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NITROGEN CYCLING IN A SOIL-TREE SYSTEM
IN A SAHELIAN SAVANNA. EXAMPLE OF ACACIA SENEGAL

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I. Introduction

The need for tree conservation in the Sahel, and the role of trees in the sahelian ecosystem equilibrium has been emphasized during the last years. One aspect of the role of trees is their impact on soil nutrients and on nutrient cycling (GRIMMIS et al, 1970, JUNG, 1969).

In the present work we try to study the nitrogen cycle in a soil-tree system in a sahelian savanna of north Senegal. Acacia Senegal was chosen because it is present in a great part of the Sahelian zone and is well represented in the study area. Beside it has some specific characters as a legume and it is used

The study area was described by HILLIS et al (1972). The mean annual precipitation is 300 mm per year falling during a three month wet season. The relief is a succession of dunes and depressions. The trees are scattered on the

These equations were used to calculate the biomass of the tree studied for soil N. Samples of wood and leaves were analyzed for N content. (N content of root is assumed to be the same than that of wood). Branches and trunk had the same N content of about 0,43 % (standard error of 0,09 for 13 samples). N content of trunk was 0,32 %, N content of leaves was 3,0 % (standard error of 0,25 for 12 samples).

2 - Accumulation of nitrogen in the herbaceous standing crop

The biomass of herbs under the trees was measured in 1976 and 1977 at the end of the wet season, in October, and N content was determined. Because of the low precipitation in 1977 (120 mm) the biomass of herbs was weak, but the N content was higher. Nevertheless the accumulation of N was lower than in 1976.

The following values, of 1976, are assumed to represent a "mean" year. The biomass of aerial parts under Acacia was 0,42 kg/m² (standard error of 0,1 for 8 samples) with a mean N content of 1,07 % (standard error 0,3). The biomass of roots was 0,26 kg/m² (standard error of 0,03) with a N content of 1,66 % determined on a composite sample.

The total N immobilized is 6,7 g/m² under the trees in the open it was 4,7 g/m².

In 1977, with low rainfall, the aerial biomass of herbs under Acacia was only 0,23 kg/m² with 1,33 % N. The root biomass was not measured, but we can estimate the total accumulation of N about 6 g/m².

III. Return of nitrogen to the soil (table 2)

Nitrogen is returned to the soil by tree litter, leaching of leaves and branches by throughfall, herbaceous litter, roots.

Acacia leaves are turning yellow before they fall. Yellow leaves taken off from the trees or freshly fallen on the soil have been analyzed. They showed a N content of 2 %, that is two third of green leaves content. One third of leaf nitrogen is withdrawn to the trees before leaf fall. The N content of yellow leaves was used with the leaf biomass to calculate the annual return to the soil by litter. Annual return by tree roots was not measured.

Troughfall was studied during two years to estimate the amount of nitrogen leached from the tree crown. The N content of rain under the tree and in the open was determined. During the wet season of 1970, for 4200 mm of rain, 2.2 g of N/m² was brought ^{to the} soil, from which 1.8 g/m² was washed on the tree crown, and 0.4 g/m² was supposed to be brought from the atmosphere. Stem flow was measured during some times but the amount of N returned to the soil by this way was small.

In the studied area all the herbaceous species are annual, so it can be assumed that all the nitrogen accumulated in the herbaceous standing crop is

1. The nitrogen content of herbaceous biomass and its

During the wet season mineral N was produced mainly in the form of $\text{NO}_3\text{-N}$. The two years of measurement had different rainfall (330 mm in 1976, 120 mm in 1977). Nevertheless the amount of mineral N produced is the same, as there was enough rainfall to achieve the mineralization of the mineralizable N present in the soil.

The results of the table 4 show a great variability, and the relation between N mineralized and the age of the tree (tree girth) is weak. The mean value is $3,7 \text{ g N/m}^2$ (30 g/tree) for *Acacia* on the dune, and $0,2 \text{ g/m}^2$ (142 g/tree) for trees at the foot of the slopes.

Some measurements were done during the dry season and showed a very low production of $\text{NH}_4\text{-N}$ which is probably due to chemical-physical factors (DOLIBERGUE et al. 1971). The amount of $\text{NH}_4\text{-N}$ produced ranges from $0,5$ to 1 g/m^2 for the whole dry season. Some occasional showers occur during the dry month which may bring about a production of mineral N, if the soil is moistened thus in 1976, there was a mineralization of 5 g N/m^2 for the whole dry season with two showers.

V. Possible inputs and outputs

Inputs and outputs have not been measured but some observations were made on this subject.

Inputs are mainly due to rainfall and to fixation of atmospheric nitrogen by microorganisms. Nitrogen concentration in rain was low and its contribution to inputs was about $0,4 \text{ g N/m}^2/\text{year}$, as previously noted.

Symbiotic fixation could occur in a leguminous tree as *Acacia corniculata*. Seedlings grown in the laboratory as well as seedlings found in the field showed numerous nodules. However the search for nodules on adult tree roots was negative, except in one tree for ten trees sampled. It is possible that symbiotic fixation occurs during the first years of the tree life, but rarely in adult trees. In the laboratory it was observed that nodulation was inhibited when seedlings were grown in soil taken off under an old *Acacia*, but not in soil taken off in the open. In the latest soil, addition of nitrate inhibited nodulation. The active nitrate production in soil under the tree during the wet season could be partly responsible for the absence of nodules in adult trees, but very few is known on this subject.

The dryness is perhaps another factor. Good nodulation was reported by ORCHARD et al. (1956) in Acacia collinsii forests in a wetter zone, and they observed that nodulation decreased with increasing soil N. NOES et al. (1967) found a poor nodulation in an Acacia harveyana forest during a dry year, but they observed a substantial nodulation in wetter years.

Non-symbiotic fixation in soil was not investigated.

Outputs by denitrification seems to be possible, at least in the lower part of slope and in depressions where the soil can be temporarily water-logged. Losses of mineral nitrogen was observed once during the wet season of 1976, after a heavy rainfall (BARNARD-REVERSAT, 1977).

Losses of nitrogen out of the ecosystem must not be important as water flow in the soil does not go deeper than 3 m, which is the depth of tree^{roots} according to A. COCHET who studies the water balance in this ecosystem. Nevertheless it can happen that NO_3 or soluble organic nitrogen is leached beneath the bulk of the herbaceous roots after a heavy rainfall, particularly during a year as 1977 where the herbaceous standing crop was low and the amount of mineral N in it was smaller than the amount produced by mineralization. This could be the explanation for the NO_3 distribution observed in a profile established after the 1977 wet season under Acacia, and shown at figure 3.

VI. Conclusions

Taking the mean for adult Acacia situated in the lower part of slopes, the annual flow of nitrogen was about 12 g/m^2 , which is a relatively high value, comparable to some forest ecosystems. It can be supposed that an Acacia forest issued from plantation should have an active N cycle. An important part of nitrogen flow passes through the herbaceous stratum, and is then available to cattle.

Compared to the nitrogen cycle out side the cover of trees, nitrogen flow is 2,5 to 3 times greater under the tree, as shown in table 5. The turn-over of soil N is 10 %/year in the open, and 14 % under the tree. The higher N accumulation in herbs under the tree is not only due to a higher biomass, but also to a higher N content.

If the year 1976, with mean rainfall, is compared to a year with low precipitations as 1977, it appears that only N flow from vegetation to soil is lowered :

	1976	1977
return by tree leaves	0,8	0,8
return by throughfall	1,8	0,6
return by herbaceous litter	8,7	6,0
total	<u>11,3</u>	<u>6,3</u>

The production of mineral N in soil was about the same for the two years, as the soil was humid for a sufficient number of days to achieve the mineralization of the mineralizable N. Only if this number is not reached should the mineral N production be decreased. However a succession of several dry years with low herbaceous growth should result in a decrease of mineralizable N.

In conclusion, rainfall is the main environmental factor influencing the nitrogen ^{cycle} ~~flow~~ in the system studied :

- by limiting vegetation growth and then nitrogen utilization and return,
- by controlling mineral N production in the soil, more or less strongly according to the amount of precipitation,
- eventually by causing denitrification or leaching of mineral N in the soil.

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Table 4

Mineral N produced in the soil from June to October

tree n°	1	2	3	4*	5	6	7	8	9*	10*	11*	12	open D	LS
N g/m ²	3.6	3.8	4.2	8.4	6.2	5.5	14.9	3.1	8.4	7.0	6.3	9.0	2.2	4.5
N g/tree	41	22	19	48	153	183	152	39	139	86	83	290	-	-

* measured in 1976, others in 1978

Table 5

Main flows and stocks of N under Acacia and in the open for a year with mean rainfall. (means for the lower part of slopes)

		Acacia	open
N immobilization in vegetation	g/m ²	32.6	4.7
N return to the soil	g/m ² /yr	11.3	4.7
total N in soil	g/m ²	86	46
N mineralized	g/m ² /yr	11.5	4.9

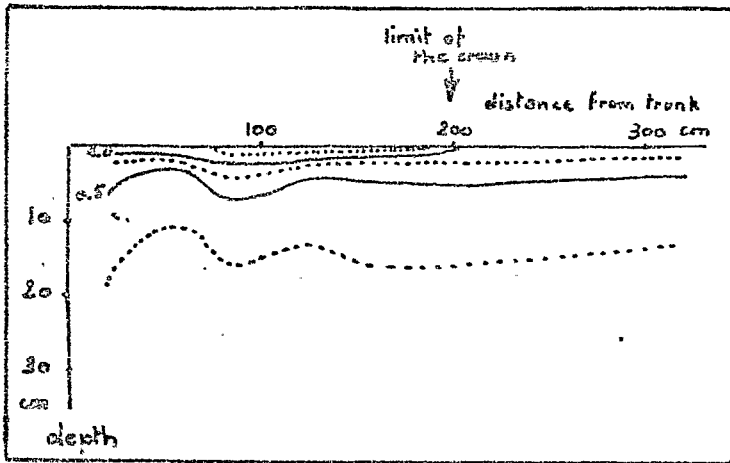


Fig. 1. Curves of equirepartition of total N under an Acacia (N ‰)

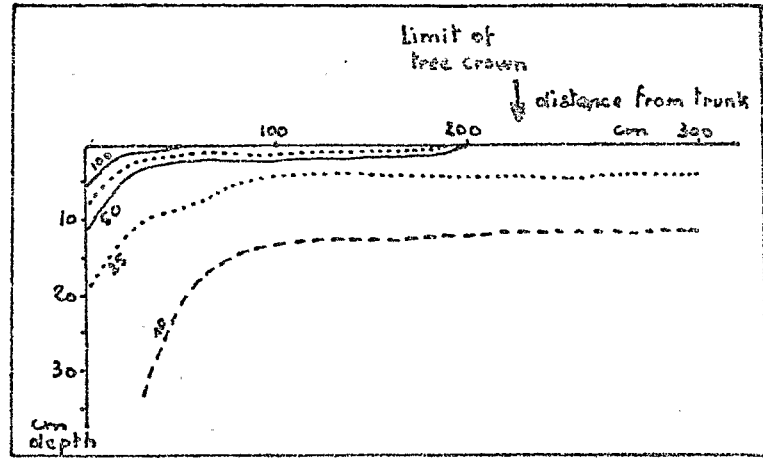


Fig. 2. Curves of equirepartition of mineralizable N under an Acacia (NO₃-N ‰ of soil / 3 weeks)

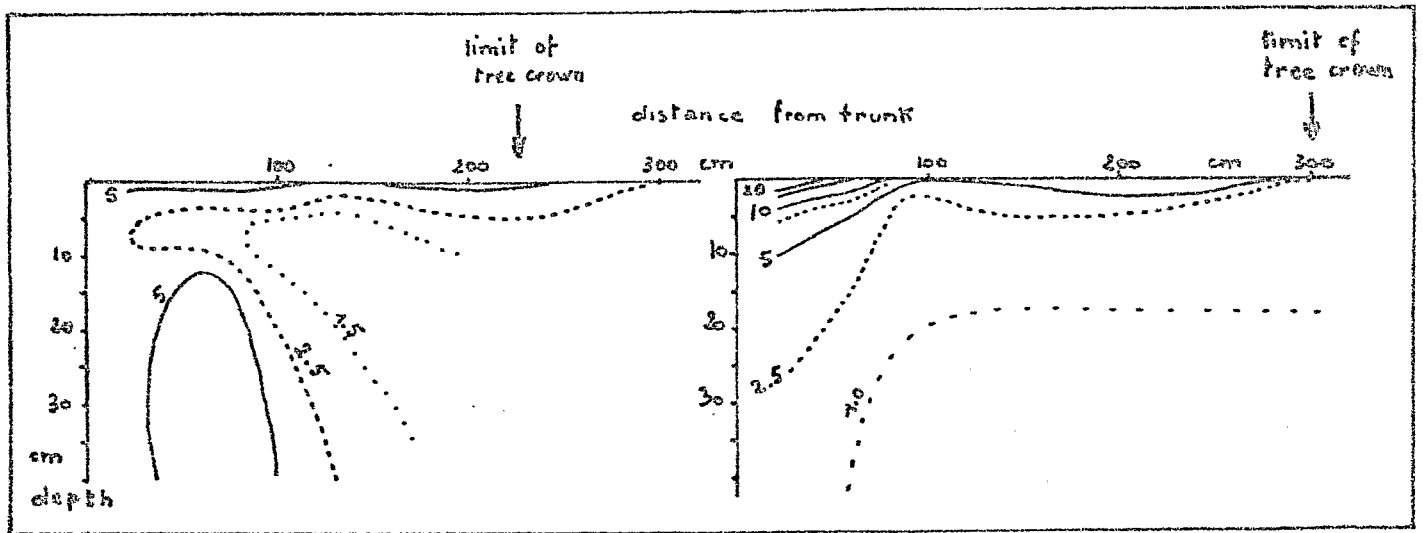


Fig. 3. Curves of equirepartition of NO₃-N under two Acacia A: after the wet season of 1977, B: after a mean wet season, 1975. (NO₃-N ‰ of soil)