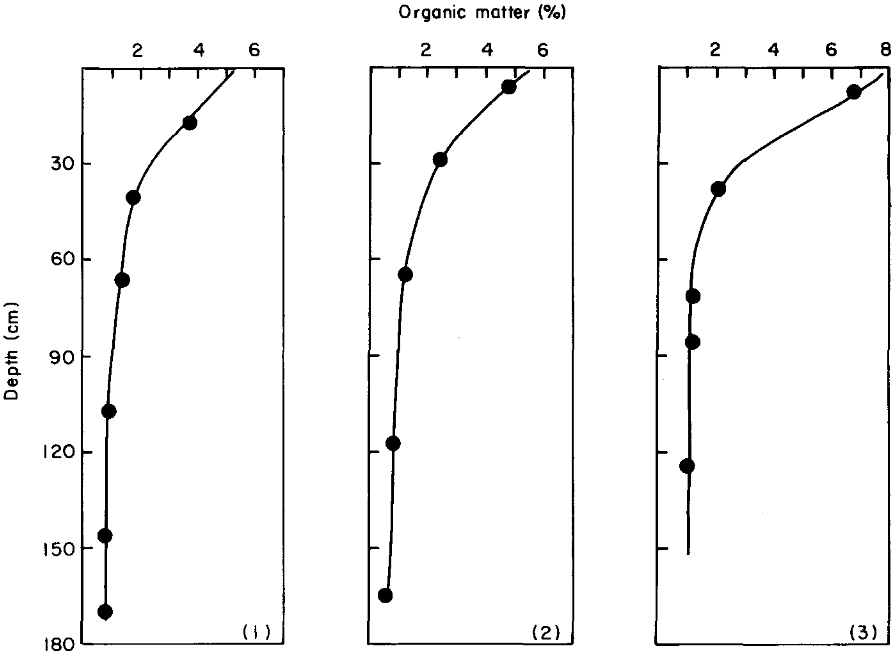

Figure 4. Organic matter content as a function of depth in three floodplain soils. Profile numbers are keyed to Figure 2.

probably occurred infrequently enough at Tipu that floodplain utilization by the Maya paid off in the long run.

The location of cacao orchards on the floodplain must also be reconciled with ethnohistoric data which indicate that at least 8000 trees were grown at Tipu (Jones, 1982). Wright *et al.* (1959: 158) suggest that each cacao tree should have an area of about 3 × 3 m. Based on the extent of the floodplain mapped in Figure 2, we estimate that at least 20,000 cacao trees could have been grown in the area to the west of the river alone.

We emphasize that our data indicate the *probable* location of cacao cultivation based on an assumption that the Colonial Period Maya wanted to maximize yields. However, non-agronomic factors (e.g. socio-political considerations) may well have entered into the decision-making process for locating cacao orchards. Investigation of these factors is beyond the scope of the present paper, but they are an important part of Maya land use studies.

Archaeological evidence of pre-Hispanic floodplain use

Our data imply that the floodplain was probably an important resource for the Maya during the Colonial Period. We also wished to investigate the significance of the floodplain as an agricultural resource in pre-Hispanic times. Willey *et al.* (1965) studied prehistoric settlement in the Belize River valley about 10–15 km to the northeast of the Negroman area; although they suggested (pp. 573–574) that cacao may have been grown on the floodplain, they felt that maize and other major crops were grown by milpa techniques on bedrock uplands. Research in the last 10 years has produced artifactual evidence demonstrating that the Maya developed several systems of intensive agriculture and that upland milpa techniques were not as significant everywhere in the area as was once thought (see reviews by Adams *et al.*, 1981; Hammond, 1978; Siemens, 1982;

Turner, 1978*a*, *b*, 1983; Turner & Harrison, 1981; Wiseman, 1983). We therefore conducted shallow subsurface surveys of the floodplain in order to see if there was any artifactual evidence of pre-Hispanic floodplain utilization by the Maya.

In the course of our floodplain investigations, we uncovered a line of stones at a depth of 140–160 cm composed of both carbonate and granitic clasts of pebble to boulder size (Figures 2 & 5). The long axis of the stone line is oriented roughly east–west, or nearly perpendicular to the river. Further excavation revealed a second stone line about 10–15 cm below the first, separated by fine-grained alluvium. Several lines of evidence suggest to us that the lines of stones are artificial constructions, although such features can form by a variety of geomorphic and pedogenic processes (see Ruhe, 1959; Wood & Johnson, 1978 for good reviews of possible mechanisms). Both lithics and ceramics were associated with the upper stone line; the ceramics have been tentatively identified as Late Classic (Prudence Rice, pers. comm., 1982). Although the stone lines have both carbonate and granitic clasts, our observations of modern point bars of the Macal River and stream-cut exposures of basal floodplain sediments indicate that bedload is composed almost exclusively of granitic material from the Maya Mountains. This suggests that the carbonate clasts in the stone line were purposefully carried to the site from outcrops elsewhere. The matrix which encases the stone line and forms part of the lower soil B horizon has a silt loam texture, which is too fine-grained to have been deposited in association with the large clasts. It is possible that such poor sorting could be explained by colluvial processes; in such a case, colluvial sediments would have to be derived from the terrace above the floodplain. We did observe colluvium overlain by floodplain sediments exposed in the gullies which dissect the floodplain and are mapped on Figure 2. However, this colluvium is 2–4 m below the surface of the floodplain and has bright reddish-brown (7·5 YR and 5 YR) colors which are typical of the B horizons of the terrace soils (Table 1). In contrast, the matrix enclosing the stone line has the dull brown (10 YR or 7·5 YR hues with low chromas) colors typical of the floodplain soils that we observed in all our soil pits. Hence, both fluvial and colluvial processes can be eliminated as possible causes.

We hypothesized that the two stone lines were former field walls, separated by an episode of overbank sedimentation. To test this hypothesis, we dug a second pit 5 m west

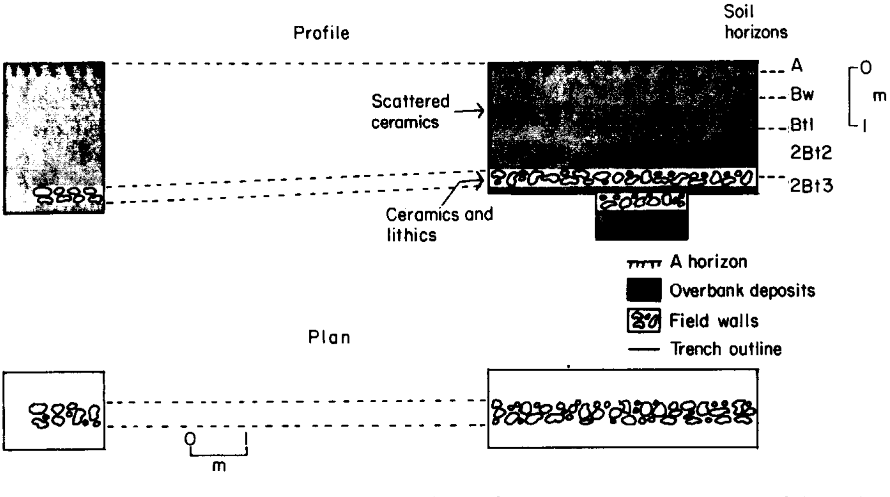

Figure 5. Profile and plan views of two trenches exposing the field walls. Location of walls is given in Figure 2.

of our trench to see if the upper stone line exhibited lateral continuity, which is what we would expect if it was a field wall. The results indicated that the stone line extends for an additional 6 m to the west (for a total length of at least 9 m) with about a 20 cm drop in elevation, supporting the field wall hypothesis (Figure 5). The upper line of stones does have some of the characteristics of wier terraces which have been recently described in some detail by Turner (1983) and Healy *et al.* (1983). In particular, the upper stone line has a slightly arched appearance in profile when viewed from the east or west (i.e. looking down the long axis). However, with the long axis oriented perpendicular to the river on an essentially flat floodplain surface, it is difficult to envision how floodwaters and overbank sediments could be effectively controlled by such a structure.

With the Late Classic age assignment for the ceramics, the upper wall could be of Late Classic age or younger (if the ceramics were reused as building material), but unfortunately, no radiocarbon-dateable materials were found at the site. Nearby, however, in a streambank exposure at a depth of 160–170 cm (Figure 2), we found abundant charcoal in fine-grained alluvium that is interpreted to be overbank sediment. A radiocarbon date on this charcoal is 830 ± 80 years (Beta–8710), which yields an average overbank sedimentation rate of 0·19 cm year^{-1}. Extrapolating this rate to the field wall site, we calculate an age of about 736 years BP for a depth of 140 cm and an age of about 842 years BP for a depth of 160 cm. Either of these age estimates would suggest that the upper field wall was constructed during the Postclassic, rather than during the Late Classic. Given the uncertainties in both methods of age determination, we suggest that the walls could be of either Late Classic or Postclassic age.

The precise function of the field walls is not clear. Turner (1978*b*, 1983) has reviewed the distribution of stone walls in the Maya lowlands and their possible uses. He suggests that they may have served as lines of demarcation (as a result of intensive land use), deterrents to pests, walkways for areas that were seasonally wet, or protection for crops. At this time, we lack sufficient data to clearly identify a function for the Tipu field walls. However, given the scale of the walls, we hypothesize that they were probably used as lines of demarcation, and this suggests an agricultural endeavor on the floodplain during the Late Classic or Postclassic.

The discovery of these features at Negroman is significant because stone walls (as opposed to stone terraces on hillslopes) have not been reported as far south as the Macal River (Turner, 1983: 31; written comm., 1984). Because the stone walls we found were buried by alluvium, it is possible that other such features are undiscovered simply because they have little or no surface expression. More shallow subsurface exploration in the Belize River drainage basin is necessary to test this hypothesis.

Conclusions

Our studies have shown that the most likely location for cacao orchards during the Spanish Colonial Period at Tipu was on the floodplain. Overall, the floodplain soils have the best combination of physical and chemical properties for cacao growth based on comparisons with published data where cacao has been grown successfully.

Jones (1982) has presented ethnohistoric evidence that there were also cacao orchards at the Colonial Period Maya settlements of Chantome, Zaczuuc, and Lucu on the Belize River. Certain of these settlements have been only approximately located (Jones, 1982: 278). Detailed soil mapping at a scale comparable to that in the present study might help to pinpoint these settlements more precisely, since areas not suitable for cacao growth based on soils data could be eliminated as candidates.

The discovery of probable pre-Hispanic field demarcation walls on the floodplain at Negroman adds to the growing evidence of agricultural relics in the Cayo District of western Belize. Although other features such as terraces (Healy *et al.*, 1983), a dam (Healy, 1983), and possibly raised fields and canals (Kirke, 1980) have been found, the stone walls reported here are the first of which we are aware in this part of Belize.

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