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YOUNG SECONDARY VEGETATION AND SOIL INTERACTIONS IN IZABAL, GUATEMALA

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SUMMARY

A study of the relationships of soils and vegetation was undertaken in the humid tropical region of Lake Izabal, Guatemala, Central America. Soils and associated 10-month-old secondary growth were analyzed for N, P, K, Ca, and Mg. In addition, organic matter, Al and pH were determined in the soil samples and plant biomass for the secondary growth were calculated.

The secondary growth biomass averaged 9,710 kg/ha for the 10-month growth period. Total nutrient content of the vegetation increased linearly with the biomass, except for Mg.

The antagonism of Mg on K and Ca nutrition was quite significant when Mg exceeded Ca in the soil under shifting cultivation. Pure stands of *Heliconia sp.* and *Gynerium sp.* appeared to be more efficient in accumulating P than stands of mixed vegetation. Chemical composition and dry matter production of native vegetation may provide additional information to evaluate soil fertility in the humid tropics.

INTRODUCTION

The relatively high temperature and rainfall in the humid tropics accelerate the processes of weathering of the primary minerals and the decomposition of the organic materials in the soil. This results in a rapid release of plant nutrients which may be leached from the topsoil when the soil is disturbed. Soil fertility in lands under shifting cultivation in the humid tropics is closely associated with rapid growth of the native vegetation which immobilize nutrients in the plant tissue and prevent losses.

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The term 'shifting cultivation' is often used to connote a common practice of land clearing in the tropics. Land is prepared for planting by cutting and burning all bushes and most trees. Fields are generally cultivated for a period of one to five years. The productivity of the soil is then restored by the regrowth of natural vegetation during the fallow period. Some advantages of fallowing after some years of cultivation suggested by Newton [6] are: improvement of soil structure, prevention of erosion, protection of organic and inorganic crumbs against disintegration, recycling of nutrients, and prevention of leaching. The uneconomical use of land and labor is the biggest disadvantage.

The methods of land selection in Africa according to Trapnell [13] are based on the association of soil fertility with types of native vegetation. However, Rounce [11] stated that good growth of the native vegetation should not be considered as evidence that the soil would successfully support other types of vegetation. This statement was based on the fact that certain types of soil were entirely unsuitable for the growth of grain crops during the initial years after clearing the land. Nye and Greenland [7] emphasized the importance of the nutrient cycle in restoring the fertility of the topsoil during the fallow period in shifting cultivation.

The present investigation was initiated to evaluate the role of young native vegetation as an accumulator of nutrients in the cycle of shifting cultivation, and to relate nutrient uptake by second growth vegetation to soil productivity in the humid tropics. The restoration of soil fertility in shifting cultivation depends to a great extent on the growth and nutrient accumulation in the fallow vegetation. A shorter fallow period and thus less land is necessary when fertility is restored more rapidly. In this investigation the possibility of using the young second growth of native vegetation as an indication of soil fertility was explored. In addition, some soil-plant relationships that could be useful in different cropping systems in the humid tropics were evaluated.

DESCRIPTION OF THE REGION

Lake Izabal occupies an area of approximately 1,200 square kilometers near the Atlantic Coast of Guatemala, Central America. Soil and vegetation samples were collected in the vicinity of the Lake.

TABLE 1

Monthly precipitation (mm) for Murcielago*, Lake Izabal, Guatemala C. A.

Month	1961–62	1962–63	1963–64	1964–65	1965–66	1966–67	Average
June	225	323	228	234	197	315	254
July	494	385	285	245	327	293	338
August	310	329	132	176	215	244	234
September	310	261	394	95	271	312	274
October	212	266	183	78	—	204	189
November	101	172	121	230	—	53	135
December	98	44	28	253	—	39	92
January	98	85	45	132	—	116	95
February	46	52	21	24	—	35	35
March	112	158	47	15	100	90	87
April	258	38	94	32	46	80	91
May	94	131	209	127	179	—	148
Total	2358	2245	1787	1641	—	—	1972

* Station elevation: 30 meters above sea level.

The region has a Tropical Moist Climate with a high average temperature and at least 20 mm rainfall per month throughout the year. Rainfall data for six years taken at Murcielago, on the northern shore of the lake, are presented in Table 1. The records suggest two maxima during the rainy season, one in July and another in September, and two minima during the drier season in December and February, respectively. Temperatures are related to rainfall distribution. The maximum temperatures, around 35°C usually occur during the drier season in early June. The temperature declines as the rainy season progresses and reaches its minimum in December and January. This minimum, around 15°C, is also related to large cold fronts which occasionally come from the north during the winter months.

Lake Izabal is surrounded by mountains with elevations higher than a thousand meters. On the southern shore they dip sharply into the Lake. Elsewhere, around the Lake, small areas of flat land are present.

The geology of the region has been described by Roberts and Irving [10]. A late Paleozoic and early Mesozoic serpentine block runs north of the Lake with occasional limestone foothills. Undifferentiated schist, gneiss, phyllite, and quartzite (metamorphic rocks of the Precambrian era) are found on the southern side of the Lake. Lands of the eastern and western shores are composed of terrestrial alluvium, slope wash, ancient lakebeds, and river terrace deposits. A deposit of Chochal limestone of Permian age is found on the southwest side and other unnamed formations of Pliocene, Miocene, and Oligocene rocks lie towards the northwest.

The soils of the area have been classified by Simmons *et al.*[12] The predominant series are: Sebach, Guapinol, Chacon, Teleman, and Polochic. The more acid soils are found on the eastern and southern shores of the Lake. The soils on the north and west are influenced by the limestone and serpentine parent material, have high concentration of Ca and/or Mg, and consequently, a near neutral pH. Most of the soils are highly weathered clays except for recent alluvium in the river floodplains.

Tropical Moist Forest and various hydrophytic associations are typical vegetation types in the region but very few areas are still undisturbed. Secondary successions of many different species predominate, especially in areas where the forests have been destroyed by fires, cut for timber, or the land has been under shifting cultivation. Pine and low scrub occupy many of the soils derived from serpentine. Almost pure stand of corozo palm (*Orbignya cohune*) occupy some second growth areas. They are a result of shifting cultivation where farmers have left these trees standing for their valuable nuts and thatching material. Other common genera found in second growth are *Heliconia, Gynerium, Cecropia,* and various legumes and grasses.

No intensive agriculture has yet been established in the region, except for the recent initiation of a few rubber plantations and an oil palm plantation on the southeastern and north side of the Lake, respectively. Most of the agricultural land is in shifting cultivation and the main crop is corn, augmented by cassava, rice, sugar cane, chili and bananas. A surplus of corn is produced and it is either sold or fed to hogs for marketing.

DESCRIPTION OF SITES

Fields of first year second growth of the native vegetation on different types of soils representative of the region around Lake Izabal were chosen for this investigation. Site locations are shown in Fig. 1. Additional details of the individual sites are included in the following paragraphs:

1. Murcielago I. – This site is situated on a gently undulating, almost flat slope. The soil consists of alluvial material derived from limestone and some serpentine parent materials. It is a friable dark brown to black clay loam with high water table and poor drainage. The former crop was corn with a yield of about 990 kg/ha. The vegetation was dense, mixed growth of many different species including a few grasses.

2. Murcielago II. – The characteristics of Murcielago I and II are almost identical, except that the soil of the second site is a yellow brown clay with poorer drainage.

3. Murcielago III. – This site is further inland than the first two sites. The soil, derived from limestone, is a firm black clay with a medium subangular blocky structure and intermediate drainage on a 5 to 6% slope. The former crop was corn which produced an estimated yield of about 900 kg/ha. The vegetation was typical of the mixed second growth of the area.

4. Murcielago IV. – This site is at a lower elevation than Murcielago III and with a more gentle slope. The soil is a friable brown clay derived from

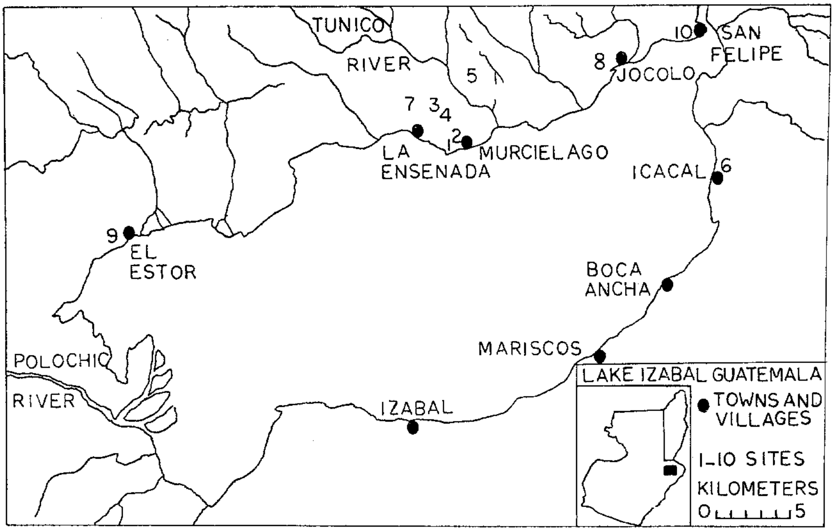

Fig. 1. Map of the Lake Izabal Region in Guatemala. Numbers identify field sites. (Based on map of Clasificación de los Suelos de la Republica de Guatemala. 1959. Ministerio de Agricultura).

limestone and serpentine parent materials. The medium crumb structure of this soil is much better than the structure of Murcielago III. Corn, the former crop, produced an estimated yield of approximately 1,100 kg/ha. Pocket gophers which have been observed at this site and in other better drained soils play an active part in the mechanical mixing of the topsoil.

5. Tunico. – This site is on a 7 to 8% slope and grew corn the year before sampling. The estimated yield of corn was low, less than 600 kg/ha. The soil is a friable, reddish-brown clay derived from serpentine parent material with medium granular structure and intermediate drainage. The growth of the vegetation was less dense compared to the other areas in the region under the same conditions. Some grasses were present, but woody bushes predominated.

6. Icacal. – The soil at this site is a sticky clay, light grey, with a fine granular structure and intermediate drainage. The parent material is probably alluvium deposited on an old latosol terrace. The growth and yield of rice was very poor with plants that showed several deficiency symptoms. Growth of the natural vegetation was also poor. Few bushes were present and grasses and bracken fern predominated.

7. La Ensenada. – The soil is a reddish clay with good drainage on a 15 to 20% slope. The soil is derived from limestone and serpentine parent materials. The structure is medium crumbs. The previous crop was corn with estimated yield of 600 kg/ha. The vegetation was sparse with tall woody bushes and few grasses.

8. Jocolo. – The land is almost flat and the soil is a young alluvial, loose, light brown loam with single grain structure overlying a sticky, yellow-reddish clay at a depth of about 50 cm. The previous crop was rice and produced very good yield according to the informant, but the actual figures could not be estimated. Growth of the natural vegetation was good and the plants were dark green. Bushes and grasses grew in a mixture with no predominant species.

9. El Estor. – The soil is a reddish sticky clay derived from serpentine on a 10 to 12% slope. The structure is fine granular and the drainage is good. The site grew corn before sampling and the yield was estimated at 500 to 600 kg/ha, which is poor for the region. Growth of the native vegetation was poor, although it was dark green. Few grass species were observed.

10. San Felipe. – The land is undulating and has a slope of about 10%. The soil is derived from an old latosol terrace close to the lake shore. It is a friable, reddish clay loam with medium crumb structure and good drainage overlying sticky clay at a depth of about 40 cm. Corn was the previous crop and the yield was estimated to be average for the region, about 700 kg/ha. Two dominant species of natural vegetation were growing in pure stands in the same field, one next to the other. These two species, *Heliconia sp.* and *Gynerium sp.*, were sampled separately.

No significant differences in the physical soil characteristics attributable to vegetation were observed, although a slight difference in soil color and slope was evident.

EXPERIMENTAL PROCEDURE

Samples of ten-month old second growth vegetation were collected on ten different fields around Lake Izabal for determination of plant biomass and nutrient content.

The associated soils were also sampled for chemical analysis. Field work was carried out at the beginning of the rainy season in 1964. The native vegetation biomass was calculated in kg/ha on an oven-dry basis with roots excluded. Duplicate vegetation samples were digested by the wet ashing method described by Ulrich *et al.*[15] Sample composition and total nutrient content of the native vegetation at the time of collection (10 months old) were expressed on oven-dry basis, 70°C.

The soil was sampled at three different depths: 0–5, 5–20 and 20–40 cm, respectively, on two locations at each site. The moist composite samples (5–7 cores) were passed through a 2 mm aluminum sieve and stored moist in plastic bags. Duplicate samples were taken to determine percentage moisture. The results of chemical analysis were calculated on an oven-dry basis, 110°C.

Total N in the soil and vegetation samples were determined by the standard Kjeldahl method modified to include nitrate. The pH of the soil was determined in a 2:1 water-soil suspension and in 1.0 *N* KCl. Organic matter in the soil was determined by the Walkley-Black wet combustion method modified by Walkley [17]. Acid soluble and absorbed P was extracted from the soil by the Bray and Kurtz method [2] and determined by the procedure described by Truog [14]. Potassium, Ca and Mg were extracted with neutral normal ammonium acetate according to the method described by Peech *et al.*[9] Potassium and Ca were determined with a Beckman B Flame Spectrophotometer. Magnesium was determined by the colorimetric method described by Carver and Robertson [3]. Aluminum was extracted with 1.0 *N* KCl and determined colorimetrically by the aluminum method described by Chapman and Pratt [4].

RESULTS AND DISCUSSION

Plant Biomass

The natural vegetation biomass varied from 3,880 to 14,140 kg/ha. These figures in Table 2 are similar to values found in other humid, tropical areas with different types of vegetation calculated on the same growth period basis for comparison as indicated in Table 3.

Unpublished data by Popenoe indicate that the average biomass of unfertilized corn for the area around Lake Izabal is 9,930 kg/ha for 10 months growth. The value increased to an average of 29,960 kg/ha with addition of fertilizer. The dry matter biomass of pangola grass (*Digitaria decumbens*) on unfertilized soil averaged 16,130 kg/ha and capulin (*Trema micrantha*) averaged 9,390 kg/ha on a similar growth period.

TABLE 2

Plant biomass* and composition (%) of ten-month old secondary growth in the Lake Izabal region

Site no. and location	Biomass kg/ha	N	P	K	Ca	Mg
1. Murcielago I	11560	1.05	0.09	1.06	0.44	1.14
2. Murcielago II	9350	1.03	0.10	0.80	0.51	0.90
3. Murcielago III	9960	1.28	0.07	1.13	0.93	0.29
4. Murcielago IV	7110	1.56	0.09	1.08	0.55	1.23
5. Tunico	14140	1.07	0.07	1.48	0.90	0.52
6. Icacal	3880	1.37	0.10	1.33	0.44	0.40
7. La Ensenada	13350	1.14	0.08	1.13	0.64	0.51
8. Jocolo	9010	1.24	0.08	0.85	0.56	0.46
9. El Estor	4430	2.08	0.13	1.34	0.69	0.82
10. San Felipe	13870	1.28	0.25	1.32	0.65	0.62
Average	9710	1.34	0.10	1.15	0.63	0.69

* Dry-weight, roots excluded. Average of two plots.

TABLE 3

Plant biomass and accumulation of nutrients in different vegetation types in the humid tropics

Location	Growth period	Plant biomass* kg/ha	Accumulated nutrients** (kg/ha) N	P	K	Ca	Mg	References
Kade, Ghana	40 years secondary forest	7000	1832.0	125.0	819.0	2526.0	346.0	Nye and Greenland [8]
Kumasi, Ghana	20 years secondary forest	5140	573.0	39.0	409.0	523.0	213.0	Nye and Greenland [8]
Benin, South Nigeria	6 years fallow *Acioa barteri*	6540	310.0	27.0	174.0	230.0	147.0	Nye and Greenland [8]
Bambesa, Congo Republic	2 years Elephant grass	16790	327.0	22.0	448.0	100.0	141.0	Nye and Greenland [8]
Central Congo Basin	18 years forest fallow	6660	555.0	74.0	401.0	556.0 (Ca+Mg)		Bartholomew *et al.*[1]
Central Congo Basin	8 years forest fallow	13530	427.0	26.0	739.0	541.0 (Ca+Mg)		Bartholomew *et al.*[1]
Izabal, Guatemala	9 months *Heliconia sp.*	8650	91.0	4.8	141.7	21.6	68.4	Popenoe (Unpublished data)

* Oven dry weight, roots excluded; *calculated* on a 10 month growth period basis for comparison.
** Over the total growth period.

The young secondary successions did not seem to be more efficient than crops in terms of dry matter production for the first year. Over a long period of time native vegetation possibly makes more effective growth than cropping systems as a result of its resistance to pests and diseases and more efficient use of space, rather than its adaptive capacity to tolerate low levels of some soil nutrients.

Soil pH

The pH values of most of the soils studied were relatively high for humid tropical soils. Except for Icacal and Jocolo soils, in which the pH range was 4.6 to 5.9 in water and 3.8 to 4.8 in *N* KCl solution, the pH of the other soils was above 6.2 in water and 4.7 in salt solution. The highest pH values, 7.7 in water and 6.7 in salt solution, were found in Murcielago II soil at the 20 to 40 cm depth and in Murcielago I topsoil as shown in Table 4.

TABLE 4

Chemical analysis of Lake Izabal soils *

Sites	Depths cm	pH		%		ppm		me/100 g		
		H_2O	*N* KCl	O.M.	N	P	AL	K	Ca	Mg
Murcielago I	0– 5	7.1	6.4	8.9	0.45	5.6	2.1	0.4	10.9	17.8
	5–20	7.4	6.4	3.1	0.20	1.5	2.0	0.1	4.7	19.1
	20–40	7.6	6.4	1.5	0.08	1.3	1.8	0.1	3.6	19.6
Murcielago II	0– 5	7.1	6.3	11.7	0.81	7.7	2.2	0.4	14.1	25.0
	5–20	7.5	6.4	3.2	0.24	1.3	3.0	0.1	6.1	27.0
	20–40	7.6	6.4	2.6	0.18	1.3	2.5	0.1	6.2	23.9
Murcielago III	0– 5	7.4	6.4	10.2	0.65	23.1	6.2	1.8	43.6	10.7
	5–20	6.6	5.3	3.1	0.32	2.8	4.3	0.4	51.1	9.1
	20–40	6.5	5.1	2.7	0.27	2.2	2.9	0.4	45.8	13.8
Murcielago IV	0– 5	7.4	6.6	8.8	0.48	6.4	1.7	1.0	15.5	25.9
	5–20	7.5	6.4	2.4	0.21	1.9	0.7	0.3	10.8	23.2
	20–40	7.4	6.4	1.6	0.13	1.4	T	0.3	6.5	21.1
Tunico	0– 5	7.5	6.4	11.0	0.68	22.1	2.0	2.2	57.2	7.4
	5–20	7.2	5.9	4.7	0.45	2.3	T	1.7	55.8	7.6
	20–40	6.6	5.4	3.0	0.34	1.1	7.0	1.1	45.9	9.0
Icacal	0– 5	5.0	4.0	7.3	0.32	9.4	86.7	0.3	1.4	2.5
	5–20	4.7	3.8	5.5	0.25	5.0	150.6	0.2	0.3	1.4
	20–40	4.7	3.8	3.4	0.16	3.4	172.9	0.1	0.1	0.4
La Ensenada	0– 5	6.5	5.2	8.2	0.58	0.6	T	1.3	19.0	27.6
	5–20	6.3	4.8	4.1	0.36	0.3	T	0.8	9.2	29.5
	20–40	6.2	4.7	2.4	0.19	0.2	T	0.4	11.6	33.1
Jocolo	0– 5	5.7	4.5	7.5	0.35	4.1	4.0	0.2	3.0	5.3
	5–20	5.7	4.4	4.0	0.30	5.4	14.1	0.1	1.7	2.3
	20–40	5.6	4.3	3.5	0.18	2.5	44.0	0.1	0.4	1.2
El Estor	0– 5	6.8	5.8	8.3	0.64	0.5	8.6	0.6	13.6	24.1
	5–20	6.7	5.6	5.2	0.45	0.6	6.2	0.3	7.8	24.6
	20–40	6.7	5.3	3.5	0.31	0.5	10.7	0.2	6.0	27.3
San Felipe	0– 5	6.7	5.7	3.9	0.27	14.6	6.9	0.2	11.0	5.5
	5–20	6.8	5.4	2.1	0.15	7.6	6.3	0.1	8.9	4.6
	20–40	6.5	5.3	2.0	0.15	10.5	7.1	0.1	9.9	4.7

* Average for two plots. T = traces.

Soil organic matter and total nitrogen

The organic matter content of most of the soils was relatively high. The range in organic matter content was 6 to almost 12% in the topsoil except for the San Felipe soil which contained only 4% as indicated in Table 4. The organic matter content at 20–40 cm depth in all soils was greater than 1.5 per cent. In some cases *e.g.* the Tunico soil; this value was as high as 3 per cent. The organic matter is the principal source of soil N and one of the main sources of P in shifting cultivation. Cation exchange properties of most tropical soils are also highly dependent on organic matter levels.

The total N and the organic matter content of the soils in the Lake Izabal region are closely related. Nitrogen values were very high in the topsoil and decreased with depth. However, levels were still high, up to 0.1% at 20–40 cm depth. The C:N ratios in the profiles of all the soils varied from 6:1 to 13:1. The rate of N mineralization is usually very high in organic materials with such a low C:N ratio under conditions of high moisture and temperature.

The total N content of the native vegetation is not very high and there usually is a good crop response to fertilizer N when applied to these soils which are high in organic matter and have low C:N ratios. These data suggest that the organic compounds present in these soils are very stable or the N is immobilized by the microbial population of the soil before it is available to the plants. Some mineral N losses can be attributed to leaching under conditions of high rainfall but this mechanism is probably only significant on disturbed bare soil.

Phosphorus

The amount of extractable P was very low in most of the soils. Values ranged from 4 to 8 ppm with few exceptions. Murcielago III and Tunico topsoils had the highest P values, 23.1 and 22.1 ppm, respectively. No correlation was found between extractable P in the soil and total P content of the vegetation. The determination of extractable P, although it is a method widely used in temperate and subtropical soils, has little value as an indication of availability of this element in tropical soils. The prediction of available P in tropical soils is a problem which still requires more research.

The total P content of pure stands of *Heliconia sp.* and *Gynerium* sp., 34.7 and 26.3 kg/ha, respectively, were very high compared to that of normal mixed vegetation with similar biomass. Apparently, those two species are more efficient in absorbing P from the soil and therefore play a very important role in the nutrient cycle. Nye [8] suggested the possibility of selecting individual species which were characterized by rapid accumulation of P and using these in fallow rotation. *Heliconia sp.* and *Gynerium sp.* seem to fulfill the conditions suggested by Nye for the region of Lake Izabal.

Potassium, calcium and magnesium

The exchangeable K in the topsoil of the study sites ranged from 0.2 to 2.3 me/100 g of soil and decreased with depth. The quantity of exchangeable K in the deepest horizon sampled was only about 30 to 40 per cent of the amount in the topsoil. No relationship was found between the total K content of the vegetation and the Ca:K or the K:(Ca + Mg) ratios in the soil. Potassium luxury consumption by the native vegetation was not observed although this element tends to be absorbed by the plants in excess of its requirements for good growth if it is available in excessive amounts in the soil. No difference in the efficiency of K uptake was observed between the mixed second growth of the native vegetation and the pure stands of *Heliconia sp.* and *Gynerium sp.*

Figure 2 shows the relationship between the exchangeable Mg in the soil and total K content of the native vegetation in mature soils high in exchangeable Mg. This relationship was highly significant

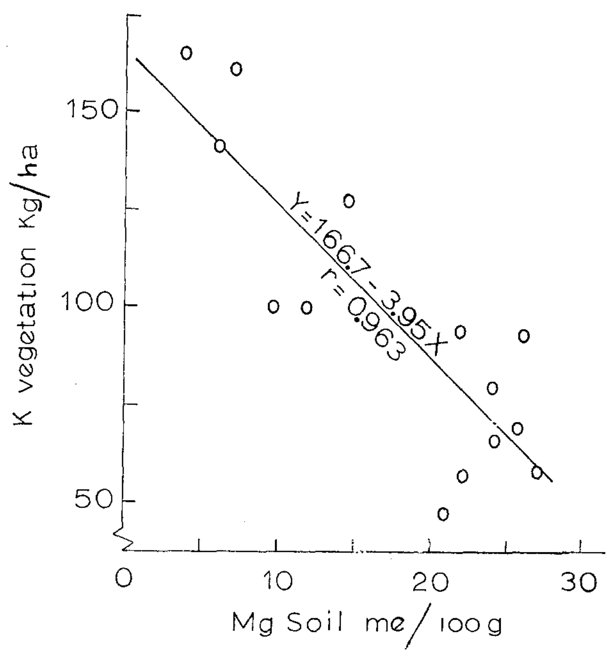

Fig. 2. Relationship between the total K content of the native vegetation and exchangeable Mg in the top 5 cm of mature soils high in exchangeable Mg in the Lake Izabal Region.

and suggests antagonism between K and Mg for absorption by the native vegetation.

Most of the soils studied were derived from limestone or serpentine, or a combination of both parent materials. The amount of exchangeable Ca was as high as 60 me/100 g in soils derived from limestone, and the amount of exchangeable Mg was as high as 34 me/100 g in soils derived from serpentine as indicated in Table 4. In one group of soils the Ca:Mg ratio was greater than one and varied from 1.5:1.0 to 10.0:1. In another group, the Ca content was lower than the Mg content and the Ca:Mg ratio varied from 1.0:1.2 to 1.0:6.0. Depth of sampling in the different soils did not change their grouping based on the Ca:Mg ratios.

Many experiments have been conducted to determine the importance of the Ca:Mg ratio in the soil and its effects on plant yield and on the uptake of these elements and K. The Ca:Mg ratios were larger than one in the majority of reported cases since the Ca content in most agricultural soils exceeds Mg. However, this is not the case on serpentine soils. The primary minerals of serpentine rocks are very rich in Mg and low in Ca, and the soils derived from this type of parent material show the same characteristics. This type of soil is very common on the north shore of Lake Izabal.

Previous analyses of crops and natural vegetation in the region around Lake Izabal shows that the Mg content was almost always larger than the Ca content. The Ca contents, Table 2, are unusually low for native vegetation.

Figure 3 shows a relationship between total Ca content of the vegetation and exchangeable Ca at different depths in mature soils with Ca:Mg ratios smaller than one. The positive relationship was significant at all the sampled depths but larger in the deeper horizons. These relationships did not hold true for the group of soils with Ca:Mg ratios larger than one or for young immature soils.

Walker *et al.*[17] studied Ca and Mg nutrition in serpentine soils with Ca:Mg ratios in the absorbed state in the soils and in culture solutions. The native vegetation was more tolerant to low ratios than crops and able to absorb larger amounts of Ca and smaller amounts of Mg under the same conditions of low Ca:Mg ratios. However, they could not state with certainty whether an insufficiency of Ca, an excess of Mg, or a combination of these, limited yield in the crop plants. Key *et al.*[6] investigated the effect of Ca:Mg

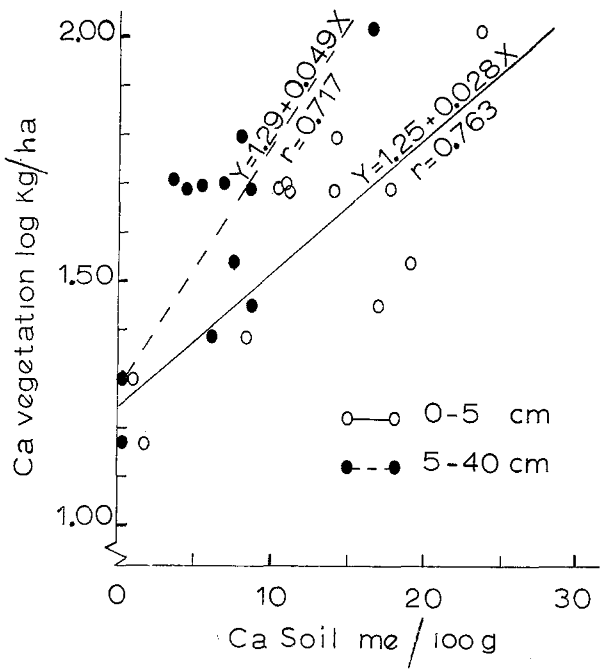

Fig. 3. Relationship between the total Ca content of the native vegetation and exchangeable Ca at different depths in mature soils with Ca: Mg ratios less than 1 in the Lake Izabal Region.

ratios ranging from 50:1 to 1:50 on plant growth. They found that the percentage of Mg in the plants increased as the Ca:Mg ratio decreased in the soil. They also observed a tendency for growth of corn and soybeans to decrease when the Ca:Mg ratio was less than one. They observed no effect when Ca exceeded Mg in the medium. The present investigation indicated that the interactions between Ca, Mg, and K in the soil affect growth and composition of the native vegetation in the region of Lake Izabal under natural field conditions when soil Mg exceeds Ca. Further investigations should be conducted to separate the effects of the three elements on the total uptake of each one by the native vegetation and crops, and the effect on yields.

Role of young secondary growth on shifting cultivation

The amounts of nutrients stored by native vegetation in ten months of growth in the Lake Izabal region were estimated as follows: N, 48.2–159.8; P, 3,5–30.5; K, 46.4–183.3; Ca, 15.0–114.5; and Mg, 13.9–118.6 kg/ha. Upon burning most of the nutrients which are accumulated in the native vegetation are returned to the soil in available forms, except for N and S which are volatilized in significant amounts.

Crop removal is one reason for the decline of nutrient levels in the soil, especially under shifting cultivation where the use of fertilizers to replace nutrients in the soil is very rare. Chemical analysis indicated that the reserves of nutrients in the soils investigated, except for Icacal, would probably be enough to support the present rate of growth of the native vegetation and, therefore, crop production at least for one year in a shifting cultivation cycle of perhaps 5 years. However, the use of fertilizers would be very helpful to establish the crops at the beginning of the growth period and extend the period during which crops could be grown.

CONCLUSIONS

The young secondary growth biomass varied from 3,880 to 14,410 kg/ha, with an average of 9,710 kg/ha. Total nutrient contents were estimated as follows: N, 48.2 to 159.8; P, 3.5 to 30.5; K, 46.4 to 183.3; Ca, 15.0 to 114.5; and Mg, 13.9 to 118.6 kg/ha. Total nutrient contents of the vegetation increased linearly with the biomass, except for Mg. Total K content of the vegetation was inversely related to the exchangeable Mg in the topsoil when Mg exceeded Ca in the soil. Total Ca content of the vegetation was related to exchangeable Ca in soils with Ca:Mg ratios smaller than one. Therefore, the antagonism of Mg on K and Ca nutrition was quite significant only when Mg exceeds Ca in the soil under natural conditions in the Lake Izabal region.

No apparent relationships were noted between the total N and P contents of the vegetation and soil total N and extractable P, respectively. However, pure stands of *Heliconia sp.* and *Gynerium sp.* appeared to be more efficient in accumulating P than stands of mixed vegetation.

Young secondary growth did not appear to be more efficient than various cropping systems in terms of dry matter production. Mixed stands of vegetation also did not appear to be more efficient than crops in the uptake of nutrients.

Chemical composition and dry matter production of native vegetation may provide additional information in the evaluation of soil fertility in the humid tropics. This approach appears to be especially true in the case of N and P, for a soil analysis alone for these two nutrients in the present investigation did not provide a useful basis for predicting the supplying power of the soil.

The future development of soil management practices and agriculture in the humid tropics depends to a great extent upon the knowledge of the effects of limiting environmental factors on crop production. More ecological research is necessary for a better understanding of these problems in tropical agriculture.

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