CHROMOLAENA ODORATA AND DISTURBANCE OF NATURAL SUCCESSION AFTER SHIFTING CULTIVATION: AN EXAMPLE FROM MAYOMBE, CONGO, CENTRAL AFRICA

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ABSTRACT

In Mayombe rain forest, shifting cultivation is the only cultivation system used by local people in order to produce cassava, their staple food. Fields are let to natural fallow after about two years, when all tubers have been harvested. Until now, abandoned fields were rapidly overgrown with fast growing trees like *Musanga cecropioides*, which within a few years made up the infrastructure of a real forest, 15 to 20 meter high. This pioneer forest constituted the first phase of a succession leading to the rebuilding of the rain forest. But in fact, such a succession could not occur, as fallow vegetation is usually cut by peasants after 5 to 15 years and enters a new phase of cultivation. *Chromolaena odorata*, for which local names account for its recent arrival and its striking invading power, is disturbing at an increasing rate this alternate cycle of cultivation and tree fallow: in abandoned fields after slash and burn of pioneer forest, regrowth is now made up almost exclusively of dense thickets of *C. odorata*. Preventing the intrusion of pioneer tree species, these thickets stop the natural succession for many years and are thus becoming the main vegetation type near villages. This new expanding feature of a traditional cultivation system is usually considered by local people as a threat; nevertheless, based upon various field observations, suggestions are made here about the potential positive effects of *C. odorata* fallows in shifting cultivation systems.

INTRODUCTION

The neotropical shrub *Chromolaena odorata*(L) R.M. King and H. Robinson is perceived by agriculturists in two contradictory ways: for most of them, it is one of the worst weeds in the world, while for a few others it is a plant with promising agronomic properties.

As in many countries of humid tropical Asia and Africa, *C. odorata* can now be found in large quantities in the Congolese Mayombe. Its expansion may be compared to a true invasion, and in some areas *C. odorata* thickets already make up the larger part of the rural landscape.

The present paper is an attempt to answer the following main questions posed by this very quick and intense spread regarding the processes involved in *C. odorata* invasion and its impact on natural and cultivated vegetation:

Which vegetation types are replaced by *C. odorata*, how are they replaced, and at what speed ?

What could be the future extension of *C. odorata* in Mayombe ?

What are the present and potential effects of this invasion on cultivation, and what are the agronomic potentialities of invaded areas ?

THE MAYOMBE MASSIF: SITUATION

The Mayombe is a low altitude hill range, lying parallel to the Atlantic coast from Gabon at the N.W. to Zaire at the S.E (figures 1 & 2). The highest ridges are situated in Congo, and reach 900m. Owing to its vigorous Appalachian relief, and despite its low altitude, the Mayombe massif forms a real obstacle between coastal and inland savannah plains. In the Congolese Mayombe, one may distinguish a western part formed by a set of hills and ridges gently sloping down to the coastal plain, and an eastern part with a regular succession of high sandstone-quartzite ridges intersected by schist valleys, which finally dips steeply to the large Niari and Nyanga valleys (Schwartz, et al. 1991).

The rainfall increases from the west (1200 mm/year) towards the highest ridges (1980 mm/year), then decreases to low levels again (1200 mm/year) at the edge of the Niari plain. Rainfall is distributed over 8 months, from October to May, but mist and drizzle are very abundant during the so-called dry season, allowing the preservation of a certain soil humidity. The amount of sunshine is very low, especially during the dry season, totalling less than 1000 hours/year (Clairac, et al. 1989). Given the low rainfall cited above, these features of the dry season in south Congo are very important, as they allow the presence of rain forest, as well as its tendency to colonize savannahs (de Foresta 1990).

Soils are mainly "ferrisols" (Duchaufour 1983): soils subjected to ferrallitic alteration, but in which still remain, owing to their relatively young age, unaltered primary minerals such as illites or micas (Gras 1970, Jamet 1975 - 1978; Lanfranchi & Schwartz, in press). These soils generally possess good physical characteristics but are chemically poor, highly desaturated and strongly acid, with a very low surface pH between 3.5 to 4.5 (Misset 1989). In about 80-90 % of the soil cover in Mayombe, these soils contain a 5 cm to 2 m depth horizon showing a considerable enrichment in residual rough elements, which can be a real obstacle for agriculture when situated at low depth. This stone-line, generally located between the B horizon and the alteration horizon, can be found at extremely varying depth, from 0 to 6 m, but usually between 0.5 and 2 m.

vegetation is markedly dominated by evergreen rain forest, with a lesser tendency towards semi deciduous rain forest (White 1983). To the west, one passes from the Mayombe rain forest to the coastal savannahs through a very progressive mosaic; to the East, the transition towards the Niari savannahs is very sharp and occurs within a few kilometers (figure 3). Nevertheless, the forest cover is sprinkled with numerous included savannahs, whose distribution, origin and dynamics are beginning to be better understood (de Foresta 1990, Schwartz et al. 1990, Schwartz et al. 1991). The Mayombe forest is at present highly degraded by agriculture around villages, and also in other parts, owing to an already long period of logging (Gibert & Sénéchal 1989). However, despite a long history of human occupation and migration, traces of which are sometimes encountered, undisturbed or almost undisturbed forest still occupies large areas (Cusset 1989).

The Congolese part of Mayombe was very poorly populated until the construction of the railway "Congo-Ocean"; after its opening to traffic in 1934, the population increased continuously, reaching about 30, 000 inhabitants in 1987, still a mean density of only 4 inhabitants/km2. This population is irregularly distributed, with half living in a small number of "village-gares" along the railway lines in the central district of Mvouti. This district, in which density still reaches only 5.8 inh/km2, has seen a threefold increase of its population during the last 50 years, and is at present the most populated rural area of the whole Congo. However, from a district area of 3,200 km2, only 900 km2 are actually used by man for plantations or shifting cultivation, 2,300 km2 of rain forest being left almost undisturbed (Boungou et al. 1989).

LES SARAS: THE ZONING OF VEGETATION AROUND A "VILLAGE-GARE"

After a comprehensive survey along the main traffic axis crossing the Mayombe massif, the "village-gare" Les Saras was chosen as a model for a study on the evolution of natural vegetation subjected to local agriculture, aiming at the assessment of both the impact of human activities on natural forest regeneration and the constraints imposed by natural vegetation upon the cultivation systems. Les Saras, located in the middle of the central Mvouti district, along both the Congo Ocean railway and the N1 road joining Brazzaville and Pointe-Noire (figure 3), is probably the most active rural area of Congo in terms of agricultural production (Mapangui & Sénéchal 1989).

Agriculture, which occupies about 75% of the working population, is devoted mainly to the cultivation of sweet banana (mainly the "Gros-Michel" variety) and cassava (tubers and leaves), which crops are conveyed by train to be sold in Pointe-Noire and Brazzaville markets (Kouba 1987). However, the larger part of cassava tuber production (by far the main staple food in Congo) is still locally used for household consumption.

Because of the lack of aerial photographs, the zoning of land use was studied along six transects following roads, railway, and small tracks; the village itself is characterized by an abundance of fruit trees, dominated by the "safoutier" (*Dacryodes edulis*), which are cultivated by almost every household in well developed home gardens. Next to the village, the landscape appears as a complex mixture of cultivated fields and natural fallows; the combination of two kinds of criteria, namely the proportion of each type of natural vegetation and the proportion of each type of agricultural plantation, allows the characterization of four main land use patterns, globally arranged in concentric rings from village fringes to undisturbed forest (figure 4):

A : a mosaic of very old, more or less abandoned banana plantations, oilpalm groves, *C. odorata* bushes, and a few cultivated fields make up the first vegetation belt. As in the second belt, fields are very small in area (about 400 to 600 m2), always devoted to an association of maize, groundnut and cassava, which is sometimes extended to other vegetables such as eggplant or spices such as chilli, and are abandoned to fallow after one year.

B :the second belt is mainly occupied by *C. odorata* thickets, again with some oilpalm groves as well as some cultivated fields; a few scattered primary forest trees (very hard timber trees belonging mainly to the family Irvingiaceae) recall that this area was once occupied by rain forest.

C : the third belt is characterized mainly by a mosaic of pioneer tree fallows at various stages of development and more or less well maintained banana plantations, with some small patches of "primary" forest as well as a few cultivated fields and *C. odorata* dominated bushes. Here, fields are larger than in A and B (about 1 ha.), almost exclusively devoted to cassava, and gradually abandoned to fallow after one to two years.

D : the fourth belt forms a progressive transition zone, with new cassava fields and banana plantations, progressing at the expense of the undisturbed forest.

Although the extension of each vegetation belt can vary from one village to another, the global distribution pattern of natural and cultivated vegetation around Les Saras may be considered as fully representative of the situation prevailing along the Congo-Ocean railway in the Mvouti district.

From this schematic description of the rural landscape around Les Saras, one may appreciate the important place already occupied by *C. odorata*, especially near the village (A and B belts). However, this description only gives an account of the present situation, and, with the history of rural landscape and agricultural practices as a reference, some information about the dynamic processes of vegetation evolution is needed to explain this present importance and to forecast its future.

THE HISTORICAL BACKGROUND OF *C. ODORATA* INVASION

The history of the Mayombe massif was greatly affected by the opening of the Congo-Ocean railway. The railway approximately follows the layout of an old forest track, the so-called "piste des caravanes", which previously joined the coastal and the interior populations. During the building works, from 1922 to 1934, the central Mayombe saw an intense and tragic activity: because of the fairly low number of local inhabitants, the colonial administration ordered "forced work" for local people and recruited about 40,000 people from Oubangui-Chari and Tchad (Nguembo and Sénéchal 1989). Sanitary conditions were very bad and, within 13 years, about 20 000 people died.

With the completion of the railway, most of the foreigners left but local people stayed in the newly built "village-gares", which became important immigration centers for populations from inside and outside Mayombe(Vennetier 1968).

The opening of this new communication axis led to a new era for forest exploitation and commercial cultivation. Large banana plantations owned by colonists appeared as early as 1936, and extended until 1961; with the independence of the country in 1958, banana cultivation for trade was resumed on old or new plantations by local people, and to the present this crop still represents their main source of income. From 1934 to 1956, as firewood was the main fuel for railway engines, large tracts of primary and secondary forest were cut along the railway (Gibert & Sénéchal 1989). Moreover, the railway opening allowed the expansion of selective timber exploitation, which became the major economic activity of central Mayombe until 1974 (Gibert and Sénéchal 1989), the most important present traces of which lie in the road network centered on some "village-gares".

Until the railway building, the villages were small and few; they were occupied for a certain number of years and then shifted to other places following events such as the death of an important member of the community or epidemic diseases; agriculture was exclusively devoted to shifting cultivation for household purposes, with small temporary fields (about 0.5 ha.) scattered inside the undisturbed forest and linked together and to the village by small paths running under the forest cover.

Since 1934, the railway and the associated N1 road, as well as the concession roads network, gradually provided a means of forest penetration, allowing local people to gradually colonize new areas for cultivation.

From an ecological point of view, two main transformations have been brought by the railway opening:

- local intensifications of human impact upon vegetation, with the introduction of permanent plantations and the expansion of cultivated fields - fields which are no longer separated by tracts of undisturbed forest but only by various stages of fallow vegetation;
- expansion of more or less wide strips supporting only a heavily disturbed and easily invaded vegetation, a direct consequence of the settling of roads and railway.

These transformations obviously paved the way for the invasion of *C. odorata*.

According to Cruttwell McFadyen (1988), *C. odorata* appeared for the first time in Central Africa around 1940, with Nigeria as the first affected country; it became a major weed there by the late 1960's, and since then has spread to Ghana, Ivory Coast and Cameroon.

Although information about its arrival in Congo is lacking, according to local people, *C. odorata*, which is called locally "matapa mbala" (the invader) or "Lantana Ngouabi" (a combination of the previously important colonizing plant and the name of a previous Congo president), arrived in Mayombe during the early 1970's after a rapid progression along the railway. From then on, it has been gaining more and more importance in the rural landscape, owing to its biological properties.

C. odorata is a fast growing heliophilous shrub, reaching sexual maturity after a few months. Probably owing to the constantly high relative humidity characterizing the Mayombe climate, *C. odorata* shrubs never wilt on the stalk, even during the dry season; branches supporting flowers and fruits die, but are quickly replaced by new ones.

In Mayombe, *C. odorata* flowers and fruits during the dry season, from July to mid-September, releasing each year an enormous number of small, wind dispersed seeds; although recently released seeds can germinate in heavy shade (Marks & Nwachuku 1986), the germination of soil embedded seeds requires the red/far red light ratio characteristic of open vegetation (Erasmus & van Staden 1986).

As it has already been reported by some authors, *C. odorata* seeds can make up an important proportion of the surface soil seed banks (Yadav & Tripathi 1982, Epp 1987). Around Les Saras[1], although absent from the large areas of undisturbed forest which surrounds the agricultural landscape, viable *C. odorata* seeds appear in the small remnants of undisturbed forest located in the "C" belt, as well as in old pioneer forest, although there they are still largely out numbered by pioneer tree seeds (Table I).

In the "parcelle Likibi", the history of which is described below, the thicket already shows the tremendous dominance of *C. odorata* within the soil seed bank, with more than 1000 seeds/m2 after only two years of fallow. This number still increases in the fallows that follow cultivation on *C. odorata* thickets located in the "B" belt, reaching about 2000 seeds/m2 two years after the abandonment of the field.

THE LINKS BETWEEN SHIFTING CULTIVATION AND *C. ODORATA*

A comparative survey of the vegetation associated with the two main agricultural systems shows that the invasion of *C. odorata* is closely linked to shifting cultivation, banana plantations showing only rare and minor signs of disturbance.

[1] Six plots with different vegetation types were tested. In each plot, 8 sites were selected at random and in each site, 6 elementary surface soil samples were taken using a 3.2cm radius and 8cm long cylinder, and mixed together. Samples taken in Les Saras on February 10, 1989, were brought to Pointe-Noire the same day. The next day they were placed on a 2cm layer of sterilized soil in germination trays. These 48 germination trays (6 plots, 8 samples per plot), placed under slight shade and a plastic cover to protect from rain were watered every day and checked bi-monthly for new seedlings for 6 months, i.e. until August 4, 1989. After each counting identified seedlings were removed and the others were mapped.

Bearing in mind the main biological features linked with the settling and growth of *C. odorata*, four main reasons, linked to local agricultural practices, may account for the relative preservation of banana plantations from *C. odorata* invasion.

According to local people, the best soils for banana cultivation are those supporting undisturbed forest; therefore new plantations are almost exclusively opened on primary or old secondary forest lands, areas located at the fringes of the cultivated zone, where *C. odorata* is still lacking, even in the soil seed bank.

Usually, some tall trees are preserved during the forest clearing, and banana trees are therefore planted extensively under light shade, in microclimatic conditions which are not favorable to the growth of *C. odorata*.

The cleared forest is not burnt, allowing, between the banana trees, a rapid recovery of a dense cover of pioneer trees, lianas, and forest herbs which hamper an early colonization by *C. odorata*.

Owing to periodic cleanings (usually once a year), fast growing species able to support repeated cutting are progressively favoured; the regrowth associated with banana trees evolves quickly and reaches its equilibrium as soon as the fifth year, staying unchanged or almost so until the abandonment of plantation (the oldest productive plantations are about 30 years old). This stable vegetation is dominated by large rhizomatous herbs belonging to the Marantaceae family (especially *Thaumatococcus daniellii*) and by ferns (mainly *Cyclosorus afer*); these plants grow vigorously after each cleaning, restoring within a few weeks a very dense cover, which protects plantations from any new settling of *C. odorata*.

In cassava cultivation, on the contrary, in every dry season almost every household opens a new field and abandons an old one, leaving every year large areas with almost bare soil susceptible to invasion by *C. odorata*; in addition, more and more pioneer forest and *C. odorata* thickets (with their high number of soil embedded *C. odorata* seeds), are now used for this temporary cultivation.

C. ODORATA AND THE DISTURBANCE OF NATURAL SUCCESSION

At present, the general trends of natural succession following slash and burn cultivation of fields opened on undisturbed forest still follow the classical scheme encountered everywhere in the humid tropics (Richards 1952, Hallé et al. 1978, among others).

The abandoned fields are invaded first by herbs which achieve their cycle within a few weeks, and are then quickly replaced by a few pioneer tree species, almost always largely dominated in Mayombe by *Musanga cecropioides*.

Two years after the abandonment, the fallow makes up a real forest with an already dense canopy, some 8 to 10 m high; as the number of species increases gradually (Table 2), owing to the settling of sciaphilous species under the already dense canopy, the relative importance of pioneer species, estimated by such parameters as relative density or relative basal area, slowly decreases until the progressive death of the upper canopy layer after about 20 to 25 years.

The structure of this pioneer forest evolves with time, mainly because of natural thinning and individual tree growth, and may be characterized as early as the second year by two layers: an upper one made up almost exclusively of *Musanga* trees culminating at about 15 m height and quickly stabilizing at around 22-25 m, and a lower one showing large floristic variations from site to site, but mainly dominated by some Rubiaceae and some *Macaranga*. This undergrowth, inside which even after 16 years of fallow the constant presence of cassava should be noted, densely occupies the space from the ground level to various heights, from 3 to 8 m depending on its local composition, and has its development largely hampered by the *Musanga* canopy.

In the past, 10 to 15 years old fallows were often chosen for new cultivation owing to their relatively easy clearing, starting then a new and almost identical succession. When villages, and with them their cultivated areas, were abandoned, the succession could extend: after the death of the *Musanga* canopy, the pioneer forest was replaced by a secondary forest which itself led after a more or less long period (100-150 years or more?) to the regeneration of a "primary" forest floristically and structurally similar to the initial one.

In Mayombe, as well as in most parts of the humid tropics, this classical succession can no longer be achieved as fields are reopened after less and less years, owing mainly to permanent settling of villages and to increasing population densities. Fallows of shorter duration lead to floristic and structural transformations, favouring species able to reach maturity earlier and to deliver seeds in greater amounts. In Mayombe, although other traces of past shortening in the fallow-field cycle can be encountered, as *Pteridium aquilinum* or *Dicranopteris linearis* formations, the most obvious evidence of the increasing cultivation intensity is given by the occurrence of large tracts of *C. odorata* dominated thickets.

At present, when a plot of pioneer forest, whatever its age and previous vegetation ("primary", secondary or pioneer forest), is opened for cassava cultivation, the colonizing vegetation following the abandonment of the field is largely dominated by *C. odorata*.

This process has been clearly shown on the "parcelle Likibi": half of the field was set up on a previously undisturbed forest, the other half on a five years old pioneer forest succeeding directly to undisturbed forest. After two years of fallow, the regrowth on the first half is a typical young pioneer forest 8 to 10 m high, with a tree density of 7650 ind/ha and a basal area of 25 m2 (Table 2); on the second half, the fallow is made up of a few scattered pioneer trees emerging 3 to 5 m above a 2 m high thicket. Although this thicket presents a relatively important species richness (47 species were counted on a 25 m2 plot), *C. odorata* is by far the dominant species, as shown by its aerial biomass[2] accounting for 57 % of the total above ground phytomass of the thicket (Table 3).

2 Biomass was used as the more meaningful parameter to assess the relative importance of species or groups of species in *C. odorata* thickets. In each fallow, a $25m^2$ representative plot was chosen, in which species or groups of species were cut to ground level, sorted and weighed on the spot. Samples were then brought to the laboratory and dried in an oven at 105 C for constant weight to assess the dry/fresh weight.

The importance of *C. odorata* within the regrowth is naturally much more pronounced when the vegetation slashed and burnt for cultivation is already dominated by *C. odorata* (Table 3): after one year of fallow, the 2 m high thicket is mainly composed of *C. odorata* (only 8 species were counted on 25 m2), which accounts for about 67 % of the phytomass (trees excluded). After three years, the vegetation is still very dense and species poor (only 10 species counted on 25 m2), reaching 2.5 to 3 m high, with a very few slightly emerging or completely included trees. *C. odorata* here accounts for about 76 % of the biomass (trees excluded).

In the oldest thickets found around Les Saras (7 years old), although some signs of evolution may be observed, such as the differentiation of a few tree spots (about 10 % of the fallow area) and the disappearance of *C. odorata* under these spots, *C. odorata* is still largely dominant, accounting for 84 % of the phytomass (Table 3).

The comparison of the previous examples of *C. odorata* thickets shows that once settled they stay almost unchanged for years, and probably because of their extremely dense canopy but perhaps also because of the allelopathic properties of *C. odorata* (Ambika and Jayachandra 1980), they do not allow the growth of other successional species, therefore making up a kind of successional locking. This locking is obviously long lasting, but one may foresee a slow evolution of thickets towards impoverished kinds of pioneer forest, with the support of the few surviving trees, which will after some years create many unsuitable spots for *C. odorata*. However, this foreseeable succession is not likely to occur in practice because fields are now reopened after fallow periods of only 5 to 6 years, not long enough to allow such an evolution.

C. ODORATA: CONSEQUENCES OF AN INVASION

The zoning of vegetation and land use around Les Saras as described above provides an account of the agricultural landscape and of the relative importance of *C. odorata* as it existed at the time of study in 1988-1989.

From the railway opening until the early 1970s, this landscape has undergone important but mainly quantitative transformations: expansion of the area under cultivation, and increase of pioneer forest fallow areas at the expense of the undisturbed forest.

From the arrival of *C. odorata* until now, huge qualitative transformations began to be superimposed on this trend: appearance of long lasting low thickets at an increasing rate and reduction of areas supporting a forest cover, whatever its composition.

Bearing in mind the present natural succession trends, it seems obvious that *C. odorata* thickets are bound to extend, and it may be assumed that, except for a narrow strip of pioneer forest and cassava fields along the undisturbed forest border, the whole agricultural landscape will be reduced within a few years to one large area of *C. odorata* thickets, only locally shared by banana plantations and cassava fields.

This completely new process of replacement of classical pioneer forest fallows by *C.*

odorata thicket fallows is clearly visible on the ground, and is perceived by rural people (who indeed have a ringside seat) as extremely frightening. The first attempts of cultivation, following the traditional slash and burn practices, ended in complete failure. Although they may fully be explained by the vigorous resprouting properties of *C. odorata*, many people attributed these failures to a substantial decrease in soil fertility, and these people now believe that soils under *C. odorata* thickets are lost for agriculture.

However, this bad reputation could slowly change. As reported above, *C. odorata* thickets next to the village, in the A and B belt, are now more and more used for cultivation of maize, groundnut and cassava in mixture. Such fields are often completely managed by women, but also sometimes by men who do not "own" any forest fallow or who are too old to have their field far from the village; they are usually very small, and only constitute secondary fields. Provided cultivation operations are correctly undertaken, such as the removing of *C. odorata* stumps and careful weeding, these fields can yield successful crops.

We had the opportunity of following one of these fields from its opening during the 1988 dry season to the cassava dominated stage, just before the abandonment to fallow. All crops (mainly maize, groundnut, eggplant, chilli and cassava) were vigorous and healthy, and, although it was not possible to undertake any quantitative study, their productivity could be judged as fairly high.

A comparative study of soil characteristics in fallows of various age, structure, floristic composition, and history, was carried out at Les Saras[3]. No significant differences in soil nutrient composition between undisturbed forest and pioneer forest fallows (HFDS 16, 10, 12, 11) were observed, but this study clearly shows an improvement of soil chemical fertility under *C. odorata* thickets (Table 4).

Two years after the abandonment of a field opened on pioneer forest fallow ("parcelle Likibi": HFDS 9), the soil fertility is still similar to undisturbed forest soil fertility, but after 7 years (HFDS 14) the nutrient enrichment appears clearly, mainly with an increase in calcium , which is well reflected by a tremendous improvement in pH (2 points!).

This global improvement of soil chemical fertility does not appear to be affected by further cycles of cultivation/fallow, as may be deduced from the soil analysis of a three years old fallow following cultivation of a field opened on *C. odorata* thicket (HFDS 13).

In addition, it should be noted that in the two *C. odorata* thickets (HFDS 13 and 14), contrary to the other vegetation types, the soil was characterized by intense biological activity, shown by the important humus horizon depth (15 cm compared to about 3 or 5 cm under undisturbed or pioneer forest) and by the abundance of earthworms.

[3] Surface soil samples (0-10cm depth) were taken in all vegetation types at half slope. Each sample was made up of 16 elementary samples taken within a $100m^2$ area (10m x 10m) according to a systematic sampling in which the first sample was chosen at random, and then mixed together for further analysis. In addition, soil profiles were studied in each vegetation type. In order to assess the evolution of soil characteristics under various treatments, each fallow type was associated with the nearby undisturbed forest where soil samples were taken using the same methodology.

The combination of these results with the above examples of successful cultivation shows that a shifting cultivation system using *C. odorata* fallows could lead to a global and stable improvement of soil fertility, and that *C. odorata* thickets in Mayombe are not unsuitable for agriculture, provided that peasants adapt their cultivation practices slightly to the new conditions: the thicket should be slashed, left to dry for some days, and burnt; the remaining *C. odorata* stumps should be uprooted. As it seems that most of the soil embedded seeds are not destroyed by the high temperatures associated with burning[4] (Table 5), an early weeding, followed or not, depending of the composition of crop mixture, by periodical ones are needed in order to prevent the growth of *C. odorata* seedlings.

CONCLUSION

From its arrival in Mayombe in the early 1970's until now, *C. odorata odorata* has drastically transformed the agricultural landscape, which will probably be completely invaded by *C. odorata* thickets within a few years. The analysis of natural succession after slash and 9cultivation shows that *C. odorata* invasion has led to a heavy disturbance of the "classical" cycle known by local people for generations, with the replacement of the various pioneer forest stages by stable *C. odorata* thickets. The incapacity of villagers to control this new process, associated with the speed as well as the intensity of the invasion, has led to an understandable anxiety among local people, expressed by the overall opinion that *C. odorata* thickets are unsuitable for agriculture.

It should be stressed that the shortening of fallow periods in shifting cultivation systems usually leads to an increasing soil degradation. Contrary to this very general trend, under *C. odorata* thickets soil fertility seems to be fairly well improved, although more studies are needed in order to confirm and to explain our data.

In the framework of slash and burn cultivation, the soil improvement exhibited by *C. odorata* fallows seems to be stable with time, a fact which could be of great value for the future of agriculture in humid tropical Africa, allowing, within the traditional systems and without any inputs, a process of agricultural intensification. Assuming that field yields are similar in a 15 years cycle based on pioneer forest fallow and in a 2 years cycle based on *C. odorata* fallow, the global production over time in the second system would be five times higher!

Indeed *C. odorata* should be recognized as a weed, but only for a few given crops and only under given cultivation systems. In Indonesia, for instance, *C. odorata* has been reported as a weed mainly for rubber, but although rubber estates seem often to be invaded, smallholders' "jungle-rubber" plantations are never hampered.

4 Six distant surface soil samples, each made up of 10 elementary samples taken with a 3.2cm long and 8cm radius cylinder, from a 3 years old *C. odorata* fallow were brought to the laboratory. They were mixed together and divided in 6 equal parts to be subjected to various temperature conditions. Then, they were placed in germination trays and checked for new seedlings using the same method as in the seed bank assessment experiment.

Considering the present distribution of *C. odorata* as well as its foreseeable future extension (Cruttwell McFadyen 1988), it seems urgent not only to find better ways to eradicate and to control *C. odorata* where it appears effectively as a weed, but also to assess its promising agronomic potentialities in order to use *C. odorata* in its beneficial aspects for the benefit of rural people.

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Fig. 1 Les grands ensembles de relief du Congo
Simplified geomorphology of Congo

1. Plaine côtière - *Coastal plain*
2. Mayombe *(massif)*
3. Vallée du Niari - *Niari valley*
4. Chaillu *(massif)*
5. Plateau et colline - *Hill and plateau*
6. Cuvette congolaise - *Congo basin*

1, 3, 6

5

2, 4

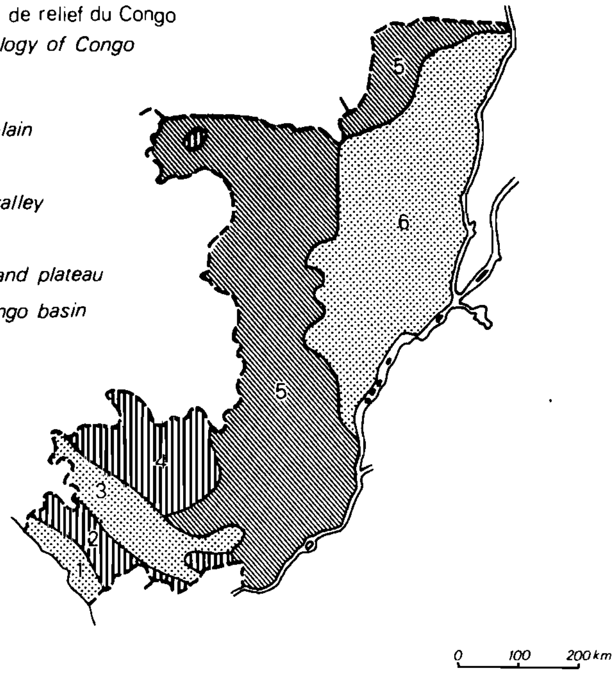
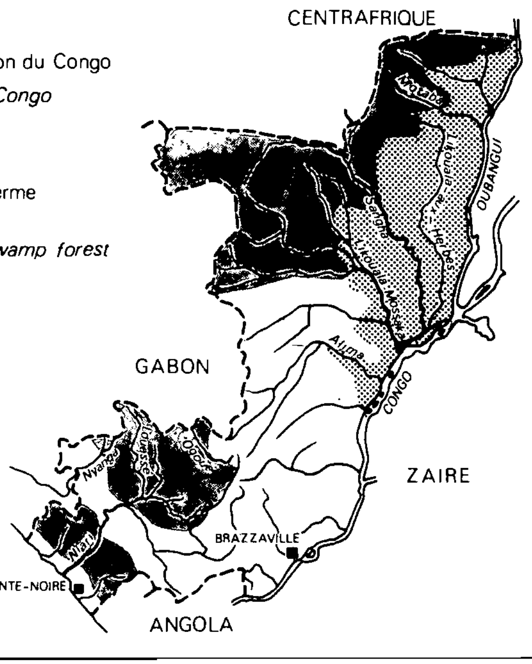


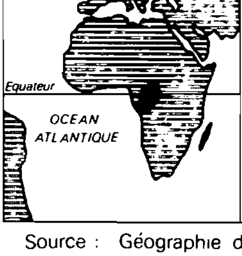
Fig. 2 Carte de la végétation du Congo
Vegetation map of Congo

Forêt dense de terre ferme
Lowland rain forest

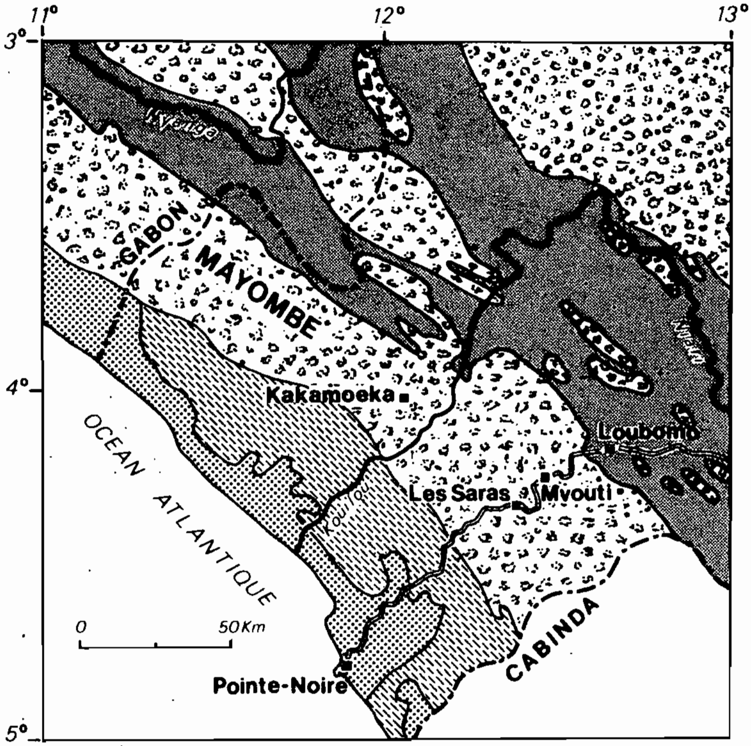
Forêt dense inondée - *Swamp forest*

Savane - *Savannah*





Source : Géographie de la République Populaire du Congo



savanes côtières - *coastal savannahs*

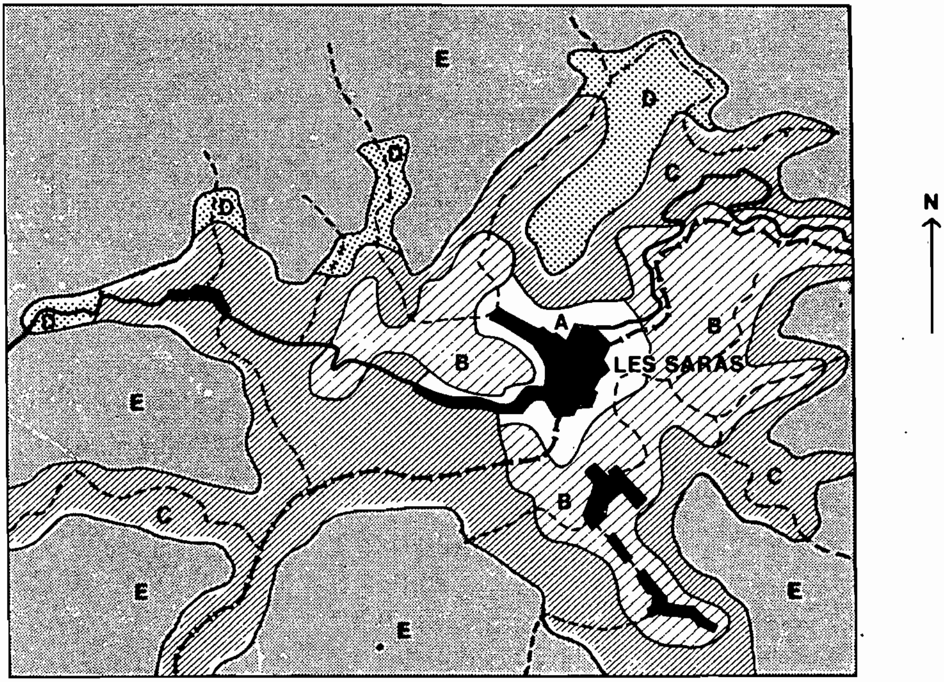
mosaïque forêt-savane de la façade maritime
occidental forest-savannah mosaic

forêts - *rainforests*

savanes du synclinorium Niari-Nyanga
Niari- Nyanga savannahs

railway Congo-Ocean

Fig.3 Le Mayombe congolais - *Congolese Mayombe*



Chemin de fer / *Rail way*

Route N1 / *N1 Road*

Anciennes Pistes Forestières / *Former logging Roads*

A. B.C.D.E: See text for detailed composition

0 5 10 Km

Legends for Figure 4:

Zone A: Mosaic of old banana plantations, oilpalm groves, small cassava fields and *C. odorata* thickets;

Zone B: mainly *C. odorata* thickets, with a few small oilpalm groves and cassava fields;

Zone C: mosaic of pioneer tree fallows and banana plantations, with a few cassava fields and *C. odorata* thickets;

Zone D: new cassava fields and banana plantations at the fringes of the still undisturbed forest;

Zone E: "primary" forest

Fig 4 : ZONATION CULTURES ET DE LA VEGETATION AUTOUR DE LES SARAS
LAND USE AND VEGETATION ZONING AROUND LES SARAS

Table 1: Soil seed bank under various vegetation types (mean number of seedlings per m2)

Vegetation types Species or species group	F1	F1(2)	FF	CF1	CF2
Chromolaena odorata	0	37	29	1119	2035
Ruderal Herbs (20 species)	0	112	702	485	5179
Pioneer Trees (16 species)	243	1039	900	506	112
Forest Herbs (4 species)	0	8	24	0	0
Unidentified (? species)	83	128	83	37	651
TOTAL	327	1376	1740	2147	7970

F1: undisturbed forest far from the village
F1(2): small patch of undisturbed surrounded by fields and fallows
FF: 16 year old pioneer forest fallow after cassava cultivation on undisturbed forest
CF1: 2 year old *C. odorata* fallow after cassava cultivation on pioneer forest fallows
CF2: 3 year old *C. odorata* fallow after cassava cultivation on *C. odorata* fallow

Table 2: Main floristic and structural characteristics of pioneer forest fallows after cassava cultivation (Les Saras, MAYOMBE)

Species or group of species	FF1				FF2				FF3			
	N	%	A.B. cm2	%	N	%	A.B. cm2	%	N	%	A.B. cm2	%
Musanga cecropioides	164	54	9611	96.9	174	53	21070	98.1	36	20	16345	85.1
Manihot esculenta	30	10	81	0.8	4	1	14	0.1	13	7	47	0.2
Bertiera racemosa	60	20	67	0.7	56	17	93	0.4	12	7	64	0.3
Porterandia cladantha	0	0	0	0.0	22	7	27	0.1	22	12	94	0.5
Macaranga spp.	0	3	69	0.7	5	2	50	0.2	7	4	153	0.8
Other species	34	11	77	0.8	39	12	138	0.6	46	26	538	2.8
Other species (resprouts)	9	3	13	0.1	30	9	88	0.4	43	24	1960	10.2
TOTAL (plot)	306		9918		330		21480		179		19201	
TOTAL (per Ha.)	7650		247950		8250		537000		2983		320016	

FF1 (400m2); 2 year old fallow ("parcelle Likibi")
FF2 (4oom2); 3 year old fallow
FF3 (600m2); 16 year old fallow ("parcelle Likibi")

N: number of trees with diameter at breast height higher than 1 cm
A.B.: basal area (trees with diameter at breast height higher than 1 cm)

Table 3: Above ground Phytomass of *C. odorata* fallows (Dry weight) of various *C. odorata* fallows

	C. odorata Fallows							
Species or	CF1		CF3		CF2		CF4	
group of species	Kg/Ha	%	Kg/Ha	%	Kg/Ha	%	Kg/Ha	%
Chromolaena	5876	36	8320	65	18052	64	13856	84
Cassava	1912	12	200	1	1968	7	508	3
Pioneer trees	5772	36	520	4	7248	26	604	4
Resprouts	604	4	0	0	0	0	0	0
Vines	1444	9	0	0	880	3	1480	9
Herbs	548	3	3840	30	20	0	120	0
TOTAL	16156		12880		28168		16568	

CF1: 2 years old, after cassava cultivation on pioneer forest
CF2: 3 years old, after cassava cultivation on *C. odorata* fallow
CF3: 1 year old, after cassava cultivation on *C. odorata* fallow
CF4: 7 years old, after cassava cultivation on pioneer forest

Table 4: Main chemical characteristics of surface soils under undisturbed forest, pioneer forest fallows and *C. odorata* fallows

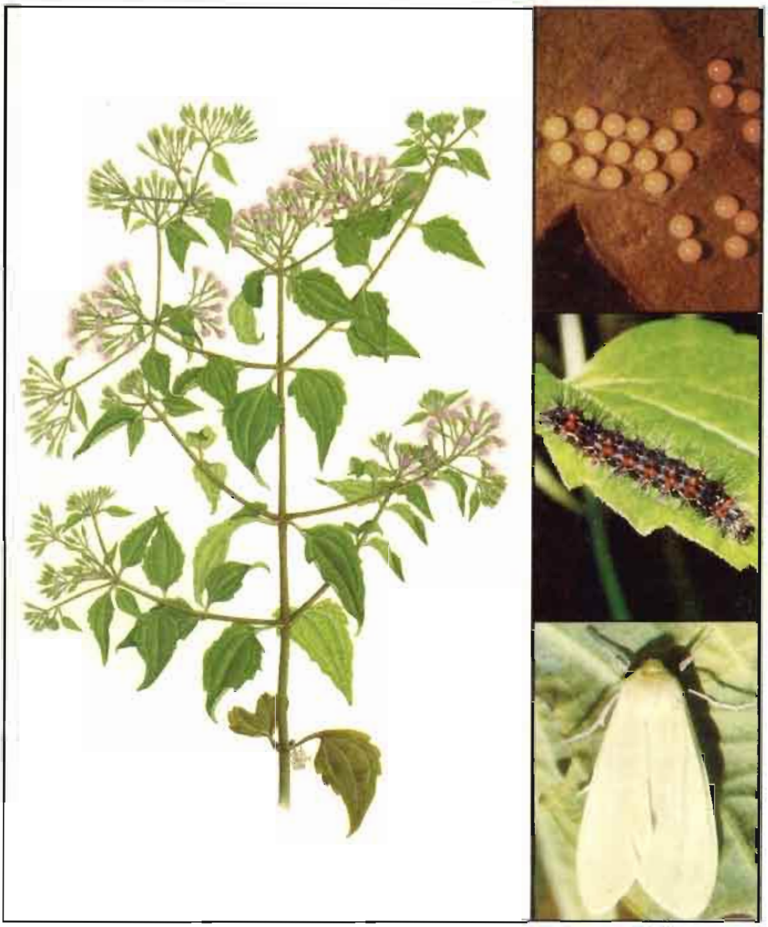
No.HFDS	pH (H20)	C %	N %	C/N	Ca me/ 100g	Mg me/ 100g	K me/ 100g	Na me/ 100g	S me/ 100g	C.E.C. me/ 100g	S/CEC %
16.0	4	3.62	0.197	18.4	0.81	0.21	0.27	0.23	1.52	35.15	4.3
10.0	4.2	2.9	0.195	14.9	0.85	0.12	0.26	0.23	1.46	33.03	4.4
8.1	4.6	2.03	0.169	12.0	0.84	0.27	0.18	0.1	1.39	24.43	5.7
12.0	4.5	2.3	0.15	15.6	0.42	0.16	0.22	0.03	0.83	14.92	5.5
12.1	4.3	2.23	?	?	0.56	0.25	0.29	0.17	1.27	33.38	3.8
11.0	4.9	1.6	?	?	1.52	0.27	0.21	0.13	2.12	20.78	10.2
5.1	4.3	2.05	0.15	13.5	0.52	0.27	0.14	0.03	0.96	12.67	7.6
9.0	4.1	2.15	0.16	13.9	1.15	0.27	0.22	0.12	1.76	31.03	5.7
13.0	<u>6.3</u>	1.82	0.17	10.6	<u>7.06</u>	0.94	0.27	0.29	<u>8.56</u>	25.53	<u>33.5</u>
8.1	4.6	2.03	0.17	12.01	0.84	0.27	0.18	0.1	1.39	24.43	5.7
14.0	<u>6</u>	1.94	0.13	14.7	<u>5.71</u>	0.63	0.18	0.27	<u>6.79</u>	22.33	<u>30.4</u>
4.1	3.8	2.38	0.14	17.5	0.3	0.1	0.27	0.1	0.77	27.83	2.8

HFDS 8.1; 12.1; 5.1; 4.1; undisturbed forest
HFDS 16: 2 year old pioneer forest fallow
HFDS 10: 3 year old pioneer forest fallow
HFDS 12: 7 year old pioneer forest fallow
HFDS 11: 16 year old pioneer forest fallow
HFDS 9: 2 year old *C. odorata* fallow (CF1, "parcelle Likibi")
HFDS 13: 3 year old *C. odorata* fallow(CF2)
HFDS 14: 7 year old *C. odorata* fallow (CF4)

Table 5: Effect of high temperature on the soil seed bank under *C. odorata* fallow (number of seedlings per m2, two months after treatment)

Species or species group	80°c 5 minutes	80°c 1 hour	80°c 12 hours	130°c 5 minutes	130°c 1 hour	No Treatment
Chromolaena odorata	1412	497	60	1431	20	1352
Oldendia corymbosa	5149	5388	2266	5050	497	5189
Lindernia numuraliifolia	1869	1889	159	1431	0	2087
Ageratum conyzoides	417	755	0	596	0	596
Laportea aestuans	636	1491	40	517	20	457
Peperomia pellucida	119	80	20	60	0	119
Musunga cecropioides	0	298	0	0	0	60
Physalis angulata	179	517	99	139	20	278
Paspalum spp.	258	338	99	557	0	258
Cyperaceae spp.	338	437	179	179	0	239
Asteraceae sp. 1	60	60	20	60	0	0
Phyllanthus sp. 1	20	60	0	99	0	40
Phyllanthus sp. 2	0	60	0	0	0	0
unidentified spp.	139	40	0	99	0	40
TOTAL	10974	12565	3101	10636	557	11014

ECOLOGY AND MANAGEMENT OF *CHROMOLAENA ODORATA*



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