3. Some Soils Common to Caracol, Belize and Their Significance to Ancient Agriculture and Land Use

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During the Classic Period Caracol, Belize was one of the largest and most important cities in the Southern Maya lowlands of Central America (Chase and Chase 1987). An area of approximately 100 square kilometers was occupied by over 150,000 persons (Chase and Chase 1991). Most food production for this center occurred within this same area and its immediate periphery, an area encompassing about 200 square kilometers. In-field farming was carried out within the terraced fields that characterize all of Caracol's residential settlement. The site's many causeways were conducive to out-field farming and the transportation of goods throughout the city. Whatever was not locally produced was presumably imported into Caracol from somewhat further afield.

Since soils are basic to most agricultural production we must consider their nature and properties in order to understand the food support system. The Classic Maya also utilized soils for other purposes relating to construction engineering and incorporated them into structural fill. This study of the soils at Caracol was undertaken for several purposes: (1) to measure the effect of ancient agricultural practices on modern soils; (2) to understand the fertility of present day soils in order to make assumptions concerning the fertility of ancient soils and, thus, the food production capacity of these soils; (3) to investigate how the ancient Maya manipulated soils for agricultural and engineering purposes; and (4) to aid in the development of a farming-gardening operation modelled after ancient Maya practices for the purposes of studying and demonstrating sustainable agriculture in the tropics and for the purposes of eco-tourism.

Many earlier researchers interested in the ancient Maya assumed that "slash-and-burn" shifting agriculture was widely practiced, using agricultural models based on the ethnographically-known modern small farmers in this area (Reina 1967). More recent studies (Donkin 1979; Dunning 1993; Flannery 1982; Harrison and Turner 1978; Pohl 1990; Turner and Harrison 1983) point out that intensive agricultural practices such as raised beds in wetlands (or drainage systems), terraces, and fertilization were employed by the ancient Maya. That the Maya had to have used more than slash-and-burn can be demonstrated through considerations of carrying capacity and prehistoric population estimates (cf. Culbert and Rice 1990).

During the Classic Period, the Maya constructed extensive stone-walled terraces on and between the rolling hills that characterize the site of Caracol, Belize, presumably to conserve soil and water and to intensify agriculture. In 1990 and 1991, four soils in the upper and lower portions of two terraces were examined and described (Coultas et al. 1993). Two other soils were studied in 1992; one occurred in a basin at the foot of a series of surrounding terraces and the other occurred on a steep non-terraced slope near a hillcrest. In 1993 the occurrence (position) of this second non-terraced soil was delineated relative to the terraced soils which occurred on the hill's lower slopes. During 1993 an extensive area of a calcareous soil which occurs in a non-terraced area of minimal slope some 6 kilometers northeast of Caracol's epicenter was also sampled.

The climate at Caracol is warm, humid, and tropical with approximately 1.8 meters of rainfall per annum. There is a distinct dry season which usually occurs from January through May. Elevation ranges from 500 to 600 meters and the topography is karstic. The limestone which underlies this region is relatively pure calcite. There are no perennial streams within 15 km of epicentral Caracol and ground water occurs at a depth of over 140 meters. Vegetation is composed of a dense, non-deciduous, broad-leafed forest with a closed canopy; numerous palm trees also occur in the area (cf. Johnson and Chaffey 1973).

Methods and Materials

Soils were examined by auger along Caracol's Pajaro-Ramonal Causeway, Northeast Causeway, Northwest Causeway, and the modern road entering the site from the east and northeast. Most intensive examinations were made within a 5 square kilometer area around the site's epicenter (as represented by the architectural complex of Caana), but this study represents the principal soils in, at least, a 25 square kilometer area.

Soils were described and sampled following the procedures outlined by the United States Department of Agriculture Soil Conservation Service (Anonymous 1981). The following determinations were performed on all soil horizons: pH in 1:1 water and 1:2.5 KCl where appropriate (Jackson 1958), total N (Bremner 1965), organic C (Jackson 1958), extractable macro-and micro-nutrients using the Mehlich 3 method on acidic horizons (Mehlich 1984) and the AB-DTPA method on calcareous horizons (Soltanpour and Schwab 1977). Total P content was determined after digestion with perchloric acid (Olsen and Sommers 1982). Metallic elements were determined using an ICP mass spectrometer (Jarrell Ash model 750). Calcium carbonate equivalence (CCE) was determined by digesting the soil in 0.5N HCl and back-titrating with NaOH (Anonymous 1971). Electrical conductivity (EC) was determined following procedures outlined by Jackson (1958).

Particle size was determined after oxidation of organic matter with H_2O_2 using the pipette method (Day 1965). Mineralogy of the 2 micro and finer clay fraction was determined by X-ray diffraction instrument (Cu-K alpha radiation; Whittig 1965).

Results and Discussion

The soils on the terraces are very dark-brown in color; with depth they grade to dark brown and contain clay textures (Table 3.1). The terraced soils are relatively shallow over their limestone base. They have a well developed fine or medium angular blocky structure that is very firm when dry. Reaction is near neutral in the upper horizons but alkaline just above the limestone. There is a thin layer of organic material (partially rotted leaves) at the soil surface. Roots are common throughout the soil but are most abundant near the soil surface. Slickensides (shiny surfaces caused by the shrinking and swelling of clays) occur in the lower horizons of the three soils with the deeper horizons, but not in the soil that is only 38 centimeters thick.

The soil in the depression or "bajo" at the base of a series of terraces (Table 3.2) has a clay texture at the surface; this clay texture continues to a depth of at least 165 centimeters. The matrix color ranges from black at the surface to dark gray with depth. Red and reddish-brown mottles are common from 5 to 165 centimeters, indicating a fluctuating watertable which does occur at this locale. Although this soil contains large amounts of smectites (Table 3.8), no slickensides have developed. This indicates that this site does not dry significantly during the yearly dry season.

The steeply sloping non-terraced soil (hillcrest) is morphologically different from soils described above (Table 3.2). It contains the least amount of clay (Table 3.8), but a large amount of $CaCO_3$ (and/or $MgCO_3$) throughout. It has a loam or silt loam texture with fairly uniform clay content with depth. It has the highest sand content of any soil examined. The surface soil is dark brown to a depth of 66 centimeters and has a granular to weak subangular blocky structure. Below 66 centimeters, the colors of the soil are light red and red; pieces of soft pinkish-white limestone are common. The boundary between the A, AC, and the C horizon is wavy to irregular.

The other non-terraced soil examined is located approximately 6 kilometers northeast of central Caracol and occurs in an extensive are of very low slope (less than 4%). Although the soil occurs in a saddle in a relatively high position, the vegetation that characterizes the area is indicative of bajo-like conditions elsewhere at the site. A thin organic (Oe) horizon overlies a very dark gray-brown A1 horizon which is calcareous and has a silty clay texture (Table 3.2). A number of pottery sherds and one obsidian chip occurred in the upper soil layers. The soil becomes more calcareous and lower in clay content with depth. The boundaries between the lower AC horizon and the C horizon are clear to abrupt and wavy to irregular in appearance. Although this soil contains more organic C at the surface than the steep hillside soil, the sequence of horizons, the high CCE, and the wavy to irregular topography of the lower A, AC, and upper C horizons are similar in the two calcareous soils. The soil on the flatter slope, however, has a thinner solum and the A1 horizon is much higher in clay than the steep hillside soil.

Most horizons of the terraced soils are near neutral in reaction as measured in water (Table 3.3). These soils became more acidic upon measuring with KCl, suggesting the presence of extractable A1. Organic C content is high at the surface, ranging from 5.68% to 6.38%. Organic C content decreases with depth, but significant amounts occur at the soil-rock interface. Total N is low relative to organic C with C/N ratios ranging from 27 to 63, but with most horizons in the 35 to 42 range. Total P and extractable P contents are highest at or near the surface. Total P amounts range from 468 to 826 mg/kg in the terraced soils. Calcium is the most abundant extractable element in all soils. It ranges from 6,172 to 9,771 mg/dm^3 in the terraced soils using Mehlich 3 extractant (Table 3.5). Magnesium is the next most abundant element with Ca:Mg ratios lowest at the surface (14-16). Potassium content is highest at the surface (82 to 90 mg/dm^3) of the terraced soils. Micro-nutrients, except for Mo, are highest at the surface and decrease appreciably in the lower horizons (Table 3.5). Extractable Mo tends either to be fairly uniform with depth or to increase somewhat in the horizon overlying the rock.

The soil in the bajo has a thin surface organic horizon (Table 3.4). The C:N ratio is relatively narrow compared with the better drained terraced soils suggesting more micro-biological activity. The non-terraced hillcrest soil has a relatively high organic C content (approaching an organic layer) at the surface that decreases gradually with depth. The C:N ratios are relatively narrow, as in the bajo. Total P amounts in the steeply sloping hillside soil ranges from 810 parts per million at the surface to 420 parts per million at a depth of 85-104 centimeters. This is similar to the levels and distribution of P in the terraced soils. Total P amounts in the bajo soil ranges from 1570 parts per million at the surface to 840 parts per million in the subsoil. Extractable P content is higher in both the bajo and non-terraced hillside soil than in the terraced soils, suggesting movement of available P from the upland to the bajo and, possibly, applications of P containing amendments to the steep calcareous soil. Salinity is not a problem with any soil examined as indicated by conductivity measurements (Table 3.4).

Most macro and micro-nutrients are in adequate supply for most agronomic crops in both the bajo and hillcrest soils (Table 3.6). Zinc is limiting in the hillcrest soil, except in the 0-8 centimeter layer.

The particle-size analyses and mineralogical data of the terraced soils are shown in Table 3.7. All soils are high in clay ranging from 64.8% to 75.2% with no indication of clay translocation. These soils contain very little sand (4.5% to 12.0%) with slightly higher amounts in the horizon adjacent to the limestone. The mineralogy of the clay is predominantly smectite with small amounts of kaolinite and quartz. There appears to be no particular pattern to the distribution of the clay suites except that there is an increase in kaolinite and a decrease in smectite with depth in the soils at the lower site on the upper terrace.

Except for the 0-5 centimeter horizon of the bajo soil, particle-size content and distribution are similar to the terraced soils (Table 3.8). The surface of the bajo soil contains a relatively high silt content which is difficult to explain. It is doubtful that winds would have been the agency of transport. The clay mineralogy of the bajo soil, however, is similar to that of the terraced soils.

The non-terraced hillcrest soil has a loamy texture with silt being the predominant particle size (Table 3.8). The sand content is higher than in any other soil examined and the clay content is lowest. Calcium carbonate equivalence is high at the surface, increases to a depth of 66 centimeters, and then decreases slightly. Clay mineralogy is predominantly smectite, excluding calcite.

Both the non-terraced hillcrest and the relatively flat calcareous soil pose some intriguing questions concerning origin and genesis. While the terraced soils are associated with the bajo soil in a fashion that could be predicted topographically, such is not the case with the calcareous hillcrest and relatively flat soil. Large deposits of this deep calcareous loamy material are common throughout Caracol in hillcrest positions. This is not what one would expect from natural factors of soil formation. Over a rolling limestone surface we would expect thinner soils on the steeper hillsides and hillcrests, unless silty materials were blown in and differentially deposited on the higher surfaces (this is a common phenomenon in Western Iowa where silty loess caps the glacial till). This mode of deposition is not possible when one considers the large limestone rocks (and smaller quartz stones) interspersed in the loamy matrix. Archaeologically, it is clear that these extensive deposits of loamy material were not deposited by the ancient Maya, but are naturally occurring. If anything, the only manipulation of these areas by the Maya involved the removal of the original soil horizons above the calcareous deposit for use else-

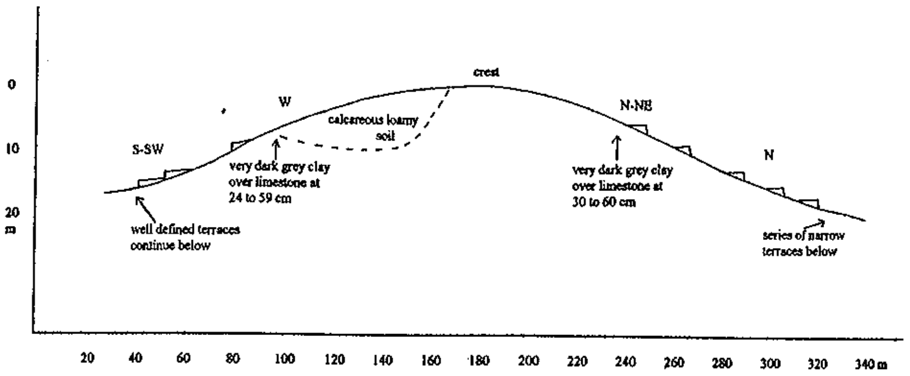

Figure 3.1. Slope, slope direction, and soils across a ridgecrest along the Northwest Causeway.

where, in either building or terrace construction. These calcareous deposits also differ from "sascab" (Isphording and Wilson 1973), the highly calcareous material found under caprock formations, which is also known from archaeological contexts at Caracol. Several calcareous deposits have recently been excavated for use as modern road-building material. These deposits rest on an irregular hard limestone surface near ridgecrests. The position of the hillcrest soil that was examined is illustrated in Figure 3.1; this soil occurs on a 18% to 25% convex slope facing west. There is an abrupt boundary between the thin dark gray-brown clay soil in the terraced areas and the thick calcareous soil both at the ridgecrest and where the slope flattens to 8% to 10%. Stone-walled terraces occur shortly after the slope flattens. Laterally, this calcareous soil extends an estimated 200 m in a N-S direction.

From a soils standpoint, these calcareous soils (both the steeply sloping hillcrest and the relatively flat soil) are relatively fresh (young) deposits because of their high carbonate content. Some downward movement or weathering of Ca/Mg carbonates has occurred in the soil surface. With fairly well distributed rainfall (and a January through April dry season) of over 1.5 meters we would expect at least this much leaching within a millennia.

The organic C content and distribution is of interest and suggests possible management practices. The hillcrest soil contains a high organic C content in the 0-8 cm layer, approaching that of an organic soil. The terraced soils contain organic C in the range of 5.7% to 6.4% in the surface 20 centimeters. If you average the organic C content of the surface 23 centimeters of the hillcrest soil, the organic C content is similar. This suggests that the hillcrest soils were not manipulated for agricultural purposes and, as a result, high organic C accumulated at the surface. The shrink-swell nature of the terraced soils also results in a "churning" effect, mixing the organic C to greater depths. Although the hillcrest soils have a much steeper slope than the terraced soils, little erosion occurred, possibly because of the continuous tree cover.

The effect of the terraces on the soil slope and thickness at Caracol has been previously discussed (Coultas et al. 1993). The terraces have been effective in slowing soil erosion or, at least, the soil is thicker just above the terrace than it is at the upper side of the terrace floor. Because of terracing, the effective slope has been reduced from a steeper hillside gradient to less than 2%. There has been some obvious human disturbance: the culling of stone from the inter-terrace soil, the construction of the terrace, and often the presence of some pottery sherds and other artifacts throughout the soil horizons of a terrace, including those immediately above bedrock.

Although all soils were examined at the end of an extended dry period, the soils did not have vertically oriented, wide cracks from the surface tapering into the subsoil. In similar soils exposed to the sun in the dry season in northern Belize, wide surface cracking tapering into the subsoil is common (Coultas et al. n.d.). It is probable that if the terraced soils were cleared for planting they would become warmer and drier at the end of the dry season and surface cracking would occur.

The presence of slickensides raises questions concerning soil disturbance by humans and the time required for the development of this feature. It is likely that such a feature can develop in a few hundred years (L. Wilding [Texas A & M], personal communication 1993). If the cracking at the surface became wide enough and with massive movement of the subsoil material, it is possible that some artifacts dropped on the soil surface could have become mixed deeply in the soil by natural processes. The archaeological situation, however, indicates that large sherds and other refuse were sometimes directly deposited on the cleaned bedrock before the replacement of the covering soil comprising a terrace.

Summary and Conclusions

Although the terraced soils are high in clays, difficult to work with modern equipment, and relatively shallow, they are high in many nutrients needed for crop production. They are well supplied with organic C which, along with the highly smectitic clays, enhances the soil's capacity to hold nutrients and water. Nitrogen and available P are the elements most limiting to crop production, now and probably during Classic Maya times. Calcium and Mg are in good supply, and the Ca:Mg ratios are favorable in the surface layers. Potassium is adequate in the surface soil in the terraces, but becomes limiting for most crops with depth. The non-terraced soil of the bajo and hillcrest have higher K levels. Micro-nutrients are high in all surface soils, but decrease with depth. Soluble salts do not limit crop production as indicated by the low EC measurements and the relatively low Na content.

The relatively flat calcareous soils would be very productive for most crops. Their low slope and stone-free condition make them easier to farm than the steeper, stonier terraced soils. The former soils contain relatively less clay which makes them easier to till. Soil depth is much greater in the calcareous soils. This permits deeper rooting and therefore the roots have a greater volume of soil to exploit for nutrients and water. Available P is greater in the surface of the calcareous soils than in the terraced soils and other nutrients are in adequate supply. High levels of carbonates often reduce the availability of certain nutrients, but this is not indicated by the chemical tests.

All soils are relatively young and unweathered, as indicated by the high content of smectitic clay, the high content of bases, and the lack of significant morphological development. There has been no clay translocation in the soils. Horizon boundaries are gradual (except at the rock-soil interface) and smooth in the soils on the terraces and in the bajo. In both the hillcrest with its higher slope and the other calcareous soil with its lower slope the wavy A/C boundary suggests some disturbance, possibly wind-thrown of trees due to shallow rooting.

What has been the effect of ancient agriculture on the modern soils at Caracol? Certainly the terraces have been effective in slowing erosion and, presumably, conserving moisture. Rocks have been culled from the inter-terrace soil for the construction of terraces and probably other structures and platforms. The surface horizons are higher in available plant nutrients than the subsoil. Whether this is due to fertilizer applications by the ancient Maya or natural bio-accumulation is a moot question. Elevated P levels are sometimes used by archaeologists as an indicator of ancient intensive agriculture, or at least habitation (Dunning 1993), but we can conclude little from our data. We are of the opinion that fractionating P compounds following Chang and Jackson's (1957) procedures will yield few clues concerning very ancient agricultural practices. Since we found high total P levels in the bajo which received runoff from the terraces, this procedure needs testing at this site. Sandor, Gersper, and Hawley (1986) found that total P and most P fractions were reduced by cropping between A.D. 1000 and 1150 on terraced soils in southwestern New Mexico. Total P levels and P fractions vary considerably due to differences in parent material and other factors of soil formation. Sandor and Eash (1991) found that total P levels in volcanic ash in Peru ranged from less than 100 to around 1900 mg P/kg soil. Agricultural activity can certainly affect P levels either positively or negatively.

The origin of these soils raises some interesting questions. Healy, Lambert, Arnason, and Hebda (1983) stated that the lack of a "C" horizon (layer of disintegrating limestone in this case) in the terraced soils indicated major disturbance and concluded that the soil was transported and deposited by humans. There is an abrupt boundary between the soil and the underlying limestone, but there is a thin transitional layer (some limestone gravel and lighter colors) just above the limestone. The sequence and uniformity of horizons, both vertically and horizontally, do not suggest major disturbance. The mineralogical data, however, do suggest a lithological discontinuity. The limestone is nearly pure calcite while the soil clays contain high levels of smectite and no calcite. Possibly the terraced soils contained a significant loamy, calcareous horizon which was mined by the Maya to be used in construction, but this material could have been obtained more easily from other locales given the prevalence of the hillcrest type soils in the Caracol area.

For the sake of argument, if soil development on the terraces did not occur in situ and soil material was not transported and deposited by humans, then what else could account for its origin? Wind and water are two other agents for transport of parent material. Volcanic activity is common to the west in the Peten, but no minerals common to volcanic deposits were found. It is our opinion, however, that a fraction of the soil minerals have been weathered from wind-blown deposits. There are no stream systems in the area which could account for such deposits. Marine transgression must have occurred at one time, but well back in the geologic past. Bloom, Pohl, and Stern (1985) found buried wood near sea level on the Hondo River in northern Belize; it dated to around 3,000 years before present and had been placed in canals that were constructed for drainage or raised-bed crop sites. The Caracol soils, at an elevation of over 500 meters, are much older, and it is unlikely that the youthful features of these soils would have persisted from the time of marine transgression.

The terraced soils have some of the properties associated with Vertisols, i.e. high amounts of smectite clay and slickensides. They do not form wide deep cracks to the surface under present conditions of vegetation. They do have dark colored, high base status surface horizons which would qualify them for Mollisols except for the fact that the peds are very firm when dry. We therefore classify the terraced soils as Vertisol taxajuncts. The hillcrest soil has a mollic surface, friable granular structure, and qualifies as a Mollisol (Calciustoll). The bajo soil has a thick dark-colored surface horizon which probably has a high base status. Since the aggregates would likely be very firm when dry, we can not class it as a Mollisol; and since it has neither slickensides nor significant cracking (permanently wet), it is not a Vertisol. We therefore classify it as an Inceptisol (Humaquept). We classify the calcareous soil on low slopes as a Vertisols taxajunct for the same reasons cited for the terraced soils.

We can conclude, then, that these were reasonably productive soils for the ancient Maya. They may have enhanced their productivity with a compost of plant and animal wastes, and we have some evidence for this. They protected the soil from destructive erosion and conserved water with the systematic construction of stone terraces. Importantly, the examination of modern soils do not suggest the likelihood of a failure in soil productivity during the Classic Maya Period, thus raising serious questions with regard to Healy, Lambert, Arnason, and Hebda's (1983) conclusion that the collapse of Maya civilization at Caracol could have been due to a destruction of the soil base.

Table 3.1: Description of four soils on two terraces at Caracol, Belize. The area was densely forested and slopes were 1-2%.

Horizon	Depth cm	Munsell Color moist	Text.	Structure	Consist.	Other
Lower part of lower terrace						
A	0-20	7.5YR 3/2	c	f,m blky	v. firm	abund. f., med. roots, occ. shards
Bss	20-38	7.5YR 4/2	c	"	"	f to l roots with slickensides
Bw	38-55	7.5YR 4/2	c	"	"	f to m roots
2R	55	white limestone, wavy surface				
Upper part of lower surface						
A	0-20	7.5YR 3/2	c	f, m blky	v. firm	abund. f to 1 roots
Bw1	20-34	7.5YR 4/2	c	"	"	freq f to m roots
Bw2	34-38	7.5YR 4/4	c	"	"	freq gr occ f roots
2R	38	white limestone, wavy surface				
Lower part of upper terrace						
A	0-20	7.5YR 3/2	c	f, m blky	v. firm	abund. f, m roots
Bw	22-32	7.5YR 4/2	c	"	"	freq f, m roots
Bss	32-53	7.5YR 4/2	c	"	"	occ m, f roots, slickensides vertical cracks
Bw	72-80	7.5YR 4/3	c	"	"	rare f roots
2R	80	white limestone, wavy surface				
Upper part of upper terrace						
A	0-20	7.5YR 3/2	c	f, m blky	V. firm	abund m, f roots occ 1 roots
Bw	20-32	7.5YR 4/2	c	"	"	occ m, f roots vert. cracks
Bss	32-52	7.5YR 4/2	c	"	"	occ f to 1 roots slickensides
Bw	52-55	7.5YR 4/2	c	"	"	rare m, f roots, calc gr
2R	55	white limestone, wavy surface				

Abbreviations: c=clay, f=fine, m=medium, blky=blocky (mainly angular), v=very, l=large, wk=weak, gr=gravel (some calcareous, some not), abund=abundant, freq=frequent, occ=occasional, calc=calcareous

Adapted from Coultas et al. 1993.

Table 3.2: ·Description of 3 non-terrace soils at Caracol.

Horizon	Depth cm	Munsell Color Moist	Text.	Structure	Consist.	Other
			Depressional soil at base of terrace			
OE	5-0	black 10YR 2.5/1	c	f gr	fr	abund f, med roots
A1	0-10	black 2.5Y 3/0 mot red 2.5YR 4/6	c	wk sbk to mass	v sticky	occ f, med roots
A2	10-28	v dk gr 2.5Y 3/0 - 4/0 mot reddish br 2.5YR 4/4	c	"	"	"
A3	28-46	dk gr 2.5Y 4/0 mot reddish br 2.5 YR 4/3	c	"	"	rare roots
A4	46-61	"	c	wk sbk	"	" "
A5	61-81	"	c	sbk	"	shiny ped faces
C	81-160	dk gr matrix rbr mottles	c	mass	"	no roots
			Steeply sloping hillside soil			
A1	0-8	dk br 7.5YR 3/2	l	gran	fr	abund roots occ ls gr
A2	8-23	"	l	gran, wk sbk	" "	abund roots freq ls grav.
A3	23-41	v dk gr br 10YR 3/2	l	"	"	occ roots, wvy bdry freq ls grav.
AC1	41-66	dk br 10YR 4/3	l	"	"	"
AC2	66-84	br. 10YR 4/3 ry mottles	si l	"	"	"
C1	84-104	lt red matrix 2.5YR 6/8 red lamellae + pinkish white soft limestone 2.5YR 4/8	l	wk platy	"	no roots freq ls grav occ ls boulders
C2	104-200	lt red matrix 2.5YR 6/8 pinkish soft ls more abund	-	single grn	los	"
			Relatively flat soil 8 kilometers northeast of central Caracol			
Oe	4-0	dusky red 2.5YR 3/2	Organic	mass	fri	abund f roots calcareous
A1	0-15	v dk gr br 10YR 3/2	si c*	sbk	sticky	calcareous, sherds, abund f, med roots
A2	15-25	dk gr br 10YR 4/2	si c	sbk	sticky	calcareous, sherds freq. f, med roots
AC1	25-39	gr br 10YR 5/2	si cl	wk sbk	sticky	calcareous occ f roots
AC2	39-47	gr br & lt gr br mixed 10YR 5/2, 6/2	si cl	wk sbk	-	occ f roots $CaCO_3$ grav wvy. bdry
C1	47-56	lt gr br & white 10YR 6/2, 8/2 mixed	si cl	wk sbk	-	calcareous rare f roots
C2	56-66	lt gr & white 10YR 7/2, 8/2 mixed	si l	gran	-	calcareous rare f roots
C3	66-91	white 10YR 8/2	si l	-	-	calcareous

Abbreviations: c=clay, l=loam, si l=silt loam, cl=clay loam, mot=mottled, v=very, dk=dark, gr=gray, br=brown, lt=light, f=fine, gran=granular, w=weak, sbk=subangular blocky, mass=massive, grn=grained, fr=friable, ls=limestone, grav=gravel, wvy=wavy, bdry=boundary, abund=abundant, occ=occasional, los=loose

*Estimates

Table 3.3: Some physical and chemical properties of some terrace soils at Caracol.

Depth cm	pH H_2O	KCL	Organic C	Total N	Total P PPM	Extract P PPM	Electric. Conduct. mmhos/cm
			----------%----------				
Lower part, lower terrace							
0-20	6.4	5.6	5.68	0.138	623	10.0-	0.50
20-38	6.3	5.4	2.88	0.083	604	8.8-	-
38-55	7.6	6.8	2.11	0.055	598	4.6+	-
Upper part, lower terrace							
0-20	7.0	6.4	6.38	0.152	807	10.9-	0.75
20-34	6.8	6.1	2.32	0.062	690	8.0-	-
34-38	7.3	6.5	2.32	0.037	643	5.0+	-
Lower part, upper terrace							
0-22	6.9	6.0	5.84	0.120	485	9.5-	0.50
22-32	6.3	5.5	2.50	0.061	654	8.4-	-
32-55	5.8	4.9	1.66	0.026	526	7.8-	0.17
75-72	7.3	6.4	1.41	0.046	604	9.3-	-
72-80	7.8	6.9	1.20	0.031	612	2.9+	-
Upper part, upper terrace							
0-20	6.8	5.9	5.84	0.100	826	10.1-	0.84
20-32	6.1	5.1	2.39	0.088	748	7.9-	-
32-52	6.1	5.2	1.66	0.039	468	7.4-	-
52-55	7.6	6.8	1.58	0.039	602	5.5+	-

Phosphorus was extracted from the upper horizons of all soils using Mehlich 3 procedure. In the horizon just above the limestone, which was alkaline in pH, the ammonium bicarbonate--DTPA extraction was used.
The symbol - indicates low of extractable P and + indicates medium levels.

Adapted from Coultas et al. 1993.

Table 3.4: Some physical and chemical properties of three non-terrace soils at Caracol.

Depth cm	pH H_2O	KCL	Organic C	Total N	Total P PPM	Extract P PPM	Electric. Conduct. mmhos/cm	CCE %
			----------%----------					
Soil in depression								
5-0	5.4	4.8	17.3	1.50	1570	33.2 m	0.7	
0-10	5.2	4.8	3.0	0.35	1510	19.9 m	0.3	
10-28	5.4	4.9	1.3	0.20	1080	16.0 m	0.2	
28-46	5.4	4.8	1.2	0.13	910	14.4 l	0.1	No Free $CaCO_3$
46-61	5.3	4.8	0.8	0.13	850	15.0 l	0.1	
61-81	5.0	4.5	0.8	0.11	840	13.7 l	0.1	
81-160	4.9	4.4	0.9	0.13	930	12.8 l	0.1	
Steeply sloping hillside soil								
0-8	6.9	-	11.0	0.54	810	31.2 vh	1.0	56.9
8-23	7.3	-	3.1	0.34	770	14.2 h	0.7	65.6
23-41	7.3	-	1.9	0.21	690	7.9 h	0.6	71.1
41-66	7.5	-	0.8	0.08	490	5.2 m	0.4	77.8
66-84	7.6	-	0.7	0.07	460	5.3 m	0.4	76.4
84-104	7.7	-	--	0.03	420	3.7 m	0.3	69.6
104-200	--	-	--					
Relatively flat soil 8 kilometers northeast of central Caracol								
4-0	7.4	-	19.1	0.65		15.8h		37.8
0-15	7.7	-	5.0	0.33	Not determined	5.1m	Not determined	51.4
15-25	7.9	-	1.6	-		-		60.8
25-39	8.1	-	0.6	-		-		70.8
39-47	8.1	-	0.5	-		-		67.7
47-56	8.1	-	-	-		-		80.1
56-66	8.2	-	0.5	-		-		89.2
66-91	8.4	-	0.2	-		-		89.9

*Mehlich 3 extractant used in depressional soil; Ammonium bicarbonate DTPA extractant used for sloping soil. vh = very high, h=high, l=low for agronomic crops

Table 3.5: .Some extractable macro- and micro-nutrients from some terrace soils at Caracol.

Depth	Ca	Mg.	K	Mo	Zn	B	Cu	Fe	Mn
cm	mg/dm^3 or PPM								
Lower part, lower terrace									
0-20*	6,674h	475h	85h	0.6	1.5h	1.6h	2.0h	75.3	92.6h
20-38*	6,815h	225h	52m	0.6	0.8m	0.7h	1.1	57.6	46.0h
38-55**	113	4.6	14-	1.0	0.5-	0.0	1.1h	18.9h	3.8h
Upper part, lower terrace									
0-20*	7,951h	508h	90h	0.6	2.3h	2.6h	3.1h	57.3	152.3h
20-34*	6,472h	236h	48-	0.6	0.8m	0.4m	0.9	56.0	28.2h
34-38*	102	7.5	11-	1.0	0.4-	0.0	0.9h	17.1h	3.5h
Lower part, upper terrace									
0-22*	6,843h	443h	82h	0.6	1.6h	1.6h	2.0h	63.4	106.6h
22-32*	7,235h	200h	50m	0.6	0.9m	0.7h	0.9	50.9	36.3h
32-53*	6,172h	143h	34-	0.6	0.6m	0.2m	0.9	50.4	23.6h
53-72*	9,771h	56-	37-	0.6	0.5m	0.3m	1.2	29.6	49.3h
72-80**	124	2.8	11-	0.6	0.41	0.0	1.3h	6.1h	1.41
Upper part, upper terrace									
0-20*	6,933h	471h	82h	0.6	1.5h	1.2h	2.1h	80.6	77.3h
20-32*	6,455h	123m	40-	0.6	0.8m	0.2m	0.8	59.3	29.6h
32-52*	6,212h	73-	35-	0.6	0.8m	0.2m	0.9	62.3	40.2h
52-55**	97	0.6	8-	1.1	0.5-	0.0	1.4h	15.3h	3.9h

*Mehlich 3 extractant reported in mg/dm^3

**Ammonium bicarbonate - DTPA extractant reported as parts per million

Adequacy for agronomic crops: h=high, m=medium, l=low.

Adapted from Coultas et al. 1993

Table 3.6: Some extractable macro- and micro-nutrients from non-terrace soils at Caracol.

Depth	Ca	Mg	K	Mo	Zn	B	Cu	Fe	Mn
cm	mg/dm^3 or PPM								
Depressional soil									
5-0	8,591 h	407 vh	314 vh	1.1 h	11.2 h	2.5	5.6 h	494	38.2 h
0-10	14,193 h	520 vh	138 h	1.2 h	6.6 h	1.6	7.8 h	277	44.2 h
0-28	14,181 h	477 vh	97 h	1.2 h	3.2 h	1.2	6.7 h	164	66.8 h
28-46	12,938 h	375 vh	74 h	1.2 h	1.8 h	1.0	5.5 h	108	101.8 h
46-61	12,557 h	310 vh	73 h	1.2 h	1.8 h	1.0	4.4 h	99	99.3 h
61-81	12,151 h	274 vh	66 m	1.2 h	1.4 h	0.9	4.2 h	103	95.1 h
81-161	12,096 h	240 vh	66 m	1.1 h	1.5 h	0.8	4.4 h	112	93.7 h
Steep hillside soil									
0-8	240	7.8	132 h	4.5 h	1.9 h	1.0	1.9 h	4.1 h	12.0 h
8-23	333	18.8	91 m	2.1 h	0.7 l	0.5	1.8 h	5.0 h	2.9 h
23-41	551	25.7	123 h	0.5 m	0.6 l	0.3	1.6 h	7.2 h	2.8 m
41-66	560	15.2	148 h	0.5 m	0.4 l	0.3	1.0 h	5.8 h	1.7 l
66-84	576	14.6	62 m	0.5 m	0.4 l	0.3	0.9 h	6.2 h	2.3 m
84-104	558	17.6	42 l	0.5 h	0.4 l	0.3	3.2 m	3.2 l	1.0 l
Flat soil 8 kilometers northeast of central Caracol									
4-0	2271	110	214h	0.2	1.4m	0.4	3.1h	5.3h	6.4
0-15	2096	88	177h	0.1	1.3m	0.1	8.3h	10.0h	3.5

*Mehlich 3 extractant used with depressional soil and reported as mg/dm^3.

Ammonium bicarbonate EDTA extractant used with steep hillside soil and flat soil (calcareous); reported as PPM.

vh= very high, h=high, m= medium, l= low for agronomic crops

Table 3.7: .Particle-size analysis and clay mineralogy of four terrace soils at Caracol.

					Clay mineralogy		
Depth	Sand	Silt	Clay	Texture	Smectite	Kaol.	Qtz.
cm		%			relative	%	
			Lower part, lower terrace				
0-20	5.8	19.0	75.2	c	86	7	7
20-38	7.8	26.2	66.2	c	82	10	8
38-55	12.0	21.2	66.8	c	84	7	9
			Upper part, lower terrace				
0-20	4.0	28.4	67.6	c	80	9	11
20-34	6.7	20.1	73.2	c	88	7	5
34-38	17.0	15.0	68.0	c	84	10	6
			Lower part, upper terrace				
0-22	4.5	24.3	71.2	c	85	4	11
22-35	5.8	21.4	72.8	c	87	8	5
32-53	6.1	21.1	72.8	c	84	10	6
53-72	6.1	22.3	71.6	c	79	14	7
72-80	7.2	28.0	64.8	c	72	21	7
			Upper part, upper terrace				
0-20	Not determined						
20-32	4.9	26.3	68.8	c	83	10	7
32-52	7.1	20.9	72.0	c	81	14	5
52-55	7.9	19.7	72.4	c	80	14	6
			Mineralogy of the limestone was over 99% calcite.				

Adapted from Coultas et al. 1993

Table 3.8: Particle-size analysis, clay mineralogy, and calcium carbonate equivalence of two non-terrace soils at Caracol.

						Clay mineralogy	
Depth	Sand	Silt	Clay	Texture	Smectite	Kaol.	CCE
cm		%					%
				Depressional soil			
5-0	1.0	40.2	58.8	c	1	2	-
0-10	2.0	28.0	70.0	c	-	-	-
10-28	2.0	28.0	70.0	c	1	2	-
28-46	2.0	22.8	75.2	c	-	-	-
46-61	4.0	22.0	74.0	c	1	2	-
61-81	3.6	23.4	73.0	c	-	-	-
81-161	3.4	24.2	72.4	c	1	2	-
				Steeply sloping hillside soil			
0-8	26.5	49.1	24.4	l	1'	0	56.9
8-23	32.2	41.8	26.0	l	-	-	65.6
23-41	35.3	40.3	24.4	l	1	0	71.1
41-66	31.6	44.0	24.4	l	-	-	77.8
66-84	22.6	55.0	22.4	si l	1	0	76.4
84-104	11.7	64.3	24.0	l	-	-	69.6
				Relatively flat soil			
4-0	organic						37.8
0-15	15.1	40.9	44.0	si c	not determined		51.4
15-25	18.7	44.4	36.9	si cl			60.8
25-39	32.1	32.0	35.9	si cl			70.8
39-47	24.1	34.6	41.4	si c			67.8
47+	loam texture						80.1

c= clay, l = loam, si = silt
Clay mineralogy: 1 = >75%, 2 = 1-25%, 0 = none
Clay samples were treated with acid before X-ray, thus, the calcite clays which were probably in the sample were destroyed.