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LEAF-LITTER AND CHANGING NUTRIENT LEVELS IN A SEASONALLY DRY TROPICAL HARDWOOD FOREST, BELIZE, C.A.

by J. D. H. LAMBERT,

Department of Biology, Carleton University, Ottawa

J. T. ARNASON,

Department of Biology, University of Ottawa, Ottawa

and J. L. GALE

Department of Biology, Carleton University, Ottawa, Canada

KEY WORDS

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SUMMARY

Total above ground plant biomass in a 45 year old seasonally dry tropical hardwood forest was estimated to be approximately 56,000 kg/ha oven dry weight. Nutrients immobilized in the standing vegetation were: N, 203 kg/ha; P, 24 kg/ha; K, 234 kg/ha; Ca, 195 kg/ha; Mg, 47 kg/ha; Na, 9 kg/ha; Mn, 1 kg/ha; Cu, 0.5 kg/ha; Zn, 3 kg/ha; Fe, 4 kg/ha. Total nutrients returned each year through the litter were: N, 156 kg/ha; P, 9 kg/ha; K, 59 kg/ha; Ca, 373 kg/ha; Mg, 32 kg/ha; Na, 5 kg/ha; Mn, 1 kg/ha; Al, 21 kg/ha; Zn, 0.3 kg/ha; Fe, 9 kg/ha. Half of the nutrients immobilized in the standing vegetation were found in the leaves and are returned annually to the soil. Although litter fall is interrupted during the year, the mean nutrient content of the litter was high – 5.2%.

A decomposition rate of 0.48 percent per day was considered high for a seasonally dry tropical hardwood forest. Fluctuations in soil nutrient levels showed a sharp increase at the start of the rainy season. Later during the dry season nutrient levels decreased to concentrations similar to what they were just prior to the rainy season. Soil organic matter levels were very high – 20% in the top 12 cm.

INTRODUCTION

Vegetation biomass, nutrient content, leaf-fall and soil nutrient reserves have been determined in part or whole for a number of different tropical forest types[3,4,6,10,12]. As part of a longterm milpa agriculture study initiated in the Orange Walk District of Belize in 1977 a one hectare plot of tropical hardwood

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forest, known locally as 'high bush', was cleared, burned and planted with corn. Knowledge of the species composition, nutrient content of individual species, rate of leaf-fall and soil nutrient status of the undisturbed forest is considered necessary as a control reference relative to nutrient changes, and weed species succession in adjacent cultivated land. In addition it is important that we understand how local environmental conditions may affect leaf-fall, and rate of litter decomposition, which are the important soil building processes of the forest fallow period in shifting agriculture.

Data are presented on the nutrient composition of selected tree and sapling species. Leaf-fall and the nutrient status of the litter have been determined on a weekly basis. Changes in soil nutrient levels were monitored weekly to determine changes in soil nutrient reserves over a twelve-month period.

SITE

The northern part of Belize is physiographically a part of the Yucatan Peninsula and is a heavily karsted limestone plateau of Cretaceous Age. The study area is located at Indian Church on the New River Lagoon. Locally the site is underlain by a creamy pink, moderately hard, amorphorous limestone.

The vegetation is classified as broadleaf deciduous forest of the lowland dry tropical zone[15]. According to Beard[1] the site falls within the semi-evergreen seasonal forest zone.

The vegetation of the Indian Church area was analysed in a previous study[9]. High Bush forest is the most prevalent of six common ecotypes in the area and along with a palm forest association (Cohune Ridge), it is the most suitable for agriculture. High Bush forest is extremely diverse with close to 100 species now recorded in the Indian Church area. Tropical hardwoods dominate with a mixture of some palms.

The Maya ruins of Lamanai are evidence of ancient habitation at Indian Church. In fact, the area was used by Maya farmers up until 1925 when an epidemic decimated the village of Indian Church. Forests in the area have been exploited for their Mahogany. It is the intention of the Belize Ministry of Agriculture to re-establish farming in the district and at present milpa farmers are returning to the area.

Precipitation for the twelve month period was 1720 mm. A distinct dry season occurs from January to May. Two distinct wet periods occur during the rainy season – June and September. These two months are generally associated with crop planting. Mean annual temperature at Indian Church was 26.4°C. Relative humidity was high, 100% was not uncommon for weeks at a time.

MATERIALS AND METHODS

Because of the diversity of the High Bush Forest a prerequisite for establishing the location of the one hectare milpa was an analysis of the standing vegetation. A total of twenty 10 × 10 m plots within a one square kilometer area were quantitively sampled. Within each plot the presence of all tree species and their basal area at breast height and all saplings (dbh > 12 sq. in) were recorded. Representative samples of all species were collected for later positive identification.

Quantitative data on the tree and sapling composition were summarized for the site. Relative frequency, relative density and relative dominance were determined and the values for each tree species were summed to provide importance values, which for all trees totalled 300. Relative frequency and relative density were determined and summed for all saplings. Numbers of trees and saplings per hectare and strata height were calculated.

To determine the biomass and nutrient content of the standing vegetation one 10 × 10 m plot was destructively sampled. Leaf, branch and trunk for each tree, sapling, liana and seedling were separated into component parts and weighed. Height of trees and saplings were measured after cutting. Representative samples of leaves and wood were weighed and oven dried at 60°C for 24 hours and reweighed to determine dry weight. Samples of the oven dried materials were taken for nutrient analysis. Litter in the destructive plot was also collected and weighed. Samples were oven dried, weighed and samples taken for nutrient analysis.

Litter was collected in four 1 m^2 plastic net traps placed on the existing litter under four different groups of trees. The litter falling into the traps was collected weekly, oven dried and ground for analysis. Collections were made every week between May 1977 and April 1978. Five soil cores, 10 cm in depth were taken each week and pooled. A sample was taken to determine percent soil moisture. The remainder was air dried, ground and sieved through a 1 mm mesh.

One soil pit was dug to bedrock at the time of sampling. The horizons were noted and measured. Samples of each were taken for chemical and physical analysis. Textural analysis was completed using the hydrometer method [2]. Total N was determined by micro-Kjeldahl technique; available phosphorus colourmetrically; exchangeable cations (Na, K, Mg, Ca) and trace elements (Fe, Al, Zn, Mn, Cu, Co, Mo) by atomic absorption spectrophotometer. Cation exchange capacity (CEC) was determined using techniques described by Jackson [7].

In the initial determination of percent soil organic matter samples were muffled at 450°C for 24 hours and weighed. Loss was considered to represent the organic content of the dample. Such values when compared with nitrogen values gave such high C/N ratios as to indicate no decomposition or mineralization to be occurring. Consequently samples were tested with HCl to remove any carbonates present, dried and weighed, muffled and weighed again. Weathering of the underlying limestone bedrock has resulted in a high carbonate residual which must be removed before a true organic matter content can be determined.

Plant identifications were verified by the Missouri Botanical Garden, St. Louis, Missouri and a representative of every species deposited in their herbarium and also at Carleton University.

RESULTS AND DISCUSSION

Vegetation and nutrient composition

Synthesis of the High Bush vegetation is given in Tables 1 and 2 showing Importance Values and number of individuals per hectare for the trees and saplings. Canopy height was approximately 20 m and the dominant tree was was considered small, only 10% in the tree layer and 4% in the sapling layer.

The number of saplings is large, a total of 3618 individuals per hectare. Only two tree species had saplings present in the sampled plots. However, there are a number of saplings that do attain tree size. They are: *Brosumim alicastrum*, *Protium copal* and *Pimenta diocia*.

The dry weight and nutrient levels of the individual trees, saplings, lianas, seedlings and litter in the destructive sample are presented in Table 3. Clearly, the nutrients are concentrated more in the leaves than the branches, twigs and wood on a per weight basis. However, in the case of *Crysophila argentia*, a common

Table 1. Tree composition for high bush (Importance values and trees/hectare)

Species	IV	#/ha
**Guazama ulmifolia*	76	190
Trichilia havanesis	40	100
Spondias mombin	32	35
**Enterobolobium cyclocarpum*	26	5
Cupania belizenis	22	55
Trichilia hirta	22	55
Sapindus saponaria	19	40
Parmentiera aculeata	13	30
Hirtella panicuiata	6	10
Anona cherimola	6	10
**Pithecolobium* sp.	6	5
**Cedrela mexicana*	4	5
Dendropanax arboreus	4	5
Piper amalago	3	5
Lonchocarpus quatemalensis	3	5
Bursera simaruba	3	5
Stemmandenia donnell-smithii	3	5
Simaruba glauca	3	5
Citrus sp.	2	5
Guarea giabra	2	5
Erythoxylon affine	2	5
Trophis racemosa	2	5
	Total	590

*emergent trees above closed canopy

Table 2. Sapling composition for high bush (saplings/hectare)

Piper amalago	1690	*Acacia collinsii*	15
Trichilia hirta	280	*Hirtella panicuiata*	15
Sabal mauritiformis	230	*Trichilia havannesis*	10
Aechmea magdelanae	225	*Nectandra* sp.	10
Crysophyla argentea	225	*Dendropanax arboreus*	5
Protium copal	220	*Entrolobium cyclocarpum*	5
Cupania beliziensis	165	*Zuellania gridonia*	5
Permentiera aculeata	95	*Bursera simaruba*	5
Desmoncus schippii	95	*Pisonia aculeata*	5
Aliberta edulis	60	*Coccoloba belizensis*	5
Guatteria amphifolia	50	*Citrus* sp.	5
Pithecolobium sp.	48	*Bactris major*	5
Heisteria sp.	45	*Guarea giabra*	5
Sapindas saponaria	40	*Schizolobium pavoniana*	5
Lonchocarpus guatemalansis	30	*Brosimum alicastrum*	5
Simaruba gluca	25	*Cordia* sp.	5
Crataeva tapia	20	*Eugenia xatapensis*	5
Pimenta dioica	20	Unknowns	40
		Total	3618

Table 3. Biomass and nutrient reserves of standing vegetation

		Biomass kg/100 m²	N %	P mg/g	K mg/g	Ca mg/g	Mg mg/g	Na mg/g	Mn mg/g	Cu mg/g	Zn mg/g	Fe mg/g
Tree layer												
Guazuma ulmifolia -	leaves	1.4	2.58	0.33	23.0	13.0	4.0	0.07	0.22	0.010	0.02	< 0.05
	twigs	4.2	0.74	0.88	5.5	1.5	1.1	0.08	0.020	0.010	0.02	< 0.05
	wood	140.0	0.1	0.33	2.7	2.6	0.24	0.03	0.020	0.010	0.02	< 0.05
Cupania belizensis -	leaves	7.2	1.88	0.96	8.5	9.0	4.1	0.3	0.055	0.015	0.07	< 005
	twigs	46.2	0.93	0.66	0.5	4.75	0.75	0.23	0.020	0.010	0.2	< 0.05
	wood	186.9	0.17	0.36	3.7	3.25	0.85	0.08	0.020	0.010	0.02	< 0.05
Trichilia havannesis -	leaves	2.2	2.13	0.09	20.0	1.0	0.2	0.28	0.020	0.010	0.02	< 0.05
	twigs	8.8	0.46	1.61	17.5	7.3	1.11	0.29	0.020	0.010	0.02	< 0.05
	wood	33.0	0.23	0.34	2.61	1.0	0.22	0.2	0.020	0.010	0.13	< 0.05
Saplings												
Guarea giabra -	leaves	2.79	2.43	0.81	12.0	20.0	1.8	0.3	0.02	0.015	0.23	0.05
	branches	12.0	0.62	0.61	4.2	3.5	1.1	0.12	0.02	0.1	0.02	< 0.05
	wood	17.4	0.34	0.29	3.2	2.0	1.0	0.25	0.02	0.1	0.02	< 0.05
Protium copal -	leaves	1.74	1.19	0.26	5.7	5.0	1.0	0.44	0.02	0.1	0.02	< 0.05
	branches	2.99	0.27	0.28	1.3	4.0	0.31	0.29	0.02	0.1	0.02	< 0.05
	wood	14.9	0.14	0.42	3.7	2.7	0.5	0.14	0.02	0.1	0.02	< 0.05
Hirtella panicuiata -	leaves	1.42	1.79	0.7	8.0	12.0	0.15	0.04	0.03	0.1	0.09	0.05
	branches	2.96	0.57	0.12	6.0	5.25	0.35	0.37	0.02	0.1	0.100	< 0.05
	wood	7.3	0.8	0.55	2.7	3.5	0.25	0.24	0.02	0.1	0.04	< 0.05
Trichilia havannesis -	leaves	0.18	2.13	0.09	20.0	1.0	0.2	0.28	0.02	0.1	0.02	< 0.05
	branches	4.95	0.46	1.61	7.3	7.5	1.11	0.24	0.02	0.1	0.02	< 0.05
	wood	3.2	0.23	0.34	2.6	4.25	0.42	0.11	0.02	0.1	0.02	< 0.05
Sabal mauritiformis -	leaves	7.03	0.59	0.66	15.0	7.75	14.5	0.3	0.02	0.1	0.07	0.25
Piper amalago -	leaves	4.43	0.7	2.54	22.0	6.0	1.4	0.31	0.02	0.1	0.20	0.25
	branches	0.5	2.34	0.18	14.0	1.7	0.7	0.29	0.02	0.1	0.20	0.25
Crysophyla argentia -	leaves	3.83	0.73	0.16	5.25	3.2	0.75	0.31	0.02	0.1	0.20	0.25
	branches	2.17	1.15	1.3	6.7	1.75	3.0	0.34	0.02	0.1	0.20	0.25
Lianas -	leaves	0.5	4.10	1.43	20.0	25.0	6.5	0.3	0.26	0.025	0.4	0.85
	wood	36.0	0.52	0.43	3.0	6.0	1.5	0.18	0.02	0.01	0.02	0.25
Seedlings -	leaves	1.4	1.74	1.05	19.0	22.5	0.4	0.38	0.055	0.015	0.23	0.05
	wood	1.6	1.09	1.48	13.0	13.8	2.05	0.33	0.075	0.02	0.245	0.23
Leaf litter		71.8	0.90	0.12	3.93	40.0	3.4	0.16	0.175	0.015	0.135	

sapling, highest nutrient levels occurred in the branches. Highest nutrient levels are found in the lianas. While lianas constitute a rather insignificant percentage of the total biomass they are extremely conspicuous component of any tropical forest. Whether their rapid rates of growth necessitate such high accumulations of nutrients is not known. They obviously form a major nutrient reserve pool in the High Bush forest.

Accumulated standing biomass and nutrient totals for the five recognizable strata and percentage composition of total leaf, branch and wood are presented in Table 4. For a site estimated to be between 40–50 years of age, the total biomass of 56,670 kg/ha (oven dry) was considerably higher than secondary forest sites reported by Tergas and Popenoe[14] but much lower than reported by Greenland and Kowal[6] for a secondary forest (50 years) in the Congo and Golley *et al.*[5] for a primary tropical forest in Panama.

In the tree layer a high percentage of the nutrients are immobilized in the wood, On the other hand in the saplings the largest reserves are in the leaves. The total leaf biomass accounts for only five percent of the total biomass. Nutrient levels held in the leaf litter are returned annually to the soil as a percentage of total nutrients contained in the vegetation are high.

The nutrients contained in the wood are approximately fifty percent of the total. Therefore only half of the immobilized nutrients will be released to the soil when the forest is cleared and burned, since the larger trunks rarely burn completely. While this addition will be considerable it was far below that quoted by Greenland and Kowal[6] for a moist tropical forest in Ghana.

Percent composition of the above ground components of the vegetation are shown in Table 5. The values correspond closely to those presented by Greenland and Kowal[6] and for litter by Cornforth[3] and Ewel[4]. The only difference was for acetate extractable calcium in the litter. The high levels found in the soil are probably due to the occurrence of limestone fragments. Those in the litter are due to the presence of $CaCO_3$ crystals at the soil/litter interface. Ewel[4] does not give any reason for the high Ca levels in one 14 year old stand studied in Guatemala. Calcium content in the living vegetation determined in our study was not high, but neither were the P, K and Mg values low suggesting the high organic content of the soil is high enough to hold sufficient levels of cations for plant use.

Nutrient values in living leaves as expected were higher than the litter. Phosphorus mobility in the plant appears to result in only a small percentage being returned to the soil in the litter. Continuous decomposition results in a small but constant supply of phosphorus. Levels in the soil varied very little during the year, less than 0.012 ppm.

Table 4. Total standing biomass and nutrients in high bush forest (kg/ha)

Forest components		Biomass	N	P	K	Ca	Mg	Na	Mn	Cu	Zn	Fe
Trees/	leaves	1080	21.8	0.8	13.7	8.5	3.5	0.28	0.07	0.02	0.14	0.06
	twigs	5920	50.1	4.8	52.2	38.0	4.9	2.7	0.12	0.06	0.95	0.29
	wood	36640	53.7	11.1	115.3	100.4	20.0	2.6	0.73	0.37	1.15	1.66
Saplings/	leaves	1890	22.2	2.0	19.2	17.7	11.8	0.69	0.03	0.02	0.14	0.24
	twigs	2290	15.8	1.9	13.0	11.2	2.7	0.55	0.06	0.03	0.07	0.11
	wood	7120	14.5	1.5	13.9	11.4	2.7	1.0	0.09	0.04	0.10	0.18
Seedlings/	leaves	140	2.4	0.14	2.7	3.2	0.01	0.05	0.01	0.002	0.03	0.01
	twigs	160	1.7	0.23	2.1	2.2	0.3	0.05	0.01	0.003	0.04	0.04
Lianas/	leaves	50	2.0	0.07	1.0	1.25	0.3	0.02	0.01	0.001	0.02	0.43
	wood	360	18.8	1.2	0.8	1.8	0.3	0.65	0.01	0.004	<0.01	0.9
Sub-Total		55970	203.0	23.7	233.9	195.4	46.6	8.59	1.14	0.55	2.65	3.92
Leaf and Wood litter		7180	64.8	0.9	28.0	287.2	24.4	11.5	1.72	0.11	0.96	
Total			267.8	24.6	262.1	482.6	71.0	20.09	2.81	0.66	3.61	
Percent composition in standing biomass												
Leaves		5	23	12	16	15	31	13	10	8	12	19
Twigs/Branches		15	33	29	29	26	17	38	17	17	40	11
Wood		80	43	58	55	59	52	49	83	85	48	70

Table 5. Mean nutrient composition of forest vegetation

	Percentage composition				
	N	P	K	Ca	Mg
Leaves	1.5	0.1	1.2	1.0	0.5
Twigs	0.8	0.08	0.8	0.6	0.09
Wood	0.2	0.03	0.3	0.3	0.05
Litter	1.0	0.01	0.4	2.8	0.3

Litter

The total amount of litter falling on the forest floor during the twelve month period was 12607 kg/ha (oven dry). Litter was not separated into leaves, twigs and wood. The amount recorded is slightly higher than the values recorded by Nye[10] but within the range reported by Ewel[4] for moist tropical and sub-tropical forests.

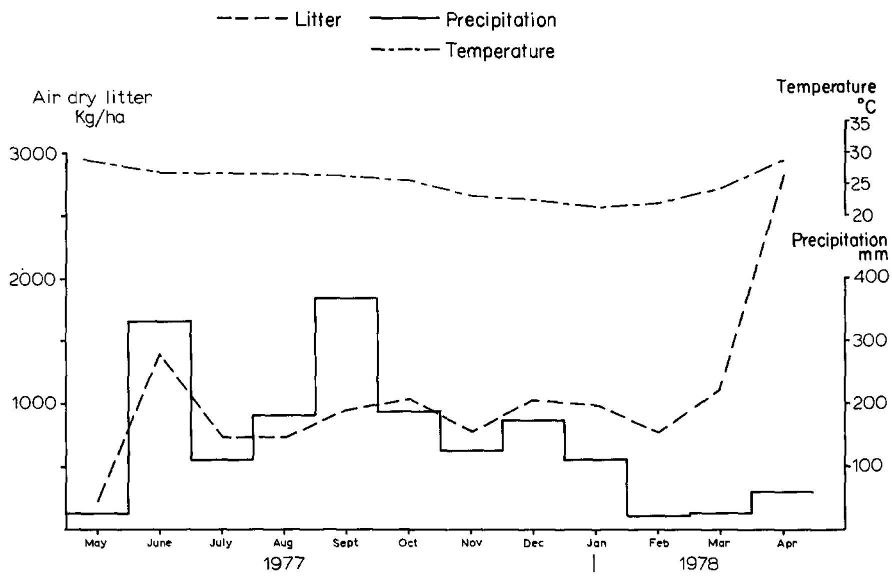

Fig. 1. Litter fall, temperature and precipitation in a seasonal tropical hardwood (High Bush) forest, Belize, C.A.

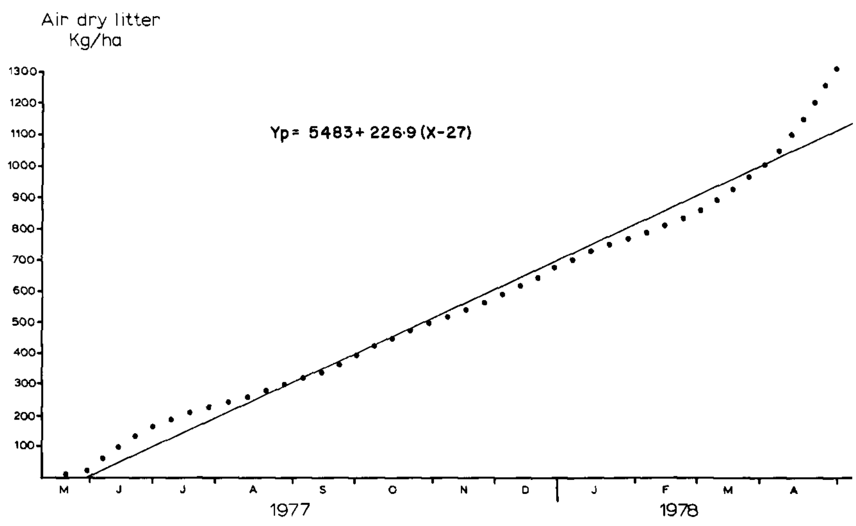

Fig. 2. Litter fall, cumulative total of weekly collections, May 1977 to April 1978

The seasonal variation in litter deposition plus monthly precipitation and temperature data are presented in Fig. 1. Although the fall of litter is continuous during the year the influence of precipitation, either the lack of or amount of, is clearly indicated. There were two periods when monthly litter-fall significantly exceeded the average. These occurred in April at the latter part of the dry season and June following the start of the rainy season. Mean monthly temperatures show very little variation ranging from a low of 21.5°C to a high of 28.8°C. Coolest temperatures were recorded in January and February.

The cumulative total of weekly litter collections for the fifthy-two week period are shown in Fig. 2. Line of best fit has been drawn and is significant to the 0.5 per cent level.

The high rate of decomposition of organic matter in the tropics has been well documented[10,11]. In the present instance the rate of disappearance of litter can be determined if litter fall and amount of litter on the ground are known using Nye's[10] Equation:

$$A = kL$$

where A is the litter fall per year; L is the amount of litter on the forest floor; k is the annual decomposition rate factor.

Total litter fall for the twelve month period from May 1977 to April 1978 was 12607 kg/ha, on the forest floor litter at time of sampling was 7180 kg/ha (oven dried).

The decomposition rate factor is:

$$k = \frac{12607}{7180} = 1.77 \text{ per year}$$

Thus the rate of decomposition is 177 percent per year or 0.48 percent per day.

Using Olson's[11] model the time required to complete 95% decomposition is $\frac{3}{k}$ or $\frac{3}{1.77} = 1.7$ years.

This rate of decomposition must be considered high for a seasonally dry tropical forest.

The monthly litter fall and calculated potential monthly nutrient return to the soil for the forest is presented in Table 6. While the amount of litter reaching the forest floor obviously varies each month, the percentage of each nutrient in the litter does not change significantly – N – 1.2%, P – 0.07%, K – 0.5%, Ca – 3.0%,

Table 6. Nutrient composition of litter (kg/ha/month)

	Litter	N	Na	K	Ca	Mg	P	Fe	Al	Mn	Zn
May '77	228.0	2.7	0.1	3.6	10.2	2.1	0.2				
June	1417.4	22.7	0.3	8.0	29.2	5.2	0.7	0.9	1.9	0.11	0.04
July	732.0	10.2	0.2	3.8	19.4	1.3	0.3	0.9	1.5	0.1	0.04
Aug.	737.0	9.6	0.2	4.3	19.8	2.0	0.6	0.8	1.7	0.13	0.03
Sept.	855.4	11.1	0.3	4.8	26.9	2.3	0.7	1.0	3.4	0.13	0.025
Oct.	1066.4	12.1	0.4	6.4	30.6	2.7	0.8	1.2	3.4	0.13	0.03
Nov.	772.0	10.0	0.3	5.4	20.3	2.0	0.6	1.1	2.5	0.1	0.02
Dec.	1028.8	13.4	0.3	5.1	32.7	2.7	0.8	1.4	3.4	0.14	0.03
Jan. '78	966.0	11.9	0.3	4.5	31.8	1.9	0.9	0.7	1.5	0.1	0.02
Feb.	742.5	9.9	0.3	2.9	21.8	1.5	0.6	0.3	0.3	0.07	0.01
Mar.	1456.0	17.8	0.8	5.2	47.2	2.8	1.2	0.3	0.5	0.1	0.03
April	2606.0	27.1	1.4	4.9	83.4	5.5	1.8	0.4	0.5	0.2	0.05
Total	12607.5	155.8	4.9	58.9	373.4	32.0	9.2	9.0	20.6	1.18	0.325

Mg – 0.3% and Na – 0.03%. The values, except for Ca, are similar to figures quoted by Greenland and Kowal[6], Nye[10] and Ewel[4]. Nye[10] suggested that falling dead wood may increase the rate of the calcium cycle. While no quantitative data are available on actual fallen dead wood, by observation it was small. We feel that calcium values are high because of the calcareous nature of the soil. Ignoring the root zone the amount of nitrogen returned to the soil each year is equal to that immobilized in the standing wood.

Using the equation A = MK, where A is equal to annual nutrient addition; M mineral addition per year may be derived and compared with the actual additions determined by analysis of litter.

Using the equation A = Mk, where A is equal to annual nutrient addition; M is the nutrient content of the leaf litter on the forest floor; and k is the annual decomposition constant, the annual nutrient increase is

$$405.5 \times .48 = 1.9\,\text{kg/ha/day or } 692\,\text{kg/ha/year}$$

This agrees well with the figure obtained by analysis of the total leaf litter that fell – 629 kg/ha/year.

Only the macronutrient values have been included in the above calculations. While trace element values were high enough to detect in the litter, in the individual plant components in the destructive cut values were too low to record.

The annual nutrient return rates are comparable to those reported by Rodin and Brazelvich[12]. The magnitude of the annual nutrient addition is an indication

Table 7. High bush forest soil profile May '77

	ppm															
Depth cm	Na	K	P	Ca	Mg	Mn	Zn	Fe	Cu	Co	C.E.C.	pH	% N	% CO_3	% OM	C:N
0– 12	0.56	7.2	0.32	260	7.7	0.7	0.04	0.14	0.03	0.02	350	7.0	0.46	12	20.2	25:1
12– 24	0.55	4.9	0.17	240	4.9	0.5	0.04	0.15	0.04	0.01	350	7.0	0.31	11	15.0	27:1
24–336	0.6	3.7	0.16	340	3.7	0.3	0.03	0.13	0.03	0.01	450	7.1	0.18	18	11.8	27:1

of the importance of leaf litter in the soil building processes of forest fallow in milpa agriculture.

Soils

Results of the soil analysis are given in Table 7. The percentage of organic matter (after $CaCO_3$ removal) in the profile, even at 36 cm is far greater than that reported for tropical soils by Sanchez[13].

The soils of the High Bush forest are considered Rendolls of the Mollisol Order. The surface horizon is thick, dark and has a high organic content. There is a high carbonate level in the surface horizon that increases with depth as the organic matter content decreases. Young[16] has reported the occurrence of calcium carbonate concentrations in soils overlying limestones in the humid tropics. The high C/N ratios for the three horizons is perplexing. There is a high input of high C/N ratio organic matter throughout the year at the same time high soil C/N ratios are maintained with only a slight drop at the start of the rainy season. Further study is required on the bacterial composition of these soils and the actual mechanisms of litter decomposition.

The difference between cation exchange capacity and total exchangeable cation values is probably due to the large amounts of free $CaCO_3$ due to weathering of mollusca and limestone fragments that are present throughout the sampled soil profile. The presence of free $CaCO_3$ can result in a high base saturation condition. Samples had a plastic, sticky consistency even though the percent soil moisture was less than 35%. Leaching would not appear to be a problem in these soils.

The high organic matter content of these soils plus the base rich condition indicate the likelihood of a fertile soil of good agricultural potential.

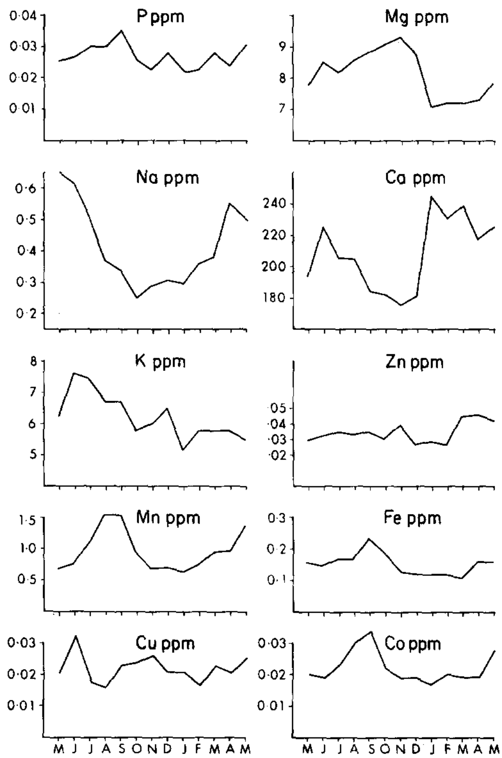

Fig. 3. Soil nutrient levels, May 1977 to April 1978

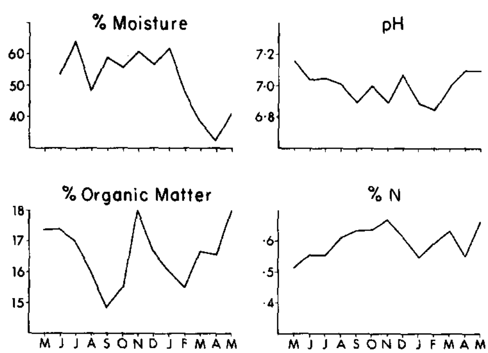

Fig. 4. Moisture, organic matter, pH and nitrogen levels, May 1977 to April 1978

Soil nutrients

Available soil nutrients, moisture, organic matter and pH values for the twelve month period are presented in Figures 3 and 4. Values have been plotted for the thirteen month period, May 1977 to May 1978. The reason is to show that nutrient levels while fluctuating significantly during the year always closely approximate levels of the previous year. The actual month of significant change, May or June, will depend on when the rains start. In 1977 they started on June 2nd; in 1978 on May 19th.

Only Na becomes increasingly concentrated in the soil during the dry season. Because it is the easiest cation to leach Na levels drop continuously during the rainy season.

An initial drop in exchangeable Mn, Co and Cu levels occurs at the start of the rains. While pH values do not indicate an increase in acidity, it is possible that the first heavy rains cause a sharp decrease in pH in the humus layer. As the three trace elements are more readily soluble in acid soils, a combination of heavy rains and acid conditions could result in a short period of leaching. With stabilizing pH levels, between pH 6.8 – 7.2, and decreasing drainage, concentrations increase during the rainy season due to rapid decomposition. The high montmorillonite clay content of the soil inhibits prolonged leaching due to its swelling properties when wet.

The increase in exchangeable cation concentration is due in part to the inability of the plants to withdraw minerals faster and the low permeability of the soil. During the dry season plants continue to take up exchangeable cations even though decomposition rates drop. The result is a decrease in soil nutrient reserve.

Acetate extractable Ca levels are very high due to the presence of limestone bedrock close to the soil surface. The carbonate content of the soil is high as observed when determining the organic matter content.

Very high levels of Ca were found in the litter of the destructive plot – 282 ppm. Samples were rechecked to determine errors in analysis. We suggest that the reason for the high and fluctuating values is due to several factors. The high evaporative powers of the atmosphere during the dry season result in a concentration of carbonate nodules at the soil/litter interface. With the start of the rains there is an initial build up of exchangeable calcium in the soil. The depletion may be due to a rapid uptake by the vegetation. The greatest tree increments were found to occur during June and July. At the beginning of the dry season evaporation of moisture in the soil leads to a build up of acetate extractable Ca on the soil surface.

Available P values while showing an initial increase at the start of the rains show very little variation during the year.

Fluctuations in trace element levels are of lesser magnitude than those of the exchangeable cations. Levels peak between June and September, then are generally followed by a sharp decline and a levelling-off to pre-rain concentrations.

There is during the rainy season a steady increase in percent nitrogen in the top 12 cm due to the increase in the rate of decomposition and nitrogen mineralization. During the dry season litter fall and decomposition rates decrease and percent nitrogen drops.

Percent soil moisture increases abruptly at the beginning of the rainy season, however maximum levels are not reached until July. For the remainder of the year, soil moisture levels remain above 50%. The start of the dry season in January results in a steady decline in soil moisture that is not reversed until the start of the next rainy season.

Soil pH values averaged for the twelve month period indicate the soil is neutral (pH 7.0). During the dry season soil pH is slightly alkaline. With the start of the rains bases are removed by leaching giving rise to a slightly acid soil.

Percent soil organic matter fluctuates during the year. The two peaks correspond closely to those periods of increased litter-fall, the end of the dry season and in the latter part of the wet season. Decomposition and mineralization would appear to be most active in September and February.

Generally, the levels of the analyzed minerals show an abrupt change at the start of the rainy season with peak concentrations occurring between July and November. During the dry season plant requirements result in a reduction in concentration so that by the end of the twelve month study period mineral concentrations were similar to what they were at the start of the rainy season.

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