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Editor’s Note

The major themes of the IUBS Decade of the Tropics will have been developed into proposals of collaborative research programmes by the end of the year 1984.

In addition to those already published on «Soil Biological Processes and Tropical Soil Fertility» (Special Issue n° 5), and «The Significance of Species Diversity in Tropical Ecosystems» (Special Issue n° 6), other special issues will be devoted to «Comparative Studies on Tropical Mountain Ecosystems», and «Responses of Savanna Ecosystems to Stress». Of common interest to each of these topics is Dr. Lavelle's synthesis on «The Soil System in the Humid Tropics», published in the present issue of Biology International.

The IUBS also shares the concern with the countries of Africa in the development and utilization of their natural resources, and welcomes the proposal made following an initiative taken by the United Nations University, for the establishment of an «Institute for Natural Resources in Africa». We believe the proposed institute will be of great help in developing the cooperation between the African scientists and IUBS, particularly in the fields of land use as well as in plant and animal resources.
The Soil System in the Humid Tropics*
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SUMMARY

The overall effect of tropical climate on the functioning of humid tropical soils may be synthesized in the simple scheme of fig. 1. Because of a potentially high microbial activity and deep alteration of the substrate leading to a low clay content, the functioning of tropical soils faces three major constraints in most cases:

i. a low and partly inaccessible humic stock, as a consequence of rapid mineralization. Particularly, tropical soils have a very low content of hydrosoluble energetic compounds as well as assimilable nutrients;

ii. a general sensitivity to erosion, due to their low colloid content;

iii. a great poverty in minerals, due to a low exchange capacity of clays and leaching.

In spite of such unfavourable conditions, tropical soils generally support the highest level of primary production on land. The reason for this might be the existence of three kinds of functional mechanisms linked to the difficult conditions prevailing in tropical soils and which may be more or less developed, depending on the degree of the unfavourable conditions. These three functional mechanisms may be described as follows:

- efficient mechanisms of nutrient conservation, involving sclerophyll, direct cycling of dead leaves in a thick, superficial and highly micorrhized root mat functioning like a filter, concentration of the nutrients in plant and possibly animal biomass and accumulation in reservoirs (termite mounds, earthworm casts);

- conservation of the soil structure through the activity of roots (rhizosphere) and soil animals;

- a precise regulation of humic reserves through the production, limited in time and highly located in space, of assimilable carbon: production of exudates in the rhizosphere and mucopolysaccharides by earthworms in the « drilosphere » (i.e. gut contents and casts of earthworms). Such energetic elements activate the microflora and thus, through a well-known priming effect, activate mineralization and humification.

The different soil systems might be classified and compared by determining the relative importance of these functional mechanisms and studying their structure and functioning. Management studies should take into account and try to conserve or improve such fundamental mechanisms in order to conserve soil resources.

INTRODUCTION

Soil ecologists working in the tropics have soon observed that the luxuriance of the vegetation may hide a great fragility and a very vulnerable equilibrium. Tropical systems have a highly rapid matter cycling and low soil reserves, both energetic or mineral. Most often, the perturbations entailed by clear cutting, fire or inadequate agriculture practices have serious consequences, as a matter of fact, soil impoverishment under conditions of aggressive climates results in rapid erosion and sometimes total destruction.

The aim of this synthesis is to describe the general features of tropical soils functioning and to define their main significant parameters. Such an approach will make possible comparative studies sorting out the effects on soil biology of all the variables, whether they are climatic, edaphic, biotic or geographic. Experimental and applied research will then be made easier.

This analysis has been voluntarily restricted to the study of moist tropical soils (with a udic moisture regime), the most typical, for their functioning is not hindered by slowed by drought.

Substrates however, can influence through mother rock acidity and topography which determine the intensity of leaching (Duchaufour, 1979).

With a basic mother rock and low leaching, montmorillonites are constituted by neoformation. They are swelling clays with a high exchange capacity and usually form extremely stable complexes with organic matter which characterize the vertisols.

B. PEDOClimate

The main climatic features in tropical soils are generally constant high temperatures and contrasted water regimes.

1. Temperature

In burnt savannas, diurnal and seasonal temperature variations are very important. In Lamto, right after bush fires, temperature can raise above the 50 °C in the two upper centimeters and amplitude reach 28 °C. Such variations tend to decrease with depth, in the two upper centimeters, the annual mean of daily amplitude is 13.9 °C as compared to 4.2 °C at – 10 cm. Vegetation cover can considerably limit the amplitude of these variations: the mean seasonal amplitude in the 0-2 cm stratum is 8 °C in the burnt savanna and 2.6 °C in a plot protected from fire (Athias, 1974).

In tropical forests, soil temperature is extremely stable and exhibits very low variations as vegetation cover has a very effective protecting role (Adis and Schubart, 1983; Lavelle and Kohlmann, in press).

2. Soil moisture

The water regime of soils varies according to three main factors: the duration of the dry season(s), the ability of the soil to hold water, and the importance of woody cover.

Field capacity and usable water range, i.e., the difference between the water potential values corresponding to field capacity (pf 2.5 or 1/3 bar) and the permanent wilting point of plants (pf 4.2 or 15 bars), are low in most of these soils with the exception of vertisols (Table 1). Such a situation is due to the fact that clay contents may be very low and that these clays, mainly kaolinite and gibbsite, have a very low water retention ability.

On acid rocks, neoformation clays, kaolinite and gibbsite, are much less active and the soils are ferrallitic or ferruginous ones.

In addition to these three main soil types, we may observe a great variety of hydromorphic soils (gleys, planosols or podzols) and andosols, a kind of volcanic soil characterized by the allophanes, a highly reactive aluminosilicic gel which combines with the organic matter and makes extremely stable complexes. Sanchez gives in Swift (1984) a correspondence among the French, US and FAO soil classifications.

Ferralitic soils and ferrisols cover 43 % of the tropics. They are generally acid and low base status soils and may be considered as the stereotype « humid tropical soils ». However, ferruginous and alluvial soils with higher base status and fertility may occur in the same areas.

<table>
<thead>
<tr>
<th></th>
<th>Lamto (Ivory Coast)</th>
<th>Laguna Verde (Mexico)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ferruginous hydromorphic soil</td>
<td>Well drained ferruginous soils</td>
</tr>
<tr>
<td>pf 2.5 (%)</td>
<td>9</td>
<td>11.5</td>
</tr>
<tr>
<td>pf 4.2 (%)</td>
<td>4.5</td>
<td>4</td>
</tr>
<tr>
<td>usable water range (%)</td>
<td>4.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Table 1.

Field capacity (pf 2.5), wilting point (pf 4.2) and usable water range in some grassland soils (0-10 cm) (Lavelle, 1978; Barois, 1982) (Water contents in % of dry soil).
In soils with little ability to hold water, the water regime is most variable as high drought periods may alternate rapidly with asphyxiating moist periods (Lavelle, 1978).

Trees, that have a much greater evapotranspiration, as grass does, have a strong effect on water regimes (fig. 2). In 1969, at Lamto rainfall fell to 903 mm. The superficial soil was physiologically dry (i.e.; moisture < pf 4.2) during 80 days in a low-slope grassland, 160 days in a shrub plateau savanna and 140 days in a gallery forest (Lavelle, 1983). It is thus paradoxal to note that with an equal rainfall, forest soils use to be much drier than savanna soils. Intensely dry periods can occur in forests, even with annual rainfall greater than 2 000 mm.

Bernhard-Reversat et al. (1979) estimate that in the tropical forest of Ivory Coast, annual drainage reaches 27 to 30 % of annual rainfall.

C. NUTRIENT RESERVES

1. Soil mineral contents

A consequence of the generally low clay contents of tropical soils and low exchange capacity of these clays is a frequent nutrient poverty. Other factors such as intense leaching and high temperature use to favour the loss of nutrients.

Significant examples of the contents of some tropical soils of America and Africa are shown in table 2. Ferralitic soils of the Amazon region are the poorest ones. P - (1.3 ppm) as well as K - (0.06 ppm) contents are lowest and Al reaches toxic concentrations (> 60 %). Ferruginous soils and ferrisols have slightly higher P and K contents. These concentrations however, remain low, as P hardly reaches 4 ppm and K, 0.23 meq. in the Lamto savanna soils.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Vegetation type</th>
<th>Soil type</th>
<th>N %</th>
<th>P ppm</th>
<th>K m. eq. 100 g</th>
<th>Ca m. eq. 100 g</th>
<th>Mg m. eq. 100 g</th>
<th>T m. eq. 100 g</th>
<th>S %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamto (Ivory Coast)</td>
<td>Loudetia savanna</td>
<td>Hydromorph trop. ferruginous</td>
<td>0.44</td>
<td>2</td>
<td>0.20</td>
<td>3.1</td>
<td>0.9</td>
<td>3.0</td>
<td>139</td>
</tr>
<tr>
<td></td>
<td>Hyparrhenia Savanna</td>
<td>Tropical ferruginous</td>
<td>0.61</td>
<td>4</td>
<td>0.23</td>
<td>3.8</td>
<td>1.2</td>
<td>4.6</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>Loudetia savanna</td>
<td>Vertisol</td>
<td>1.3</td>
<td>1.6</td>
<td>12.4</td>
<td>5.3</td>
<td>51</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>La Réunion</td>
<td>Heaths (Ericaceae)</td>
<td>Andosol</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amazonia (Brasil)</td>
<td>Tropical forest</td>
<td>Ferralitic</td>
<td>1.3</td>
<td>0.06</td>
<td>4</td>
<td></td>
<td></td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ferrisol</td>
<td>4.0</td>
<td>0.18</td>
<td>1.5</td>
<td></td>
<td></td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pianosol</td>
<td>5.6</td>
<td>0.30</td>
<td>9.4</td>
<td></td>
<td></td>
<td>9.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alluvial</td>
<td>13.0</td>
<td>0.32</td>
<td>13.5</td>
<td></td>
<td></td>
<td>13.8</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.

Nutrient contents of different soil types in tropical grasslands. (T: Total exchange capacity; S: Saturation rate) (Darici, 1978; Alvim, 1978).
Ferruginous soils of the Arnazon region have higher nutrient contents and less Al. However it is only in alluvial soils that relatively high concentrations can be found: 13 ppm of P, 0.32 meq. of K, 13.5 of Ca and Mg and an Al contents limited to 8 % (Alvim, 1978).

Vertisols which are rich in montmorillonite, a clay with high retention capacity, have a much higher mineral richness, as their exchange capacity is Laguna Verde area (Mexico) and high Ca and Mg contents have been measured in the Lamto vertisols (of respectively 11.2 and 11.1 meq./100 g, Darici, 1978). These soils still remain poor in P as their concentration does not exceed 6 to 8 ppm in the Mexican vertisols (Lavelle et al., 1981).

Andosols are some of the tropical soils that exhibit a real mineral richness as their total exchange capacity is 51 meq./100 g and their K, Ca and Mg contents are great (Darici, 1978).

However, most of the tropical soils appear to have a general mineral poverty increasing from moist savannas, experiencing a marked dry season either to more moist equatorial, or drier tropical regions. In the Amazon basin, mineral impoverishment has been shown to increase from the periphery to the center (Furch and Klinge, 1978).

2. Nutrient concentration in plant biomass

Forest soils may be very poor in nutrients which are then, mostly concentrated in plant biomass (table 3).

<table>
<thead>
<tr>
<th>Locality</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banco (Ivory Coast)</td>
<td>82.2</td>
<td>50.0</td>
<td>13.3</td>
<td>8.3</td>
<td>15.1</td>
<td>Bernhard-Reversat et al., 1979</td>
</tr>
<tr>
<td>Kade (Ghana)</td>
<td>69.2</td>
<td>(8.6)</td>
<td>(41.6)</td>
<td>(49.1)</td>
<td>(49.6)</td>
<td>Nye, 1961</td>
</tr>
<tr>
<td>Montain forest (Porto Rico)</td>
<td>62.6</td>
<td>59.3</td>
<td>18.1</td>
<td>38.9</td>
<td>20.2</td>
<td>Jordan et al., 1972</td>
</tr>
<tr>
<td>San Carlos de Río Negro (Venezuela)</td>
<td>(37.6)</td>
<td>(33.8)</td>
<td>(10.0)</td>
<td>(26.2)</td>
<td>(7.8)</td>
<td>Herrera, 1979</td>
</tr>
<tr>
<td>Panama</td>
<td>11.5</td>
<td>10.1</td>
<td>84.3</td>
<td>84.3</td>
<td>69.3</td>
<td>Gollet et al., 1975</td>
</tr>
<tr>
<td>El Verde (Porto Rico)</td>
<td></td>
<td>83.6</td>
<td>8.9</td>
<td>47.1</td>
<td>64.4</td>
<td>Odm and Pigeon, 1970</td>
</tr>
<tr>
<td>Yangambi (Zaire)</td>
<td>91.5</td>
<td>(98.0)</td>
<td>(74.6)</td>
<td>(37.8)</td>
<td>(42.0)</td>
<td>Bartholomew et al., 1953</td>
</tr>
</tbody>
</table>

Table 3.

Author

D. HUMIC RESERVES

The overall decomposition is extremely rapid on the humid tropics: it lasts 2.5 to 17 months according to the conditions (UNESCO, 1979) with a general mean value of ca. 8 months. In such systems, mineralization of organic matter as expressed by the CO₂ production is much greater than humification (fig. 3). Humification is very rapid: hydroxoluble fractions are leached towards deeper horizons and mineralized, if not mineralized before. Thus humic acids result to be mainly of residual origin.

Fig. 3. Relationship between plant production and microbial reduction with increasing temperatures (Beck, 1971).
An important part of them are fulvic acids, but such highly polymerized and little accessible compounds as grey humic acid are common in tropical savannas (Schaefer, 1974). In forest soils, brown humic acids use to be dominant.

As a result of such a rapid mineralization, organic contents are very low in spite of the high input. In African savanna soils, organic contents of the upper horizons vary from 0.7 to 2 % in ferruginous soils (Jones and Wildt, 1975; Darici, 1978; Kowal and Kassam, 1978; Lasebikan, 1983; Abbddie, 1983). Jones and Wild calculated a mean value of 1.2 % for 245 soils of West Africa, where as Goodland (1971) reports a value of 2 % for a variety of grassland soils from Brazil.

Vertisols have often higher organic contents: about 3.5 % in West Africa according to Kowal and Kassam, 1978; 4.5 % in the Lamto savannas and 7 % in the Laguna Verde pastures (Rangel, in prep.). In Lamto, the total amount of humic reserves varies from 35 to 74 t/ha in ferruginous soils and is 201 t in vertisols (Schaefer, 1974).

In forest soils, organic contents are generally greater than in savannas: they exceed 3 % in a great number of soils from Africa and Puerto Rico (Sanchez, 1976). Some lower values are reported by the same author, ranging from 0.98 to 2.13 % in randomly chosen soils from Brazil and Zaire. Some higher figures have been produced for French Guiana ferralic soils (2 to 4 % according to Puig, unpublished) and Mexico ferrisols of the Lacandon forest (5 to 6 %, Rangel in prep.).

In the Amazon forests, Alvim (1978) reports values of 1 % in ferrisols, 1.4 % in an equatorial soil, 1.3 to 2.7 % in ferralic soils and 2.2 to 3.5 % in ferruginous soils.

Thus, Schlesinger (1977) calculates a mean value of 104 t/ha for the total humic stock of these forests with variations between 37 to 205 t. Data from Ivory Coast (70 to 170 t according to Bernhard-Reversat et al., 1979) are within this range.

**E. CONCLUSION**

Soils from the tropical regions have been formed under mean high temperatures with highly contrasted regimes in savannas. Water regimes show great variations with rapid alternance of intense drought and flooding. Such conditions favour a rapid alteration of minerals and an intense mineralization of organic matter. As a result, clay content may be low. In most cases anyway, these clays have a low ability to hold nutrients. Thus, nutrient reserves for plant nutrition are often extremely low, especially in P, mineral nitrogen and K. In some extreme cases, most of the nutrient stock of the ecosystem (especially K, Ca, Mg and Na) is concentrated in the plant compartment. This is essentially true in tropical forest ecosystems where Rodin and Bazilevic (1967) have shown that the concentration of nutrients per unit of organic matter is greater than in the temperate forest (2.14 % in the former, 1.5 % to 1.7 % in the later).

For the same reason, humic stocks are very low and made of highly polymerized humic molecules. Some authors however report cases of relative depolymerization at the end of moist periods (Jagnow, 1973; Turenne, 1975, in Duchaufour, 1979).

In other respects, the alternating of dry and moist periods favour the mineralization of little polymerized fractions, which tends to increase another paradoxal feature of these soils, i.e. the absence of accessible energetic reserves.

Thus these soils often appear to be poor both in nutrients and energetic carbon reserves, therefore rather unfavourable to an optimal energetic activity and a good mineral nutrition of plants. In such a situation of low reserves and resulting physical fragility, the intensity of primary production may only be explained by the existence of highly efficient nutrient recycling mechanisms (Golley et al., 1975) and regulation mechanisms of the humic reserves that allow an optimal use of these, through a precise and limited activation of both their mineralization, and humification (fig. 4).

**II. BIOLOGICAL COMPONENTS OF THE TROPICAL SOIL**

There are three main groups of organisms in the soil:
- plants represented by their roots and litter accumulated on the soil surface,
- microorganisms, mainly bacteria and fungi,
- invertebrates.

**A. LITTER INPUT, ACCUMULATED LITTER AND DECOMPOSITION RATES**

Litter input and decomposition rates are quite different in forest and savanna. In tropical grasslands, fire regularly destroys the litter at the end of dry seasons. During the rainy season, litter tends to accumulate progressively, and the maximum weight is 0.9 to 2.9 t/ha in the Soudanian savannas of Wango Fitini (Ivory Coast) and 1.9 to 5.7 t/ha in the Guinean savannas of Lamto (Cesar, 1971; Fournier, 1982). Thus litter is never abundant in savannas and totally absent during several months. Its decomposition is rapid, and many authors doubt whether this litter is humified and added to the soil organic reserves (Sanford, 1982).

In the tropical forest, litter fall occurs all year long but displays well marked seasonal peaks. Total annual input varies from 6.3 to 12.4 t/ha and the mean quantity of litter accumulated on the soil surface ranges between 2.3 and 5.7 (table 4). The estimated decomposition periods vary from 77 to 330 days with an average of 187 days. Thus forest litter seems to be a relatively abundant resource, though it might be of poor nutritive value as a consequence of the rapid leaching of hydrosoluble organic matter and nutrients due to heavy and warm rains.
Table 4. Litter input (t/ha), accumulation on the soil surface (t/ha) and decomposition rate in different tropical forests.

<table>
<thead>
<tr>
<th>Region</th>
<th>Author</th>
<th>Litter input (L)</th>
<th>Litter accumulated (A)</th>
<th>K = \frac{L}{A}</th>
<th>Time of decomposition in days</th>
<th>Dead Wood accumulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>French Guyana</td>
<td>Puig, unpublished</td>
<td>7.0-7.6</td>
<td>3.3-5</td>
<td>1.5-2.3</td>
<td>157-243</td>
<td>7.8</td>
</tr>
<tr>
<td>Amazon forest</td>
<td>Fittkau and Klinge, 1973</td>
<td>7.3</td>
<td>4.2</td>
<td>1.8</td>
<td>178</td>
<td>17.7</td>
</tr>
<tr>
<td>Colombia</td>
<td>Jenny et al., 1949</td>
<td>8.5</td>
<td>5.7</td>
<td>1.5</td>
<td>244</td>
<td></td>
</tr>
<tr>
<td>Zaïre (Yangambi)</td>
<td>Laudelout and Meyer, 1965</td>
<td>12.4</td>
<td>5.5</td>
<td>2.3</td>
<td>115</td>
<td>17.3</td>
</tr>
<tr>
<td>Ghana (Kade)</td>
<td>Nye and Greenland, 1960</td>
<td>10.5</td>
<td>2.3</td>
<td>4.5</td>
<td>77</td>
<td>71.8</td>
</tr>
<tr>
<td>Ivory Coast (Banco)</td>
<td>Bernhard-Reversat et al., 1979</td>
<td>6.3-8.2</td>
<td>1.4</td>
<td>4.5-5.9</td>
<td>150-330</td>
<td></td>
</tr>
<tr>
<td>Ivory Coast (Lamto)</td>
<td>Devineau, 1976</td>
<td>5.7-6.6</td>
<td>1.9-3.9</td>
<td>1.3-3</td>
<td>3.8-9.8</td>
<td></td>
</tr>
</tbody>
</table>

Fig 4. General constraints in the functioning of tropical soils and related mechanisms of biological regulation.
B. ROOTS

Root biomass varies extensively according to seasons and milieux. In tropical forests, it ranges from 48 to 255 t/ha (Bernhard-Reversat et al., 1979; Müller and Nielson, 1965; Fittkau and Klinge, 1973) which makes up 8.7 to 39 % of the total plant biomass (table 5). In some extreme cases (caatinga forest growing on white sand) root biomass may represent up to 60 % (Herrera, 1978).

In savannas, biomasses are much lower: figures of 5.7 to 19 t/ha, according to savanna types and years have been measured in the Lamto Guinean savannas (César, 1971; Abbadié, 1983). In Southern Soudanian savannas of northern Ivory Coast, Fournier (1982) gives quite similar results: 9.3 to 10.9 t/ha.

In the vertisols of the tropical pastures of Laguna Verde, root biomass varies from 12.6 to 30.2 t/ha according to soil characters, and the greatest biomasses are found in the most clayey soils (Lavelle et al., 1981).

Two types of roots generally are present: tap roots and lateral roots (Golley, 1983). The surface lateral roots play an important role in forest systems as they extract the nutrients released by litter recycling. Tap and deep lateral roots extract nutrients and water from the soil itself. In some soils particularly poor in nutrients, the surface root system sometimes form a 20 to 30 cm thick mat. This mat acts as a filter, reabsorbing all the nutrients released by litter decomposition (Herrera, 1978). Stark and Jordan (1978) have stated that, when a radio-labelled phosphorus solution is sprayed over this root mat, 99.9 % of the radioactivity is soon found in the soil or washed down by leaching. Microflora such low values are only indicative as Schaefer et al. (1969) emphasizes the extreme difficulty of such estimations in the particular conditions of tropical soils. In other respects, high temperatures and contrasted hydric regimes that prevail in these soils are highly favourable to microbial activity.

In the tropical forests of Ivory Coast, 39 to 71 % of the root biomass is concentrated in the upper 20 centimeters (Huttel, 1976). In the forests of the French Guiana, 70 % of biomass is found in the upper 20 cm in well drained soils; in ill drained soils, this proportion increases up to 80-90 % (Puig, pers. comm.).

Very important variations were also observed by Odum and Pigeon in different American forests.

In savannas, root biomass (mostly grasses) is generally more superficially distributed than in forests: 65 to 75 % of biomass are concentrated in the 20 upper centimeters of the soil in the Lamto and Wango-Fiti savannas (Ivory Coast).

Among the variables influencing such distributions are trophic factors (nutrient conservation mechanisms), soil texture and hydric regime of the soil. Seasonal variations may be very important as observed by César (1971), Fournier (1982) and Abbadié (1983) in African savannas. These authors emphasize the opportunism and great plasticity of the root system that can extend at any favourable condition. Variations seem to be of greater amplitude close to the soil surface than in the deeper horizons (Fournier, 1982).

C. SOIL MICROFLORA

Very few quantitative studies of microbial communities have been done in the tropics. At Lamto, the total density was estimated from 8 to 90 x 10^6 cells/g in savannas and 40 to 90 x 10^6 in gallery forests. Grass fires seem to favour Actinomyceta as their density tends to increase just after burning. Vertical distribution is quite uniform as density decreases little, and at - 75 cm (depth) numerous cells can still be found (Pochon and Bacvarov, 1973).

Such low values are only indicative as Schaefer (1974) emphasizes the extreme difficulty of such estimations in the particular conditions of tropical soils. In other respects, high temperatures and contrasted hydric regimes that prevail in these soils are highly favourable to microbial activity.

As a matter of fact in vitro incubations of these soils show their great potential activity (table 6). Carbon
mineralization as measured by the CO₂ emitted is maximum in the upper centimeters of the profile and decreases towards the deeper horizons. Soil of the rhizosphere has generally a greater activity.

The lowest values have been measured in ferralitic soils (23 to 60 mg C CO₂/Kg/7 days with a mineralization rate of 0.35 to 0.60 %). In ferruginous soils CO₂ production varies from 114 to 292 with mineralization rates of 1.6 to 3.2 % week. 200 Kg/ha/year) in the south of Ivory Coast, despite soil acidity. Such results emphasize the great difference that exists in the dynamics of organic matter in forests and savannas.

Vertisols have a quite similar global activity (114 to 179) with lower mineralization rates (0.4 to 0.7 %). Andosols produced 231 mg C CO₂ and their mineralization rate was the lowest (0.10 %).

Nitrogen mineralization measured by classical methods is extremely low and sometimes non-existent in savannas. In the Lamto savannas, nitrifying bacteria are in a state of energetic starvation (De Rham, 1971; Abbadie, 1983). However, such low contents of mineral nitrogen are not the main limiting factor to carbon mineralization. As a matter of fact, Darici (1978) has observed that if nitrate is added to this soil, the mineralization rate of carbon does not increase. On the other hand, if such an energetic substrate as gelatine is added, the carbon mineralization is highly increased. This would mean that the real limitation to this mineralization is rather the lack of easily assimilable carbon than nitrogen.

In tropical forests, the situation is different. De Rham measured great productions of nitrates (135 to 200 Kg/ha/year) in the south of Ivory Coast, despite soil acidity. Such results emphasize the great difference that exists in the dynamics of organic matter in forests and savannas.

On the whole, tropical soils have very potentially high mineralization rates. However, in savannas, nitrogen mineralization is the lowest, as a consequence of the lack of assimilable carbon. The main problem of these soils seems to be the paradoxal need of activating mineralization, especially of organic nitrogen, and on the other hand, to maintain the humic reserves above a minimum level. As a matter of fact, the generally low clay content increases the role of organic matter in the conservation of the soil structure.

Table 6.
Soil respiration and rate of mineralization in different vegetation and soil types (laboratory data).

<table>
<thead>
<tr>
<th>Country</th>
<th>Type of vegetation</th>
<th>Soil (cm)</th>
<th>C CO₂, mg/Kg dry soil/7 days</th>
<th>Rate of mineralization per week</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aristidina savanna</td>
<td>Ferralitic 0-5</td>
<td>60</td>
<td></td>
<td>De Boissezon, 1961</td>
</tr>
<tr>
<td></td>
<td>Bataké savanna</td>
<td>Sandy 0-15 40-50</td>
<td>101</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamto</td>
<td>Hyparrhenia savanna</td>
<td>Tropical 0-6 6-15 15-25 25-35 35-45</td>
<td>157.5 108.5 94.5 63.7 77.7</td>
<td>1.61 1.26 2.03 1.33 1.54</td>
<td>Schaefer, 1974</td>
</tr>
<tr>
<td></td>
<td>Loudetia savanna (rhizosphere)</td>
<td>Sandy</td>
<td>114.1</td>
<td>1.61</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hyparrhenia savanna (rhizosphere)</td>
<td>Tropical fertuginous</td>
<td>183.4</td>
<td>1.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loudetia savanna</td>
<td>Vertisol 0-15</td>
<td>114.3</td>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wango-Finni</td>
<td>Tropical 0-5 5-15 15-30</td>
<td>281.7 123.7 105.0</td>
<td>2.31 1.49</td>
<td>Bennani, 1980</td>
</tr>
<tr>
<td></td>
<td>Shrub savanna</td>
<td>Tropical fertuginous</td>
<td>0.12</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ferralitic 0-10 10-50</td>
<td>0.60</td>
<td>1.44</td>
<td>Bernhard-Reversat et al., 1979</td>
</tr>
<tr>
<td></td>
<td>Yapo</td>
<td>Tropical 0-10 10-50</td>
<td>0.74</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ferralitic 0-10 10-50</td>
<td>0.66</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>Laguna Verde</td>
<td>Induced pasture Vertisol 0-3 3-7 7-15 15-30</td>
<td>179.4 153.3 112.7 199.5 255.5</td>
<td>0.74 0.66 0.62 2.28 0.79</td>
<td>Barois, 1982</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rhizosphere</td>
<td>255.5</td>
<td>0.79</td>
<td></td>
</tr>
</tbody>
</table>
D. SOIL INVERTEBRATE COMMUNITIES

Soil invertebrates are generally classified into three groups according to their size: Microfauna (< 0.2 mm) includes Protozoa, Nematodes and Rotifers that have an aquatic way of life. Mesofauna (0.2-2 mm) comprises Microarthropods and Enchytraeidae. Macrofauna (> 2 mm) is essentially composed of Myriapods, Insects and Oligochaeta.

These animals can also be classified in ecological groups using the earthworm classification, based on feeding habits and habitats (Bouché, 1971; Lavelle, 1981). Epigeic animals live in the litter and feed in it, whether they be detritivorous or predator.

Endogeic animals live into the soil and can be rhizophages or geophages. Among geophages, three sub-categories have been distinguished, oligo-, meso-, or polyhumic according to the relative organic richness of the ingested soil.

Anecic animals eat litter, but live in galleries into the soil (Earthworms) or in nests (Termites). Their main characteristic is to introduce litter in other decomposing systems than the litter one.

1. Community structure

Microfauna and mesofauna communities have low densities in the tropics as compared with temperate and cold regions. As an example, 32 x 10^6 Nematodes can be found in one square meter of the Lamto savanna (Couteaux, 1978; Malcevschi, 1978). Enchytraeid worms too have very low densities: 190 to 0.3 g (Madge, 1965, Thambi and Dash, 1973; Athias et al., 1975). Microarthropods have also relatively low densities. In tropical grasslands from South Africa (Ryke and Loots, 1967), Uganda (Salt, 1955), Ivory Coast (Athias, 1974), Chili (Covarrubias et al., 1964), Mexico (Lavelle et al., 1981) and Panama (Breymeyer, 1978), their mean density is ca. 38 000 ind./m², and ranges from 22 000 to 64 000. In tropical forests, from Zaïre (Meldigue, 1961), Brasil (Beck, 1971); Chili (Covarrubias et al 1964, Ivory Coast (Huttel and Bernhard-Reversat, 1975) and Mexico (Lavelle et al, 1981), the average density is 70 000/m² and ranges from 36 000 to 106 000.

Soil macrofauna constitutes the major part of the biomass of these communities. Five groups are dominant: Ants, Termites, Coleoptera, Earthworms and Myriapods (tables 7 and 8). In grasslands, the fresh biomass of the macrofauna varies between 36 and 96 g/m². Earthworms represent 49 to 91.1 % of the total, and are dominant except when annual rainfall drops below 300 mm and the dry season exceeds four to five months (Lavelle, 1983a).

Ants are always numerous, but represent only 1.1 to 7.1 % of biomass. Termites are very abundant in Africa and constitute 3.6 to 9.4 % of the total biomass. In tropical Mexican pastures, they are nearly non-existent.

Coleoptera have generally low densities and biomasses (Girard, 1983) except in the Mexican pasture, where they represent 46.9 % of biomass. Such an importance of Coleoptera (essentially represented in this case by Melolonthidae larvae) might be a particular character of American soils (Moron, pers. comm.). Other important groups, Myriapods, Arachnids and Diptera larvae, which are generally dependent on litter, vary in importance according to the density of the woody cover.

<table>
<thead>
<tr>
<th></th>
<th>Lamto Ivy Coast</th>
<th>Foro-Foro Ivy Coast</th>
<th>Laguna Verde Mexico</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>d</td>
<td>bm%</td>
<td>d</td>
</tr>
<tr>
<td>Earthworms</td>
<td>230</td>
<td>49.00</td>
<td>460.0</td>
</tr>
<tr>
<td>Myriapods</td>
<td>50</td>
<td>0.36</td>
<td>103.0</td>
</tr>
<tr>
<td>Arachnida</td>
<td>4</td>
<td>0.03</td>
<td>3.2</td>
</tr>
<tr>
<td>Coleoptera</td>
<td>230</td>
<td>0.29</td>
<td>28.0</td>
</tr>
<tr>
<td>Diptera</td>
<td>16</td>
<td>0.03</td>
<td>0.5</td>
</tr>
<tr>
<td>Termites</td>
<td>910</td>
<td>1.95</td>
<td>1 200</td>
</tr>
<tr>
<td>Ants</td>
<td>500</td>
<td>2.00</td>
<td>1 400</td>
</tr>
<tr>
<td>Others</td>
<td>75</td>
<td>0.09</td>
<td>12.0</td>
</tr>
<tr>
<td>Total</td>
<td>2 015</td>
<td>53.80</td>
<td>3 207</td>
</tr>
</tbody>
</table>

Table 7.
Soil macrofauna communities in three tropical grasslands from Africa and America (Athias, Josens and Lavelle, 1975; Lavelle, Maury and Serrano, 1981; Lavelle, 1983a) (density/m² and biomass in g fresh weight/m²).

Forest communities are much more diverse (table 9): Earthworms are sometimes dominant (29 to 57 % of biomass) but their biomass is usually reduced to 1/4 of what it is in savannas. This might be a consequence of the drier hydric regime of the soil, but also the result of a quite different soil functioning, in which their role might be less important. Epigeic animals such as Myriapods (10 to 40 % of biomass), Arachnids or Diptera have a greater development. Termites have a quite variable importance: they are nearly absent in the Bonampak forest (Mexico), relatively abundant at Laguna Verde and very abundant in some tropical forests of Puerto Rico (10.6 g/m² after Odum and Pigeon, 1970), or Trinidad where their density reaches 4 450/m² (Strickland, 1944). It is however, in African forests that their density and biomass reach the maximum (1 000 to 10 000/m² and 5 to 50 g) (Lee and Wood, 1971).
2. Spatial distribution

Soil invertebrate communities of the tropics exhibit two well-marked and original patterns in their distribution:

- a great horizontal heterogeneity, especially in the forests. This is the result of a specialization, and diversity is great (Lavelle and Kohlmann, in press). This has been observed in Earthworm communities (Nemeth, 1981; Fragoso and Lavelle, in prep.), where clear differences have been found among the various facies of the forest. In the same way, the distribution in tussocks of savanna Gramineae and the Laguna Verde forests, only 20% of the soil the suspended soils of palm trees and epiphytes. In in press), where clear differences have been found in the forests. This is the result of a specialization, 9.7% live deeper than 20 cm. In the Lacandon forest introduces a great heterogeneity in the soil meso-community (Nemeth, 1981; Fragoso and Lavelle, press). This has been observed in Earthworm litter, the soil down to quite deep horizons and also communities. At Laguna Verde this group does not exist in the pastures. In Mexican forests, anecics have been found as for example in San Carlos de Rio Negro (Amazon forest) (Nemeth, 1981) or anecic Termite communities. At Laguna Verde this group does not exist in the pastures. In Mexican forests, anecics have been found as for example in San Carlos de Rio Negro (Amazon forest) (Nemeth, 1981) or anecic Termite communities. Endogeic geophages essentially represented by meso- and oligohumic Earthworms which are specialized in feeding on organic matter of the deeper horizons of the soil (Lavelle, 1983c).

3. Trophic structure

The trophic structure of soil communities can be defined by the proportion of biomass represented by organisms of the above defined ecological categories. Such a structure varies among the different ecosystems (table 9).

The proportion of epigeic, whether they be detritivorous or predators increases with the degree of deforestation: it is minimal in the Laguna Verde pastures and increases in the shrub and the fire protected savannas of Lamto. In forests, this group constitutes about half of the total biomass. Anecics represent respectively 14.2 and 22.6% of the biomass in the Lamto savannas that have one species of anecic Earthworm and abundant Termite communities. At Laguna Verde this group does not exist in the pastures. In Mexican forests, anecics have low importance. They are more abundant in forests where large anecic Earthworms populations have been found as for example in San Carlos de Rio Negro (Amazon forest) (Nemeth, 1981) or anecic Termite communities.

Endogeic geophages essentially represented by meso- and oligohumic Earthworms are most important in savannas, whereas rhizophages may be locally abundant.

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Detritivorous</th>
<th>Predators</th>
<th>Total</th>
<th>Rhizophagous</th>
<th>Geophagous</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pastures</td>
<td>4.5</td>
<td>3.6</td>
<td>8.1</td>
<td>14.2</td>
<td>1.7</td>
<td>76.0</td>
</tr>
<tr>
<td>Burnt savannas</td>
<td>10.4</td>
<td>6.0</td>
<td>16.4</td>
<td>22.6</td>
<td>1.4</td>
<td>59.6</td>
</tr>
<tr>
<td>Tropical forest</td>
<td>28.4</td>
<td>9.8</td>
<td>38.2</td>
<td>4.0</td>
<td>5.4</td>
<td>55.3</td>
</tr>
</tbody>
</table>

Table 9.

Soil macrofauna trophic structure of different tropical forests and savannas in Africa and America (in %).
III. THE FUNCTIONING OF THE TROPICAL SOIL SYSTEM

As a consequence of the high metabolic level of their decomposers and aggressive climatic conditions, tropical soils tend to have three main unfavourable characteristics (fig. 6):

- they are very sensitive to erosion owing to their low colloid contents;
- they have poor nutrient reserves and in forests, a great part of them is concentrated in the standing biomass;
- the organic reserves are low and not easily accessible.

Three main subsystems represent the functional adaptation of the soil system to such characteristics (fig. 8):

- a litter-superficial root subsystem, the main function of which is a direct cycling of nutrients from the leaf litter preventing losses;
- two subsystems regulating the mineralization and humification of the soil reserves and the soil structure:
  - the rhizosphere, centre of very active mutualistic interactions between plants, microflora and an associate fauna. The activation of this system is produced through root exudates;
  - the drilosphere defined as geophagous Earthworm populations and the soil they influence: intestinal contents and castings of up to 30 days.

A. THE LITTER-SUPERFICIAL ROOTS SUBSYSTEM

This system involves litter, superficial roots, epigeic invertebrates and the associated microflora. It can be almost impervious in some extreme cases (Amazon forest on podzols) but most often, hydrosoluble organic and mineral elements can be washed down and litter may be exported in other decomposing systems by the anecics.

Direct mineralization of litter by the root-fungi association is just an extreme situation only found in some forests on sandy, heavily leached and desaturated soils (see ch. II).

In better soils, this system of direct cycling is less important and could result in a relative decrease of total root biomass, especially in the uppermost horizons (fig. 9).

Litter decomposition is then achieved by more « classical » processes: direct decomposition by free microorganisms, principally fungi, and also fractioning and digestion by invertebrates. In this process, a probably important (1/10 to 1/5 according to Nye, 1960) part of the released mineral and water-soluble organic elements are washed down into the soil. They are then consumed or insolubilized, and absorbed by soil colloids; thus they participate in the reconstitution of soil humic stock and activate the soil metabolism.

Nothing is known about the importance of such phenomena, particularly of the flow of watersoluble organic matter than may enter the soil.

All the epigeic fauna participates in the fragmentation: large Myriapods (Diplopods and Polydesmids), Isopods and epigeic Earthworms are the main groups of macrofauna; Microarthropods and Enchytraeidae represent the mesofauna.

Aneics have a special role as they take away part of the litter and introduce it in different systems of decomposition. Termites digest almost completely the litter, with the help of their symbiotic microflora and the nutrients remain concentrated in their constructions: the above or underground nests considered by some authors as potential nutrient reserves for the soil.
Anecic Earthworms ingest litter together with soil and thus incorporate it to the soil system, within their galleries or in their surface castings. This litter constitutes an energetic contribution to the soil and participates in the constitution of humic reserves. These anecic worms often make up less than 5% of the total earthworm biomass. However, they constitute 30% of the biomass in the Amazon rainforest of San Carlos de Rio Negro, and it would be interesting to understand the significance of their presence in such soils (Nemeth, 1981).

B. THE RHIZOSPHERE SUBSYSTEM

Darici's results (1979) suggest that one limitation to the mineralization in tropical savannas is the scarcity of easily assimilable carbon substrates. This is particularly the main limiting factor for nitrogen mineralization and perhaps to free nitrogen fixation and humification, it might be considered as a mechanism to prevent losses.

The highly condensed humic molecules may, however, become accessible when a stimulation of microbial activity is produced by addition of assimilable substrates. Microorganisms first feed on these substrates and then, by a well-known priming effect, start mineralizing more complex compounds.

Such a process occurs in the rhizosphere by means of the root exudates that stimulate the microflora. These interaction systems, though largely discussed, are very little known. The only available data deal with a few cultivated plants. It has been found that some of these plants can invest up to 10% of their gross primary production in the production of exudates (see also for example Roivira, 1969; Oades, 1978). Nothing at all is known about tropical plants and such a knowledge would be of invaluable importance to understand the functioning and structure of these ecosystems.

Microbial activity is generally greater in the soil of the rhizosphere, and some results seem to suggest that organic matter dynamics is quite different in and out of the rhizosphere (Darici, 1978; Barois, 1982). Rhizosphere is also the centre of root decomposition, which seems to be most often realized by a direct microbial activity, as invertebrate root feeders are very scarce in the soils.

C. THE DRILOSPHERE

Another regulation system of humic reserves is constituted by geophagous Earthworms and associated microfauna and microflora. It seems to be complementary to the rhizosphere as it is mainly developed far from the roots. The drilosphere is also an important system in maintaining the soil structure. In this system, very important interactions are developing among Earthworms, microflora and organic matter. The energetic supply for such interactions is constituted by the intestinal mucus of Earthworms. Other soil invertebrates such as Termites might also play a similar role and thus, such subsystems might be regrouped within a general zoosphere effect.

1. Regulation of the soil structure through the mechanical activity of Earthworms

Geophagous Earthworms feed on soils with low organic contents with the help of a symbiotic microflora that digest for them the complex compounds of the soils (Lavelle et al., 1980). They have to ingest daily large amounts of soil ranging from 5 to 36 times their own weight (Lavelle, 1978). The total amount of soil that passes through the guts of geophagous Earthworms was estimated in 800 to 1,200 t/ha/year in the Lamto savannas. This is equivalent to a 10 cm thick soil layer. Microscopical examination of the soil profile clearly shows that the 15 upper centimeters have a well aerated and granular structure. Most of the element of this structure are nothing but worm casts of different ages that kept their structure.

A low proportion of the ingested soil is rejected on the surface: 28 to 35 t/ha in the Lamto savannas, which represent an approximate volume of 30 m³ empty spaces created into the soil. This has been especially studied on Millsonia anomala. The most abundant species of the Lamto savannas (Ivory Coast) and Pontoscolex corethrurus the dominant species in the Laguna Verde Mexican pastures. (Lavelle, Sow and Schaefer, 1981; Lavelle, Zaidi and Schaefer, 1983; Lavelle, Rangel and Kanyonyo, 1983; Barois, 1982).

Oligohumic species do not exist in temperate regions and mesohumic are very scarce. Temperature is probably too low to make possible efficient interactions (Lavelle, 1983c) as Earthworms only ingest 0.5 to 2.5 times their own weight of soil, and microflora is not active enough.

On the contrary, in tropical regions, with temperatures of 23 to 28 °C, microbial activity is much more intense. In the very short time of a gut transit (20 min to 2 hours), they will digest enough organic matter to feed the worm.

As a matter of fact, important modifications of the microbial activity can be observed in the gut of the earthworm. In the anterior part of the gut, they add great amounts of water (up to 120%) and hydrosoluble organic matter mainly made of poly saccharids (16% in the anterior gut of Pontoscolex corethrurus, Lavelle, Rangel and Kanyonyo, 1983) to the ingested soil and pH increases from 4.6 to 6.9 (Barois and Lavelle, in prep.).

Microbial activity exhibits little variations in the first third of the gut, but is suddenly multiplied by 5.5 in the second third.

In the posterior part of the worm, water and watersoluble organic matter are reabsorbed while pH tends to decrease, and microbial activity is still 6.3 times greater than in the control soil.

Fresh casts have still greater water soluble contents (0.43%) than the control soil (0.28%) (Lavelle, Rangel and Kanyonyo, 1983), pH drops to a value slightly greater than in the control soil. In older casts,
microbial activity is stabilized 40% above the control value and remains at this level at least 15 to 30 days. Studies carried out on *Millsonia anomala*, a microhumic endogeic from the Lamto savannas gave quite similar results. pH is neutral (6.7 to 7.0) in the anterior part of the gut and slightly basic in the median part (7.2). In the posterior part, it suddenly drops down to 6.4 and it is only 6.1 in the casts. Microbial respiration first decreases and is temporarily null in the first third of the worm; it then increases regularly until the posterior part of the gut where it is, on average, 4.4 times greater than in the control soil, and up to 12 times greater in some cases.

In the ultimate portion of the gut and in the fresh casts, microbial respiration is still 2.4 times greater than in the control soil, and casts will still present an increased activity until 80 days after they have been deposited; this proves the extreme robustness of the involved reaction. (Lavelle, Zaïdi and Schaefer, 1983; Barois and Lavelle, in prep.).

These transformations essentially result in an increased mineralization, mainly of carbon (19.2%). Great amounts of mineral nitrogen are also released, and accumulated mainly in the form of ammonium (+270% in the casts) part of which comes from the nitrogen excretion of the worm (Barois, 1982).

Some experiments have shown that the effect of earthworms on the soil can vary according to the state of the soil system. When the watersoluble contents of soil is artificially increased, which simulates the effect of an increased mineralization, *M. anomala* individuals ingest less soil. Respiration in the casts which was activated suddenly becomes inhibited when watersoluble contents becomes greater than a determined threshold. This inhibition seems to be removed gradually at higher concentrations.

Earthworms thus appear to be able to actuate as activators or inhibitors of the mineralization, according to the soil water soluble organic contents which actually measures the intensity of mineralization.

Earthworms, at last, may accumulate in their biomass and thus lay by important amounts of nutrients (particularly Ca), nitrogen and carbon in assimilable forms. They will be returned to the soil when they die. Such an effect of soil fauna as nutrient reservoirs, might be important in some extremely poor soils (Satchell, 1974).

**DISCUSSION**

Tropical soils are able to ensure good plant nutrition and a high primary production despite their current low organic and nutrients contents and their sensitivity to erosion. This is the result of the activity of efficient conservation-activation systems in the decomposition of litter and regulation of humic stock.

They are biological systems based on mutualistic relationships between root or invertebrates (earthworms) and microorganisms; plants in the rhizosphere and earthworms in the eudrilosphere produce assimilable carbon that microorganisms use as an energy source to release nutrients and/or more assimilable carbon from the soil organic compounds, and fix nitrogen (De Rham, 1971; Davic, 1978; Lavelle et al., 1980; 1983; Kaiser, 1983). The resulting production of assimilable nutrients is strongly localized in time and space: nutrients are released when necessary in the right place where plants or microorganisms will consume them. Thus, losses are prevented while the soil structure is maintained as a result of the mechanical activity of the involved invertebrates and roots.

Apart from these endogeic systems, a litter-superficial roots subsystem has been described that may prevent if necessary any leaching of nutrients from the litter through a direct litter-mycorrhizal fungal-root cycling (Herrera, 1978; Stark and Jordan, 1978).

As far as nutrient strategies are concerned, humid tropical soils may be characterized by:

- a quite complete separation of above- and underground litter decomposition systems,
- a subsequent root material originated humic stock (Sanford, 1982),
- a possible dominance of fast over slow cycles of decomposition (Foster and Martin, 1981; Coleman et al., 1983; Swift, 1984) as short-lived organic compounds play an important role and nutrients seem to be temporarily blocked in organic compounds whose life-span might be of the order of 1 to 3 years,
- a definite influence of plants and invertebrate-microorganisms mutualistic relationships in nutrient conservation and the maintenance of the soil structure (Lavelle and Schaefer, in prep.),
- a subsequent lowest stock of available nutrients since they are immediately utilized when released.

However, the tentative model based on these observations (fig. 7) might present a rather great range of variations since geomorphological, pedological, biogeographical and climatic conditions together with the vegetation patterns induce a great variability that may result in very diverse functioning patterns.

**Geomorphology** is important because relief, drainage systems and the possible extent of great vegetation formation may enable or not the existence of some particlular types of soils (e.g. vertisols or alluvisols) with good pedological characteristics.

**Biogeography** is also relevant since the fauna of some areas may not present all the possible functional categories. This is the case of Termites, as fungi growing species do not exist in America while they predominate in Africa. This seems to be the case of earthworms, as true anecic species do not exist in Africa but do exist in American tropical forests and could be present in tropical Asia. Thus it seems that the anecic function would be performed mainly by Termites in African forests and mainly by earthworms in American ones. However, more data are necessary to support such observations.

Lastly, climate, and particularly seasonality, is very important for the most water dependent animals and microbial activity.

Thus, general studies aimed at evaluating the relative importance of soil subsystems in different pedological, biogeographical and climatic conditions are needed. This evaluation should be made in terms of quantities of carbon and nutrients mineralized or humified and stocked.

Some totally unknown elements of the functioning of these systems would be very interesting to study such as:

- fluxes of nutrients and watersoluble organic matter percolating from the litter into the soil
- quantitative and qualitative aspects of root exudates production
- root decomposition patterns;
- zoosphere functioning: generalization of observed results on organic matter-microflora-earthworms interaction systems to other zoological groups especially Termites, Ants and Coleoptera.

In parallel, applied research and new management options should emerge from the better understanding of the functioning of these soils (Swift, 1984).

This should consist in a preliminary control of the structure and functioning of the biological regulatory subsystems as defined in this paper. If disfunctionings would become apparent, manipulations could be realized in order to re-establish the regulatory subsystems when lacking, and/or improve the general conditions of their functioning.

As an example, the impoverishment of soils after clear-cutting and burning of tropical forests could be prevented through such manipulations. Forest soils have generally efficient litter-superficial roots and rhizosphere systems. Drilosphere is not so active as it is in grasslands, partly because of unfavourable water regimes and partly because the problem of humic stocks management in natural conditions might be less critical in forest soils. After clearing, soil conditions (temperature and moisture) are more typical of a savanna, and such a system should have a very active drilosphere subsystem. Most often, this is not the case as forest earthworm species are not at all adapted to savanna conditions.

So, an efficient mean to prevent soil impoverishment and final erosion would be to introduce such species adapted to the new conditions. These species generally do not exist in the same area and should be imported from savanna regions. A good knowledge of regional faunas would enable choosing of the species that fit the best the newly created conditions. In the case of well known species, the simulation model "Allez-les-Vers", which predicts populations dynamics in determined environmental conditions, is a useful tool to get an idea of what will be the impact of the introduced population and how this introduction must be done (Lavelle and Meyer, 1983).

It is likely that Africa would offer the greatest variety of adaptable species, as it has large areas of little seasonal moist savannas that present in some extent the conditions of newly induced tropical pastures.

ACKNOWLEDGEMENTS
I am greatly indebted to Drs. F. Bourlière, Y. Dommergues, M. Lepage, J.-C. Menaut, Obeng, P. Sanchez, R. Schafer and T. Younes for their constructive comments and help in the revision of the text.


BARQUIS L. (1982), Intermédiaries entre Pontoscolex coreth-urus (Oligochète), la microflore et la matière organique d'un vertisol du Mexique (Laguna Verde, Vera Cruz), DEA, ENS, 42 p.


HUTTEL C. and F. BERNHARD-REVERSAT (1979), Recherches sur l'écosystème de la forêt sub-équatoriale de base Côte-d'Ivoire. V. Biomasse végétale et productivité primaire, cycle de la matière organique. La Terre et la Vie, 29, 203-228.


Institute for Natural Resources in Africa
A proposal by the United Nations University
by Edward S. Ayensu, Secretary General - IUBS

INTRODUCTION

One of the major objectives of the International Union of Biological Sciences (IUBS) is to foster close working relations with organizations in developing countries interested in the promotion of the conservation of natural resources and the judicious utilization of such resources for the benefit of mankind. No continent has demonstrated the need for a critical appraisal of its natural resources as forcefully as Africa. The past and present exploitation of Africa's natural resources is a controversial subject which this forum is not designed to explore. However, the situation is so critical that practical steps need to be taken to examine in detail ways and means of helping to put Africa's natural resources to good use.

Under the auspices of the United Nations University, a group of distinguished African scientists, technologists and educators, as well as individuals from governmental and nongovernmental organizations met on a number of occasions to consider an institutional mechanism within which they could make some contribution. The results of their deliberations led the United Nations University to propose the establishment of an « Institute for Natural Resources in Africa » (INRA).

PRIORITY AREAS

Six areas of priority that INRA will concentrate on are:

- **Land use**, especially the management of soil resources;
- **Water resources**, including ground and surface water in the various geographical zones, inter-basin water transfers, and the various domestic and productive uses of water;
- **Plant resources**, especially nutritional, and multipurpose plants of promising economic value for human and social development (including biotechnology work on various plant species; development of potential new medications; and agro-forestry schemes);
- **Animal resources**, including conservation and development of wildlife and fisheries resources and the genetic manipulation of species that serve as food;
- **Mineral resources**, including geological surveys, mining engineering, especially the improvement of small-scale mining and mineral processing, and mineral resource policy; and
- **Energy**, including the promotion and support of research and development work in the various African nations on the different energy sources, technologies, and energy conservation, especially fuelwood and efficient afforestation programmes, and the development of integrated hydroelectric projects, as well as other renewable and non-renewable energy resources schemes.

The work in these priority areas will take into account the ecological and environmental as well as the socio-economic aspects of the use and management of natural resources. The Institute will also offer its services in the formulation of African positions on the use and management of the continent's natural resource endowment. To illustrate this point, I would like to cite as an example, an area of special concern to IUBS and that is the exploitation from forests and arid zones of plants with known medicinal value by major pharmaceutical companies in the developed and developing countries. At present, these multinational drug companies purchase large quantities of raw plant materials from individuals and small local companies at ridiculously low prices. In fact, most of the local suppliers are not even aware of the market value of what they sell. The plants collected are sent to laboratories in developed and developing countries for screening, analysis, and the subsequent preparation of drugs. These finished preparations are in turn sold at exorbitant prices to the primary raw material-producing countries — the developing nations...

INRA will make information available on most of the sought-after plants by the major drug companies so that collectors and suppliers in the developing countries will have a better idea of
the economic value of what they sell. In addition, INRA will demonstrate the feasibility of African countries to develop their own drug-manufacturing industries through full-scale screening and utilization of medicinal plants, and the establishment of new drug patent laws to help protect their investments. The IUBS Medicinal Plants Working Group meeting held in Brussels, 6 September 1983, discussed many of the points which INRA intends to address (see Biology International No.8, December 1983).

Ideally, the proposed INRA should be concerned with the whole range of natural resources in Africa. However, in order to make a practical and sustained impact, a selective approach will be pursued, combining the desirable with the feasible through incremental programmes, and from time to time, shifting the emphasis within the various natural resource sectors in order to meet the needs and interests of various institutions and countries. The work of the Institute will, of course, respect the sensitive aspects of certain natural resources within countries.

PROGRAMME OF WORK

The institute's programme of work will include four major areas:
- Research and development work, the substantive basis for the other programme activities;
- Systems analysis and modelling;
- Post-graduate training; and
- Dissemination of knowledge, and scientific and technological information services.

Research and Development Work

The R & D work is the substantive basis for the other programme activities and should be concerned with the whole range of programme priority areas that have been identified for the Institute. The R & D work is particularly important for the strengthening of indigenous scientific and technological capacities on the continent.

Systems Analysis and Modelling

The function of the systems analysis and modelling work of the Institute is: (1) to underpin the R & D and other work programmes of INRA, and (2) to bring into Africa this area of work as a powerful tool in itself. It is anticipated that systems analysis and modelling can make a significant contribution to the understanding and the efficient utilization of the natural resource endowment at the national, regional, and the continental level. International consideration of systems analysis is essential because the uneven distribution of resources in the world calls for the cooperation and responsible use and management of natural resources by all nations. Systems analysis and modelling therefore can offer African nations the advantage of generating and organizing crucially needed data to enable them to enter into negotiations at the international level with substantial backup knowledge.

Post-Graduate Training

Academic and governmental officials in Africa have emphasized from time to time the critical need for training in technical areas in a number of crucial fields in national institutions. INRA will strive to cooperate with universities and other research and training institutions to design and implement post-graduate training courses:
- to help the various African countries to increase their research and development capacities in natural resources and develop composite skills for practical application; and
- to share the knowledge and experience gained from the work of the Institute and its network of co-operating institutions in Africa and elsewhere.

Some training courses will be offered at INRA, while others will take place at universities and other appropriate institutions on the continent. As the various training courses under the auspices of the Institute progress, efforts will be made to help stimulate and strengthen the undergraduate programmes at universities and other technical institutions. It is believed that well-trained African scientists and technologists are needed urgently so that they will be more effective when interacting with their counterparts within Africa and especially with outside aid and assistance groups and agencies. Periodically, the training programmes will shift emphasis within the various principal natural resources sectors so that the different needs and interests of the African countries can be met accordingly.

Dissemination of Knowledge and Information Services

A great need exists in Africa for effective exchange of knowledge on natural resources among scientists, technologists, government leaders, national policy — and decision-makers, and staffs of subregional and regional institutions and organizations. Most African countries lack effective information and dissemination services because of the absence of the needed technological infrastructure that can facilitate effective integration of up-to-date communication including satellites and data processing systems.

INRA will initially undertake three major interrelated tasks:
- to pool existing data and knowledge on
natural resources from various parts of the world, and to organize them in useable packages;

• to identify the categories and requirements of the various users in Africa on scientific and technological data on natural resources; and

• to establish the most effective and appropriate information and dissemination systems, both to facilitate INRA’s own work and to enable it to function as a clearing house and principal source of data and other knowledge on natural resources in Africa.

The international scientific and technological community uses established procedures for exchanging data and other knowledge through publications, meetings, personal contacts, libraries, information data analysis centres, and formal and informal network arrangements. INRA will help African scientists and technologists to become active participants in these exchanges. In addition INRA and the collaborating institutions will organize workshops and consultative meetings with policy — and decision-makers on various aspects of informatics.

SUMMARY

In summary, the proposed Institute, to be established under the aegis of the United Nations University, will endeavour to achieve the following objectives:

• to help African countries to appreciate better the necessity for the mobilization of their natural-resource endowment for the benefit of their people;

• to concentrate on the development of natural resources through the generation and application of scientific knowledge and innovative technological approaches and through the promotion of planning and policy formulation for productive work;

• to ensure that the work of the Institute include the socio-economic aspects of natural resources in the context of self-reliant development;

• to work closely with national and regional institutions engaged in research and development, advanced training, and the dissemination of knowledge and information in the field of natural resources; and

• to contribute especially to the strengthening of national institutions by helping to build indigenous research and development as well as consultancy capacities in accordance with their respective natural resource endowments.

IUBS looks forward to collaborating actively with INRA in the areas of biological and natural resources that fall under its mandate.

LITERATURE ON SOIL FAUNA OF AFRICA NEEDED!

With the recent developments of new computer methods for ordination of data related to population densities of species to sites in which these species live, such as Correspondence Analysis (or Reciprocal Averaging), and the even more recent Detrended Corr. An., and classification methods such as Hierarchic Ascending Classification, it has become possible to enter long arrays of population densities of various levels of taxa, present in apparently similar ecosystems, and produce plots of differentiated taxa super-imposed upon sites, so that each site has around it a cluster of taxa, more or less characteristic for it, with the necessary biological common sense of course. This helps to identify the taxa characteristic for an ecosystem, and ecological zone, or even sites within the same system or zone. It could also help to surmise on the possibility of transferring from one system, zone, or site, to another, on its feasibility, as well as on its usefulness.

These ordination and classification methods have been successfully applied on a regional scale on 45 sites in the Mariut region, on the Mediterranean coast of Egypt. Now the need is felt to extend this experience to a continental scale for the African continent, with its large ecological zones spanning the Mediterranean, the Sahara, the savannah, the tropical and equatorial forests, the miombo, the veld, and the Cape region. Since our main interest is soil fauna, especially invertebrates, which were the material for the Mariut studies, soil fauna will be tackled in this extended study for Africa. We therefore appeal to all readers to send in whatever papers they have or information about relevant literature relating to population density data of soil fauna in Africa, to the writer. Information about the sites is essential, especially location, ecological characteristics, vegetation, human pressures, land-use, etc. Information on soil characteristics is also welcome, but the most important type of data for this project, understandably, is on population density of soil fauna. The project is entitled: « Characterization of Soil Fauna in Africa ».

Please write to: Professor Samir I. Ghabbour.
Soil Biology,
Dept. of Natural Resources.
Inst. of African Research and Studies,
Cairo University,
12613-Giza (Cairo), EGYPT.
The ICSEB Congress is a major international forum for Biological Science — the previous meetings attracted 1800 participants (Boulder, 1973) and 900 participants (Vancouver, 1980).

These Symposia are uniquely attractive to biologists because their aim is wider than that of the usual specialist meetings. They aim to integrate the diverse areas that lie within systematic and evolutionary biology. They provide an opportunity for pollination biologist to talk to palynologist, for palaeontologist to listen to reproduction biologist, for geneticist and cladist to exchange views. The ICSEB Congresses are therefore complementary to other meetings. Mycologists will still go to their Mycological Congress, and entomologists to their Entomology Conference. But ICSEB provides them with a unique opportunity to meet one another, and also to meet other biologists who work in adjoining areas, to discuss common problems and techniques and to inform one another.

At present, the Steering Committee has identified a number of broad, topical themes for Congress Symposia, for which convenors are now approaching speakers. These are: - The Biota of the Malay Archipelago; The Conservation of Tropical Ecosystems; The Measurement of Rates of Evolution; Symbiosis in Evolution; Co-evolution in Ecosystems and the Red Queen Hypothesis; Evolutionary Physiological Ecology; The Evolution of new Biochemical activities in Microbial Communities; Genome Biology and Evolution; Co-evolution and Systematics; Angiosperm Evolution and the Biological Consequences; the Reconciliation of Molecular and Classical Phylogenies; Random and Directed Events in Evolution; Developmental Constraints on Evolution; Marine Meiofauna.

It is also proposed to hold a number of Special Interest Symposia, which may be narrower in concept but which will still bring together participants from separate but related fields. Some topics have already been suggested, such as Behaviour and the Fossil Record; the Evolution of Predator-Prey Relationships; Coloniality; The Co-evolution of Fungi with Plants and Animals; Late Palaeozoic Continental Biota; Homology; Ontogeny Theory; Biochemical Evolution in Plants; The Evolution of Chemical Signalling; The Evolution, Taxonomy and Nomenclature of Protists; Island Ecology in the North Atlantic; Bryophyte Phylogeny; The Origin of Higher Plants.

The Congress will also provide sessions for other contributed papers, and poster sessions.

The organizers would like to hear from anyone who has a suggestion for a symposium title and who would be prepared to act as convenor to arrange the speakers for that topic. They would particularly welcome participants from the Continent in this first European ICSEB, and also from developing or "third world" countries.

Anyone who is interested in giving a paper in one of the above Symposia, in organizing a symposium, or in attending the ICSEB meeting, should write to:
Professor Barry Cox,
c/o ICSEB Congress Office,
130 Queen's Road,
Brighton, East Sussex BN1 3WE,
U.K.
RESPONSES OF SAVANNAS TO STRESS

Under the auspices of the IUBS « Decade of the Tropics », a programme of international collaborative research in savanna ecology has been launched. Its objective is to develop a predictive understanding of the structural and functional ways in which savannas respond to natural and man-made stresses. This understanding should form a basis for improved management aimed at increased productivity and the reversal of the widespread degradation of savanna lands.

The success of such a programme greatly depends on the setting up of a worldwide network of interested and active scientists. A proposal document summarizing the aims and of the *modus operandi* programme will be forwarded to the largest possible number of savanna ecologists. Answers will enable to prepare a final document to be published in a special issue of *Biology International*.

Copies of the proposal document may be obtained from the IUBS Secretariat, or from Dr J.-C. Menaut, Laboratoire d’Ecologie, Ecole Normale Supérieure, 46, rue d’Ulm, 75230 Paris Cedex 05, France.

The Ecology of Neotropical Savannas*

by Guillermo Sarmiento (Transl. Otto Solbrig)

Much of the world’s population — especially that in developing countries — lives and earns its livelihood on savannas of tropical areas. Nevertheless, these interesting and often unusual ecosystems have not been adequately studied as have the wet, tropical forests.

This volume, by a world-recognized authority who has spent a quarter of a century in the investigation of savannas in South America, brings together in a magnificently organized way what is known of savannas. The contents are divided into seven sections: 1) The problem of Tropical Savannas; 2) Architecture of the Savanna; 3) Seasonal Rhythms of Savanna Species; 4) Productive Process; 5) Water Economy; 6) Nutrient Economy; 7) Synthesis and Conclusions. A comprehensive bibliography of 222 items is offered.

Professor Solbrig has put into easily readable English the original Spanish of *Estructura Y Funcionamiento de Sabanas Neotropicales*. The author, with great humility, insists that he considers his book «a still provisional summary of many years of research in the Venezuelan savannas). But there is indeed nothing to take its place, and therein lies its unique value to botanists, ecologists and even to governmental organizations.

Richard Schultes

The 1984 Executive Committee Meeting will take place on October 19-20, 1984, at the Union’s Secretariat in Paris, to conduct the affairs of the Union in accordance with Article 8b of the Statutes.

In order to inform the Executive Committee of the recent work of the Union, the Secretaries of all Sections and Commissions are respectfully requested to prepare a brief summary of their activities of the year 1983-84, and to forward this report to the IUBS Secretariat no later than September 1, 1984. The report summaries will also serve in the preparation of the annual report of the Secretary General to the Executive.

At the Executive Committee Meeting, subvention requests shall be examined for 1985. It is to be recalled that all subventions should be formally requested, whether for congresses or symposia, on special forms available from the Secretariat. All requests should be returned to the Secretariat as soon as possible, and no later than August 1, 1984. Any requests received after this deadline cannot be taken into consideration.

Attention is also drawn to the priority given by IUBS to subvention requests for interdisciplinary projects and programmes of value to developing countries.

In conjunction, subventions to international biological science congresses will be allocated as loans and not as grants.

Under the provision of Articles 8 and 9 of the Union’s By-laws, National Committees and Scientific Member bodies may send a representative as an observer, at their own expense. These representatives shall have no voting rights, but are welcomed to participate in discussions.

Provisional Agenda

1. Opening
2. Adoption of the Agenda
3. Report of the Secretary General
4. Report of the Treasurer
5. IUBS Scientific Programme
6. IUBS publications
7. Cooperation with inter-governmental organizations (UNESCO, FAO, WHO, CEC, etc.)
8. Cooperation with ICSU and ICSU family
9. IUBS XXIInd General Assembly, Budapest Hungary, 1985
10. IUBS finances
11. Other matters
Financial Statement of IUBS for the Year 1983

**Statement 1.** Balance sheet at December 31, 1983 (in US Dollars)

**ASSETS**

<table>
<thead>
<tr>
<th>Cash and Banks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Petty Cash</td>
<td>16</td>
</tr>
<tr>
<td>The Chase Manhattan Bank:</td>
<td></td>
</tr>
<tr>
<td>Frankfurt/Main, in US $</td>
<td>149,611</td>
</tr>
<tr>
<td>Paris, in US $</td>
<td>39,117</td>
</tr>
<tr>
<td>Paris, in FF</td>
<td>3,013</td>
</tr>
<tr>
<td>Paris, in US $</td>
<td>100,000</td>
</tr>
<tr>
<td>Amro Bank Utrecht, in Dutch Guilders</td>
<td>1</td>
</tr>
</tbody>
</table>

**Other Assets**

| Other receivables | 1,073 |
| Loans            | 1,073 |

**Less: Liabilities**

| Sundry creditors | 7,507 |

**Excess of Assets Over Liabilities**

| Represented by |  |
| Accumulated Fund | 285,224 |

**Statement 2.** Income and expenditure accounts for the year ended December 31, 1983 (in US Dollars)

1. **Income**

| ICSU/UNESCO basic allocation | 13,539 |
| ICSU subvention               | 16,000 |
| UNESCO grants for scientific meetings | 52,400 |
| Contributions from National Members | 148,419 |
| Interest and dividends        | 13,350 |
| Gain on exchange              | 220 |
| Other income                  | 11,501 |

**Total Income**

| 255,429 |

2. **Expenditure**

A. **Meetings**

| General assembly and executive committee meeting | 16,445 |
| Officer's meeting                                 | 5,260 |

| 21,705 |

B. **Publications**

| 9,722 |

C. **Scientific activities**

| Grants to IUBS Scientific programmes | 46,853 |
| Representation at scientific meetings | 1,437 |
| Subventions to scientific meetings | 17,161 |
| Contribution to other scientific organisations | 4,732 |

| 70,183 |

D. **Administrative expenses**

| Offices of the President and Secretary - General Treasurer | 3,000 |
| Salaries                                                  | 37,512 |
| Related charges                                           | 22,952 |
| General office expenses                                   | 23,571 |

| 87,035 |

E. **Other**

| Bank charges | 593 |
| Audit fees   | 1,916 |

| 2,509 |

**Total Expenditure**

| 191,154 |

**Excess of income over expenditure**

| 64,275 |

**Accumulated balance brought forward**

| 220,949 |

**Accumulated balance carried forward**

| 285,224 |
COASTAL LAGOONS
Edited by P. Lasserre & H. Postma.
Published by Gauthier Villars, 1982 (461 pp.).
This is a special volume of Oceanographica Acta (supplement to volume V,4), representing the proceedings of the International Symposium on Coastal Lagoons held on 8-14 september, 1981, in Bordeaux, France, and organized by UNESCO in collaboration with SCOR, IABO, and the University of Bordeaux. It includes 53 scientific papers dealing with the origin of evolution and geochemistry of coastal lagoons, as well as life and management of lagoon ecosystems.

MONITORING OF AIR POLLUTANTS BY PLANTS: METHODS AND PROBLEMS
Edited by L. Steubing & H.J. Jäger.
Dr. W. Junk, Publishers, the Hague, 1982. (161 pp.).
The proceedings of the international workshop held on 24-25 september, 1981, in Osnabrück (FRG). This volume focuses on the use of bio-indicators, particularly plants, to detect and quantify the impact of air pollutants on ecosystems. It includes 23 papers concerned with the principles and problems of bio-indication through vegetation and the establishment of comparable methods of monitoring the state of the environment by plants.

CASUARINAS: NITROGEN-FIXING TREES FOR ADVERSE SITES
This book is one of a series «Innovations in Tropical Reforestation», prepared by the Advisory Committee on Technology Innovations (ACTI), of the US National Research Council. It highlights 18 species of casuarina that could have exceptional potential in reforesting difficult terrain in many parts of the world. The study was done in cooperation with the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia.

SWIDDEN CULTIVATION IN ASIA
Published by the UNESCO Regional Office for Education in Asia and the Pacific, 1983 (Vol. 1, 330 pp. - Vol. 2, 309 pp.).
These two volumes on «Swidden Cultivation in Asia» are based on a comparative study carried out in 5 countries of the Asian region - India, Indonesia, Malaysia, the Philippines, and Thailand - under the auspices of the UNESCO Man and Biosphere (MAB) Programme, in collaboration with UNEP. The first volume represents a content analysis of the existing literature, and the second provides a macro-view in terms of national profiles of the practice of swidden cultivation.

INFLUENCE OF PESTICIDES ON THE BENEFICIAL FAUNA IN FRUIT TREES
West Palaearctic Regional Section Bulletin of the IUBS Section for Biological Control, 1984 (67 pp.).
Containing 14 papers, this book deals with the impact of pesticides on beneficial arthropods, particularly treatment, sampling, evaluation, and the development of field test methods.

ATTRACTANTS AND PHEROMONES OF NOXIOUS INSECTS
Selected references compiled by A.K. Minks. West Palaearctic Regional Section Bulletin of the IUBS Section for Biological Control, 1984 (176 pp.).
This volume contains a list of pheromones/attractants arranged on alphabetic order of the Latin insect names of the insect species present in Europe, the Mediterranean area, and a large section of Africa.

SMALL SCALE VEGETATION MAPPING
Edited by P. Ozenda, P. Legris, & J.F. Dobremez.
Published in Documents de Cartographie Ecologique, Université Scientifique et Médicale de Grenoble, 1981 (134 pp.).
Concerning the proceedings of the international symposium organized by the IUBS Commission on Small Scale Vegetation Mapping, 24-27 september, 1980, Grenoble, France, this volume contains 26 papers, dealing with the present situation and future perspectives of small scale vegetation mapping contents and topics, the use of remote sensing methods, and applications to management and development.