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Foreword

This volume presents the results of an environmental impact assessment of land settlement in one river valley on the Burkina Faso–Côte d'Ivoire border. The methodology used for the assessment is quite simple and inexpensive and grew out of the environmental monitoring conducted by the Onchocerciasis Control Programme (OCP).

OCP is one of the most successful health projects in Africa. The program was launched by seven West African countries and nine donors, including the World Bank, and has expanded to include eleven countries and twenty-three donors. Thirty million people are now protected from the disease and 25 million hectares of arable land have been made available for settlement.

What has been less widely publicized than the health benefits of the Programme is the fact that, although the OCP strategy relies on the repeated application of chemical insecticides and biological control agents to the aquatic breeding sites of the blackfly vectors, there have been no significant disturbances of the aquatic environment throughout the Programme area. The environmental soundness of the OCP strategy has been demonstrated by an extensive environmental monitoring system supervised by an independent group of environmental experts. However, despite the care taken to prevent damage to the OCP rivers, there have recently been indications that other factors might be having a negative impact. To investigate this possibility, the Committee of Sponsoring Agencies (CSA: comprised of FAO, UNDP, WHO, the World Bank), the statutory body that oversees OCP, undertook to organize this assessment, with funding from the Government of the Netherlands.

The findings of the assessment are important in that they indicate that the rapid settlement occurring in many of the areas where riverblindness has been controlled may have negative consequences for the aquatic environment even when there is very little use of chemical fertilizers and pesticides. There is a need, therefore, for proactive policies by the concerned governments to ensure that when settlement occurs it does so in a manner that will not harm the environment.

Jean-Louis Sarbib
Director
Western Africa Department

Acknowledgments

The Upper Léraba pilot study was commissioned by the Committee of Sponsoring Agencies (CSA) of the Onchocerciasis Control Programme in West Africa (OCP), and jointly funded by the Government of The Netherlands and The World Bank. The original design for the study was formulated in January 1992 by the Ecological Group (EG) of the OCP's Expert Advisory Committee (EAC), in response to a request from the CSA. After internal review and reformatting into a plan of action, the proposal was submitted by the CSA to the OCP Joint Programme Committee (OCP 1992), which endorsed it during its thirteenth session (Geneva, December 1992).

In January 1993, the plan of action for the pilot study was revised to reduce its geographical scope (in its original form the plan made provision for a parallel study in Côte d'Ivoire), and implemented by a team of three senior biological scientists; Dr. David Baldry, formerly a biologist with WHO and FAO, Professor Davide Calamari, Professor of Applied Ecology, Institute of Agricultural Entomology, University of Milan, and Dr. Laurent Yaméogo, OCP Hydrobiologist.

Aerial photographic surveys and fact-finding missions in the OCP area could not have been conducted so effectively without the support of Dr. Ebrahim M. Samba, former OCP Programme Director, and his staff, who placed their facilities at the disposal of the study team while its members were in West Africa, and who provided important archival information on the Upper Léraba Basin.

Likewise, it would have been much more difficult for the study team to accurately assess agrochemical impacts without the collaboration of officials of the Government of Burkina Faso, who kindly provided climatic, hydrological and agricultural data on the Upper Léraba Basin.

The members of the study team would also like to express special thanks to Mr. Manuel Bravo, pilot of Evergreen Helicopters, Inc., for safe aerial operations in the OCP area, and to Mr. Bruce Benton, Dr. John Elder and Dr. Bernhard Liese, The World Bank, for their unstinting support and encouragement during the implementation of the Pilot Project.

Acronyms/Abbreviations

ABR	Annual Biting Rate (of Blackflies)
ATP	Annual Transmission Potential (of Blackflies)
CSA	Committee of Sponsoring Agencies of the OCP
CPUE	Catch Per Unit of Effort (of Fish)
DI	Drift Index (of aquatic invertebrates)
EAC	Expert Advisory Committee of the OCP
EG	Ecological Group of the OCP Expert Advisory Committee
FAO	Food and Agriculture Organization of the United Nations
GUS	Groundwater Ubiquity Score
JPC	Joint Programme Committee of the OCP
LUA	Land Utilization Analysis Area
L.oc	Léraba Occidentale: the main western tributary of the main River Léraba
L.or	Léraba Orientale: the main eastern tributary of the main River Léraba
L.ss	Léraba *sensu stricto:* the main River Léraba, downstream of the junction of the Léraba Orientale and Léraba Occidentale
OCP	Onchocerciasis Control Programme in West Africa
PEC	Predicted Environmental Concentration
WHO	World Health Organization

Abstract

The great successes achieved by the Onchocerciasis Control Programme in West Africa (OCP) in the large-scale control of the blinding savanna form of onchocerciasis (river blindness) have allowed vast tracts of previously abandoned valleys to be resettled and developed. Among the many issues and problems that have to be addressed, to ensure the most effective long-term management of settlement and development in these onchocerciasis-controlled areas, is that which relates to the potential impact of those development activities on the environment.

Despite the fact that for many years anti-blackfly larvicides were regularly applied to the rivers of the OCP area, the quality of the aquatic environment was preserved, partly because of the precautions taken by the OCP, but largely because of the absence of human population pressure in the areas most severely affected by onchocerciasis. However, the situation is now changing—rapidly in parts of the OCP area—and there is increasing concern for the welfare of both aquatic and terrestrial environments.

In this context, it was recognized that there was a need for the formulation of an appropriate methodology for environmental impact assessment. In 1991 the OCP Committee of Sponsoring Agencies (CSA) started to address this issue, and in 1993 launched a pilot project in one selected basin (the Upper Léraba Basin), the results of which are described in this report.

The primary objectives of the Pilot Project were i) assessment of the present environmental situation in the Basin, with a view to determining potential sources of impact on the aquatic environment, ii) quantification of chemical loads, and assessment of modification to the physical environment, and iii) identification of simple study methods which would be applicable to other areas and which could be offered as examples to predict environmental impacts of settlement and development, and offer ways to minimize those impacts.

Through the collection of geographic information and data on land utilization, as well as by an assessment of loads (fertilizers, pesticides, human and livestock wastes), an ecotoxicological impact evaluation of human activities was made, at basin scale, in the Upper Léraba Basin. More detailed evaluations of changes in the physical environment were made at medium and local scales of resolution, with special attention being given to analyses of changes in land utilization patterns between 1972 and 1993, and to determining the ecological significance of the observed changes.

It was concluded that organic loads and nutrients were only of relevance along limited stretches of the main Léraba rivers, where settlements were located close to the river banks and provided point sources of contamination. The contamination of river water by pesticides used for cotton protection was calculated by means of simple models which also permitted the theoretical concentrations of pesticides in river water to be estimated. Although the predicted concentrations of pesticides in river water were not at levels that could give cause for alarm, they could however be considered as early warning signals.

With regard to physical changes in the environment, it was concluded that about 75 per cent of the original savanna woodland had been cleared for settlement and for agricultural development (most of it over the last decade). The riverine forests of many of the smaller rivers and streams had been destroyed, and on some cleared river banks the first signs of soil erosion were detectable.

On the positive side, it was concluded that there had not been any significant disturbance of the riverine forests and associated floodplain grasslands of the main rivers.

The overall conclusion from the Pilot Project was that, on the basis of studies which were limited both in time and scope, it was possible to make valid and meaningful assessments of the Upper Léraba Basin, in terms of chemical contamination of river water, of localized changes in the biological condition of the aquatic ecosystem, and of physical degradation of the woodland savanna component of the terrestrial environment. In relation to the Pilot Project's third main objective, the investigations clearly demonstrated that the techniques employed—using input data that were very basic, but readily available from national agricultural and development authorities, and by the application of standard hydrobiological techniques and simple models—can be used as examples of quick and reliable environmental impact assessment methodologies, which are applicable to other, similar areas.

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Introduction

Since its inception in 1974, the Onchocerciasis Control Programme in West Africa (OCP) has implemented a strategy of onchocerciasis (river blindness) control which has been aimed at the long-term interruption of the transmission of the causative agent (the filarial worm *Onchocerca volvulus*), in all areas where there was a human reservoir of infection of the severe blinding form of the parasite. In operational terms, this has required the weekly application of insecticides (mainly by aircraft) to the fast-flowing stretches of rivers which constitute the habitats of the larval stages of the blackflies which are the onchocerciasis vectors.[1]

Although the OCP commenced its vector control operations with only a single chemical larvicide, the organophosphate compound temephos,[2] it was recognized from the outset that the possible impact of larviciding operations on the aquatic fauna would need to be carefully monitored. During the early years of the OCP a small Ecological Panel fulfilled this function. In 1980, when the OCP structure was reorganized, the Ecological Panel became the Ecological Group of the OCP Expert Advisory Committee, with a mandate to study "the ecological impact on the environment of the use of insecticides in the Programme" (Samba 1994).

Repeatedly, the Ecological Panel and the Ecological Group were able to demonstrate to the outside world that there had been no significant disturbances of the aquatic environments of the OCP area which could be attributed to OCP larviciding operations. In fact, the environmental soundness of the OCP strategy was repeatedly demonstrated by routine aquatic monitoring and assessment activities; the results of which were published in scientific literature (see, for example, Lévêque *et al.* 1988, Yaméogo *et al.* 1993).

Despite the proven environmental soundness of the OCP control strategy, the last few years have witnessed growing concern that human settlement and development activities in onchocerciasis-controlled areas could impose new threats to both aquatic and terrestrial ecosystems. Increases in agrochemical use and in other potentially pollutant loads, and physical change to the environment could all, directly or indirectly, have adverse effects on the quality and productivity of the valleys concerned.

From the analysis of aquatic monitoring data collected in the original OCP area during the early 1990s, the Ecological Group concluded that strong scientific evidence was available to substantiate these concerns. For example, environmental studies of some watercourses which were no longer larvicided by OCP showed that faunal recolonization was in progress, but that in certain cases, human activities had clearly contributed to a degradation of the environment, resulting in an impoverishment of the fauna. The Upper Léraba Basin (covering parts of Burkina Faso, Côte d'Ivoire and Mali) was considered to be a good example of where this type of situation existed (OCP 1992).

In 1991 these matters were discussed by the OCP Committee of Sponsoring Agencies (CSA) and later by the OCP's governing body, the Joint

Programme Committee (JPC), in the context of the CSA's future work programme of support in socioeconomic development to the OCP Participating Counties. At its 12th session (December 1991) the JPC endorsed a CSA work programme which, inter alia, would provide for the CSA to address some of the broader environmental aspects of settlement and development in the OCP area, and in the first instance, to conduct an environmental impact assessment of agrochemicals. Members of the Ecological Group who attended that JPC session welcomed this new initiative, and stressed the importance of taking a broader view of environmental issues, especially as they related to water resource conservation and management.

During 1992, after discussions between the Ecological Group, the CSA and staff of the OCP, a detailed "Draft Proposal for a Pilot Project on Environmental Impact Assessment in the OCP Area" was prepared (OCP 1992), and submitted to the 13th session of the JPC (December 1992) for approval. This proposal made provision for pilot studies in two river basins, the Upper Léraba Basin and the White Bandama Basin (in Côte d'Ivoire). However, it was decided that, in the first instance, it would be prudent to embark upon a study in only one of the basins, with preference being given to the smaller of the two; the Upper Léraba. Accordingly, in early 1993, The World Bank, on behalf of the CSA, launched a Pilot Project for an environmental impact assessment in the Upper Léraba Basin (hereafter referred to as the Basin), in accordance with the detailed terms of reference that were prepared and approved at the end of 1992 (OCP 1992).

Objectives of the Pilot Project

The primary objectives of the Pilot Project were:

- assessment of the present environmental situation in the Basin, with a view to determining potential sources of impact on the aquatic environment,
- quantification of chemical loads, and assessment of modification to the physical environment,
- identification of simple study methods which would be applicable to other areas, and which could be offered as examples to predict environmental impacts of settlement and development, and to furnish guidelines to minimize those impacts.

Although several methodologies for regional environmental impact assessments have been proposed (see, for example, proposals for thematic maps for regional ecotoxicological risk assessment by Herrchen 1994), very few impact assessments have actually been conducted worldwide (one of the few examples being that described by Di Guardo *et al.* 1993a). One of the few assessments so far made in sub-Saharan Africa, a study conducted by Calamari et al. (1992) in the Winam Gulf Basin of Kenya, had some relevance to the Léraba investigation. Although the ecological differences between the two basins were such that direct comparisons could not be made, some elements of the Kenyan experience provided guidance during the planning of the Léraba Pilot Project. Thus, to the best of the present authors' knowledge, the Léraba environmental impact assessment conducted by them is unique for West Africa, if not for sub-Saharan Africa as a whole. The authors have therefore prepared this account in such a way as to present the Léraba investigation as a model which is applicable to assessments that may be required in other parts of Africa, where environmental conditions are the same or similar.

Project activities

The Pilot Project commenced in January 1993, with the collection of geographical, meteorological and hydrometric data, with the assembly of quantitative information on agricultural practices, fertilizers and pesticides, and with the preparation of ecotoxicological profiles of the pesticides known to be used in the Basin. In May 1993, an OCP helicopter was used to make aerial reconnaissance and photographic flights over the Basin, and some adjacent areas. The aerial photographs that were taken were then used to make maps of pre-selected parts of the Basin, and to construct vegetation profiles. Details of these latter activities are given in Annex 1.

During the latter months of 1993 and during early 1994, the main Project activities were:

- quantification and assessment of organic loads, nutrients and fertilizers;
- pesticide risk assessment, employing the SoilFug model to predict pesticide runoff;
- computerization and interpretation of cartographic land utilization data;
- localized vegetation mapping around Léraba Bridge, and assessment of the status of riverine forests;

- sampling of fish and aquatic invertebrates at Léraba Bridge and at two other nearby sites;
- overall assessment of the environmental situation in the Basin, and reporting.

Other sources of information

Information on the general geography and climatology of the Basin, as well as technical information on agrochemicals, were taken from the published literature and sources are acknowledged accordingly in the text. Quantitative data on rainfall, hydrometry, soil properties, human and livestock populations, crops, fertilizers and pesticides, were obtained from the appropriate Government offices in Burkina Faso.

Historical data on land utilization (especially two maps: "Carte II6-B-24. Situation en 1972. OCP/ECO. J. C. Clanet & P. H. Somé, 1985", and "Carte II6-B-25. Occupation du sol 1983. OCP/ECO. J. P. Hervouet, 1985") were provided by OCP Headquarters in Ouagadougou.

Notes

1. See Samba 1994 for a recent overview of the OCP.
2. With the appearance of blackfly resistance to temephos in the early 1980s, the OCP arsenal of operational insecticides was progressively increased. By 1994, six compounds were in regular, rotational use; temephos, *Bacillus thuringiensis* (B.t. H-14), permethrin, carbosulfan, phoxim and pyraclofos (Samba 1994).

2

Description of the Pilot Project

The Basin, with a catchment area of approximately 5 376 km^2, was located between latitudes 10°–11°N and longitudes 4°55–5°50 W (Figure 2.1), and involved the following countries:

- **Burkina Faso** to the North: the Agro-Pastoral Zones of Sindou (44 500 ha), Loumana (60 000 ha) and western Niangoloko (297 250 ha, of which only about 99 080 ha were located in the Basin), drained mainly by north-bank tributaries of the River Léraba s.s. (L.ss) and the Léraba Occidentale (L.oc), and by the Léraba Orientale (L.or);
- **Côte d'Ivoire** to the South: the Niellé, Diawala and Ouangolodougou Sub-Prefectures of Ferkessédougou Department, drained by south-bank tributaries of the L.ss and the L.oc;
- **Mali** to the West: Kadiolo Cercle, Région de Sikasso, drained by the western tributaries of the L.oc.

That part of the Basin subjected to a medium-scale, longitudinal land utilization analysis, was located between latitudes 10°7–10°23 N and longitudes 5°01–5°13 W, in Burkina Faso and Côte d'Ivoire. It was drained mainly by L.ss, but also by L.oc and L.or in the North.

The short stretch of L.ss used for local, large-scale vegetation mapping was situated at approximately latitude 10°10 N and longitude 5°04 W, in Burkina Faso and Côte d'Ivoire.

Soils

The ferralitic/ferruginous soils of the Basin were of two main types (Anon, 1976):

- category 8d: shallow to medium depth soils (<40 cm), gravelly and/or sandy to clayish in the savanna, with danger of erosion;
- category 12: deep soils (>100 cm), alluvial/clayish near the surface and clayish below, immediately adjacent to the large watercourses (broader on the deposition banks of the rivers and narrower on the erosion banks).

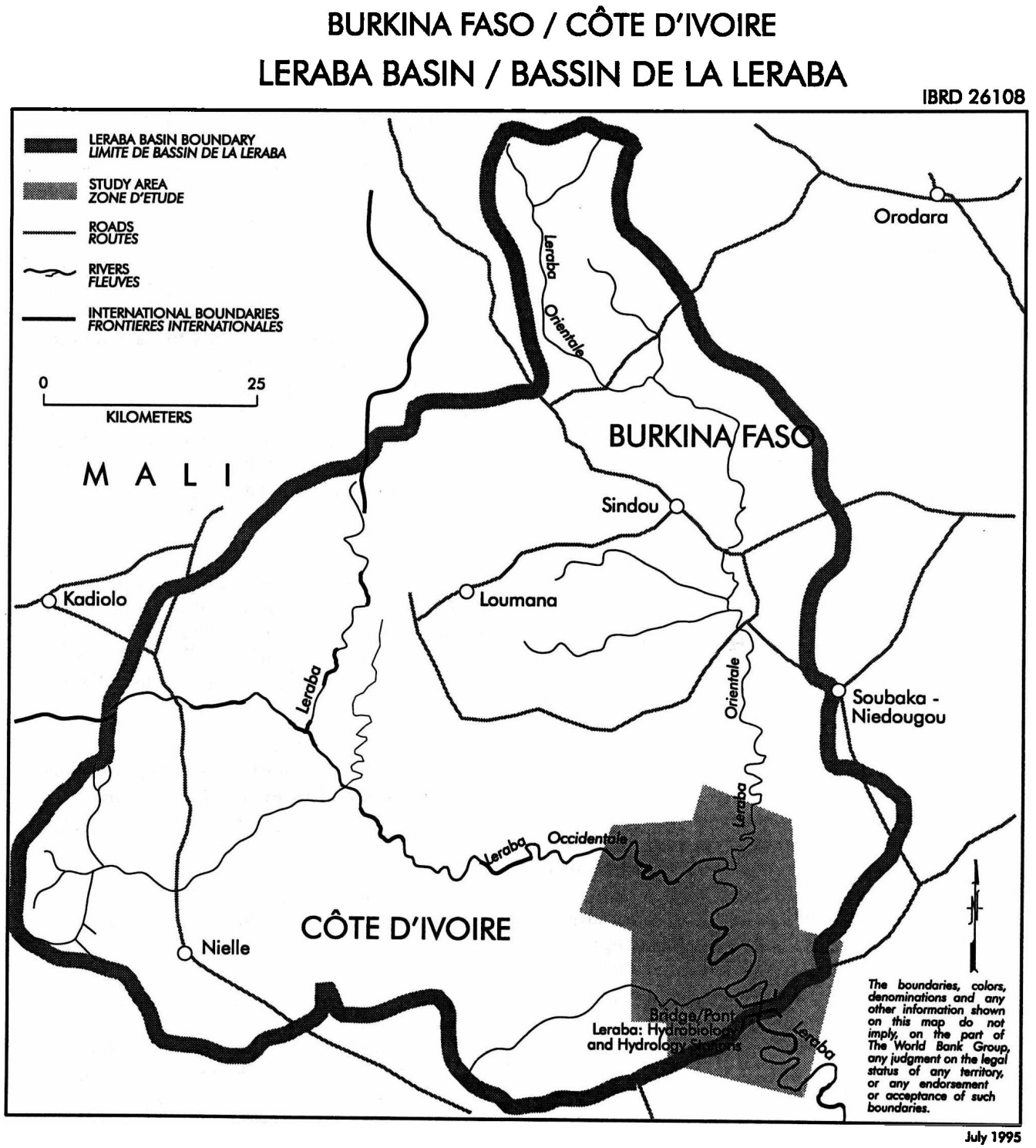
Climate

Prior to the onset of the recent drought, which started in the early 1970s, the mean annual rainfall of the basin was from 1 100 to 1 400 mm. The rainfall statistics presented in Table 2.1, clearly show that in 1992 rainfall was still below the pre-drought average.

Table 2.1 Rainfall Patterns at Sindou, Loumana and Niangoloko, Burkina Faso, 1992 (mm).

Month	Sindou	Loumana	Niangoloko
I	1.5	7.2	0
II	0	0	0
III	0	0	10.3
IV	13.1	18.8	41.9
V	129.5	152.3	25.2
VI	176.9	226.6	149.7
VII	223.7	243.1	272.4
VIII	205.2	221.6	134.3
IX	126.9	145.8	145.4
X	48.2	80.2	95.7
XI	9.2	3.5	20.8
XII	0	0	0
Totals:	934.2	1 099.1	895.7

2.1 Location and Basic Geographical Features of the Upper Léraba Basin. The Inset Labelled "A" Denotes the Boundaries of the Medium-scale Land Utilization Assessment Area.



The wet season, from April/May to September/October, was characterized by a unimodal precipitation pattern. The mean annual temperature was about 27°C.

Hydrometry

Hydrometric data collected at Léraba Bridge hydrology station during 1990 and 1991, are presented in Table 2.2, and are listed on a monthly basis.

Vegetation

The Basin was located in the dry, Sudanian vegetation zone (Péron & Zalacain 1975; Vennetier 1978; Traoré & Monnier 1980), which was characterized by savanna/woodland mosaics.

The principal climax vegetation types were, fire-tolerant savanna woodland, floodplain grassland, and fire-tender, riverine forest. Where the woodland joined the floodplain grassland, and around the rocky upland plateaus, there were densifications of the vegetation, known as ecotones. A vegetation profile taken across the main Léraba valley is presented in Figure 2.2, to illustrate the relationships between these different vegetation communities, in the absence of human interference. More precise descriptions of each of these main communities are given below.

Woodland Savanna

The woodland savanna biotope occupied the largest surface area, and constituted the one most suitable for human settlement and cultivation.

Table 2.2 Mean River Discharge Rates (m^3/s) at Léraba Bridge, 1990 and 1991

Month	1990	1991
I	1.70	1.27
II	0.85	0.85
III	0.47	0.74
IV	0.43	0.61
V	0.96	0.91
VI	3.55	2.74
VII	29.99	32.90
VIII	135.86	147.00
IX	110.58	166.00
X	36.14	30.90
XI	6.69	7.52
XII	3.06	3.12
Annual Means:	27.52	32.88

The most typical tree species of the undisturbed woodland, which rarely exceeded a height of 20 m, and seldom created a completely closed canopy, were *Isoberlinia doka, I. dalzielii, Burkea africana* and *Detarium microcarpum*. Other common species included *Uapaca somon, U. togoensis, Erythrophleum guineense, Pterocarpus erinaceus, Afzelia africana*, and *Daniella oliveri*. Species of economic importance and thus common in cultivated areas, included *Borassus aethiopum, Butyrospermum parkii* and *Parkia biglobosa*. In the northern part of the area it was not uncommon to find *Ziziphus mauritiana* and species of *Acacia*, which were more typical of the Sahelian savanna. Likewise in the south of the area some species that were typical of the more southerly Guinea savanna were also encountered, e.g. *Uapaca togoensis, Lophira lanceolata* and *Cussonia barteri*.

Perennial grasses included species of *Hyparrhenia, Cymbopogon, Ctenium* and *Loudetia*, while annuals included species of *Andropogon, Pennisetum, Eragrostis* and *Ctenium*. On the top of arid, rocky plateaus the dominant grass was *Sporobalus pectinellus*.

Floodplain Grassland

Where the ground sloped downwards below the 280 m contour line, the woodland was replaced by shallow depressions, which constituted the floodplain grasslands. Those grasslands were most extensive along L.ss, but also occurred along L.or and L.oc. and some of their larger tributaries. Being prone to flooding in years of heavy rainfall, or to becoming marshy during years of less heavy rainfall, those grasslands were generally devoid of tree/shrub cover (the tree *D. oliveri* and some fragmented parts of the riverine forest were exceptions) and supported a very limited grass flora; *Vetiveria nigritana* being the only common grass species. Largely because of these factors, the floodplain grasslands were unsuitable for the cultivation of many crop species. However, they were suitable for rain-fed rice, e.g. along the lower L.or, and provided good pasture for livestock.

Riverine Forests

The slightly higher ground that formed the banks of the larger rivers supported tall (up to at least 30 m), closed-canopy, evergreen forest. Just north of Léraba Bridge those forests were up to 165 m