Rice production on inland-valleys soils (Bas-Fonds) of the south-west Ivory Coast - agro-ecological conditions and specific pedological determinations -

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Abstract

Smallholder food production, as well as cash-crop production of cacao, coffee, etc. provide the basis of the Ivorian agricultural economy. Since ten years the importance of paddy rice production and consumption has increased steadily. Today, more than 80 percent of the local rice yield are still produced as upland rice. In the last years inland-valley (bas-fond) cultivation has gained more importance. Flat and swampy inland-valleys with low gradients are wide-spread landforms on the precambrian basement of humid tropical West Africa. At the moment, small cultivation dominates this valleys and, therefore, inland-valleys represent the last arable land for the extension of food production around national parks. The major problems and restrictions are sandy valley-bottom soils, the unsteady water supply, and especially the high rates of agrochemicals used in the cash-crop production.

Key words: Rice, Inland-Valleys, Bas-Fonds, Bassins versants, Gley Soils, Ivory Coast, Côte d'Ivoire, West Africa

Résumée

La production de la nourriture de base, aussi bien que la production intensive du cacao, du café, du caoutchouc et d'huile de palm fournissent la base de l'économie d'agriculture de la Côte d'Ivoire. Dans le dix dernières années, l'importance de la production et de la consommation de riz a augmenté solidement. Aujourd'hui, plus que 80% du rendement de riz local est encore produits comme riz pluvial. Dans les dernières dix années la culture dans les bas-fonds a gagné une importance agrandis. Les bas-fonds (Inland-Valleys) sont les vallées typiques sur le précambrien de l'Afrique de l'ouest tropical. Ces sont plan et marécageux avec des inclinations faibles. Au moment, les activités de culture dans les bas-fonds sont rares et, en conséquence, ils représentent les dernièrs zones pour l'extension de la production de nourriture de base autour des parcs nationaux. Les problèmes principaux et les restrictions sont les sols sableux dans les bas-fonds, l'alimentation en eau permanent et particulièrement les applications élevées de produits agrochimiques utilisées dans la production de culture de rente.

Introduction

Rice cultivation in Ivory Coast has experienced a profound change in the last 20 years. While WIESE (1988) recorded a total production of 490,000 tons of rice in 1994, the FAO data acquisition in 1994 scheduled a rice production of at least 760,000 tons. Simultaneously, in the course of the high urbanisation rate of the last ten years, the demand for rice on local markets rose from 385,000 tons in 1976 to more than 715,000 tons in the year 1991 (DIOMANDE 1997). The Ivorian Ministry of Agriculture (MINISTÈRE DE L'AGRICULTURES ET DES RÉSSOURCES ANIMALES, MINAGRA 1997) estimated the total need for rice at more than one thousand million tons for the year 1997. Thus, already in 1991, Ivory Coast changed from

a former rice exporter with a national production of 32,000 tons in 1976 to a net importer of over 350,000 tons of different qualities of rice from Eastern Asia and the United States. At the same time, an increasing orientation towards cultivation of wetland rice, which was almost unknown in former times, followed. The local common seed changes from *Oryza sat. var.* to the indigenous West African species *Oryza glabberima* and different hybrid varieties of *Oryza sat. x O. glab.*, for example *Bouaké 189* (WEST AFRICAN RICE DEVELOPMENT ASSOCIATION WARDA 1994). Although individual projects of intensive rice irrigation exist in the surrounding countryside of Korhogo, Gagnoa, and Bouaké, national rice production, which is cultivated by smallholders as extensive upland and lowland rice, makes up more than 80 percent of total cultivation (WARDA 1994).
The widespread inland valleys (Bas-Fonds) on the Precambrian Basement complex in West Africa, particularly in the rain forest region of the south-west Ivory Coast, have not been farmed until today. But nowadays they represent some of the last resources of land outside of national parks and protected forests (Forêt classés). The valley fringes and the colluvial footslopes of the valley (Bas-Fond) are only tilled with cassava, manioc or upland rice from case to case. Many inland-valley soils of Ivory Coast, particularly of the south-western region, have so far never been opened up to agriculture. Thereby, they represent one of the last land resources within the otherwise intensively exploited cocoa, coffee, and rubber tree plantations in this region. They gain importance in the course of concept of an integrated nature protection around the Taï National Park, in whose entire environment the natural rain forest stocks have become almost extinct since 1970 (ANHUF 1997) and replaced by large intensive cash-crop plantations. Already now, no more land for the cultivation of food-crops is available due to long term fallow systems of more than five years , shifting-cultivation, and the undiminished influx of new settlers from neighbouring countries. If the boundaries of the national parks should remain protected and respected in the future, the inland valleys could provide more or less suitable alternative areas for the extension, diversification and intensification of the smallholder food production around the borders of the national parks.

The Region

The research was carried out in the surroundings of the Taï National Park (Parc National de Taï) in the south-west of Ivory Coast and, for the purpose of a comparison, in a semi-decidous forest region near the city of N'Zérékoré in south-east Guinea. In addition to these areas two further regions in the sudanian savanna zone in the northern parts of Ivory Coast were selected (fig.1). In this text exclusively the results of the rainforest region is described in detail. This area (fig. 2/3), which is situated in the immediate surrounding of the Taï National Park, is subdivided into four areas in geological, climatological as well as agro-economical perspective. Each type of region is represented by one of the investigated inland-valleys. All these areas are situated in the midstream part or valley head of the numerous tributaries and sub-catchments, which are branched out dendritically of the major rivers "Cavally" and "Sassandra". The north-eastern boundary of the national park forms thereby the watershed between the major river systems of the Cavally and Sassandra.
The local basement of the African shield is represented by lower Precambrian (Birrimean) rocks, which are mainly granite-migmatite-gneiss complexes of approximately 1.8-2.1 billion y.b.p., as well as metamorphic rocks including sericitic greenstones and micaschists of the African orogenesis. In addition to that some smaller granitic and granodioritic intrusions are found in the west and north-west of the investigated region (PAPON 1973). In many places a thick sapolitic layer, with a mightiness of more than 60 metres, covers the unweathered basement. Only in some regions of the more rolling countryside, as well as in inselberg areas

and in some places of the valley bottoms, the basement reaches the surface. None of the investigated bas-fond the saprolite layer could be drilled through, although, some decametres downstream, unweathered rocks appear.
The precipitation at the south-west coast is averaging 2,370 mm per year (sliding means from 1951 to 1980 at the station of Tabou) and drops along a south-west to north-east striking gradient to less than 1,590 mm (ANAM 1987) in the region of Soubré. The total yearly precipitation is divided into two rainy seasons, a longer period which lasts from March to June with smaller quantities of rain and a shorter, but more clear and intensive, rainy season from the end of August to the middle of November. A distinct dry season is missing in the south-west. However, during the months of December and January, precipitation, which only occurs on a few rainy days, rarely exceed the amount of 50 mm (ANHUF 1997). The monthly average temperature in this tropical lowland region varies between 24.5 and 26.7 °C, though a maximum of 28 °C can be reached in March (SZARZYNSKI 1994) (fig. 2). The unimodal discharge of the two major river systems Sassandra and Cavally is clearly decoupled. The discharged maximum is shifted to the months of October and November and follows the highest amount of precipitation more than one month. The main reason for this anomaly is the far north extending catchment area with tributaries coming from the savanna region. Since 1980, no more natural discharge curve can be recorded downstream from the barrage of Buyo for the Sassandra river. The discharge curves of short tributaries like the investigated Bas-Fonds, with catchment areas of a size less than 1,000 square kilometres, react directly or with a short delay of only few days (CASSENAVE 1980, MUND 1993) to the variability of daily monsoon rain. During the rainy season the inland-valley bottoms are regularly flooded for several days after a rainy period.

Fig. 1: Geological map of South-west Ivory Coast with study areas (Design Mund 1999 Cartography by Bartch, 1999)

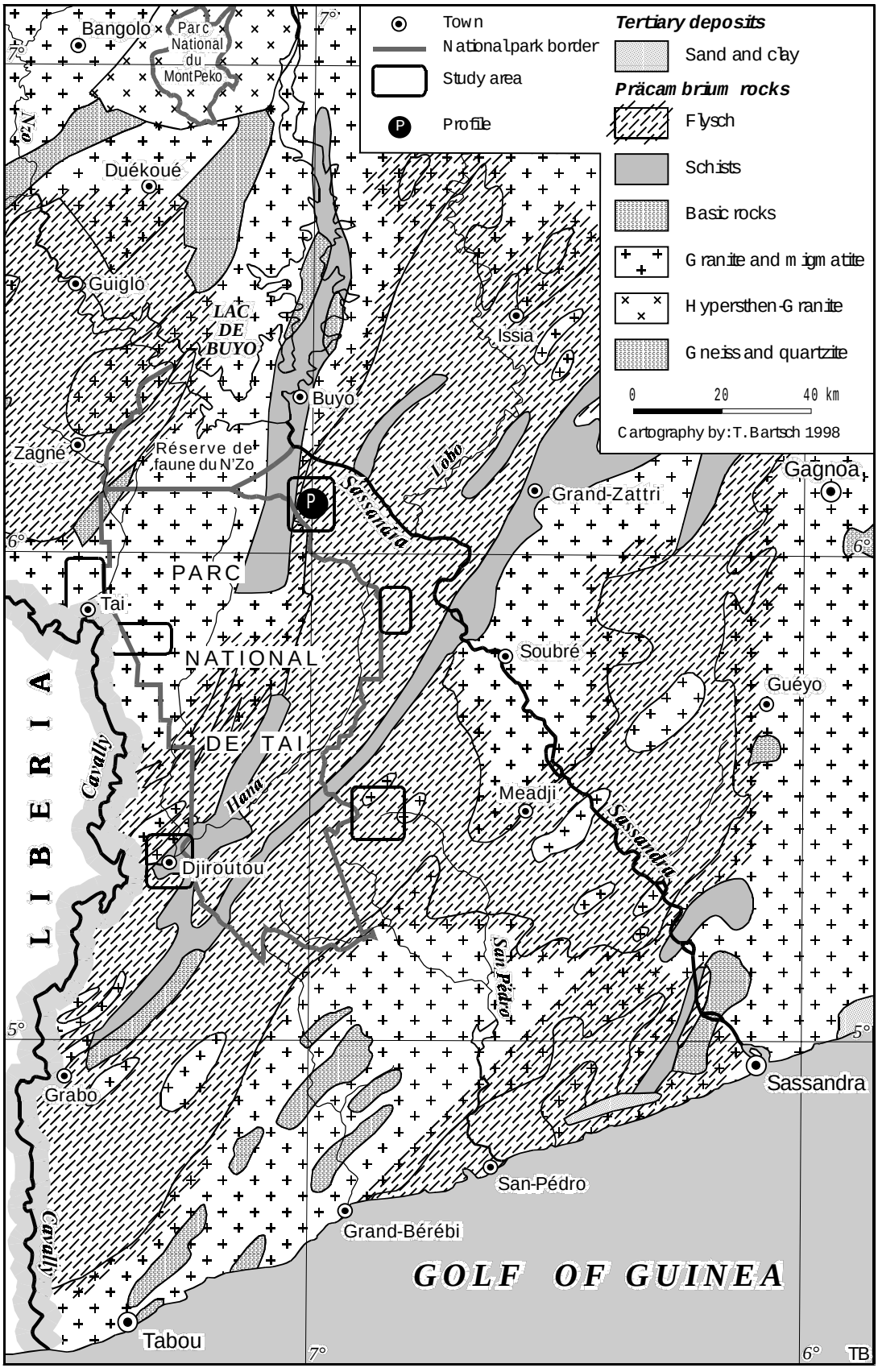


Fig. 2: Climatological map of South-west Ivory Coast with study areas and major roads (Design Mund 1999 Cartography by Bartch, 1999)

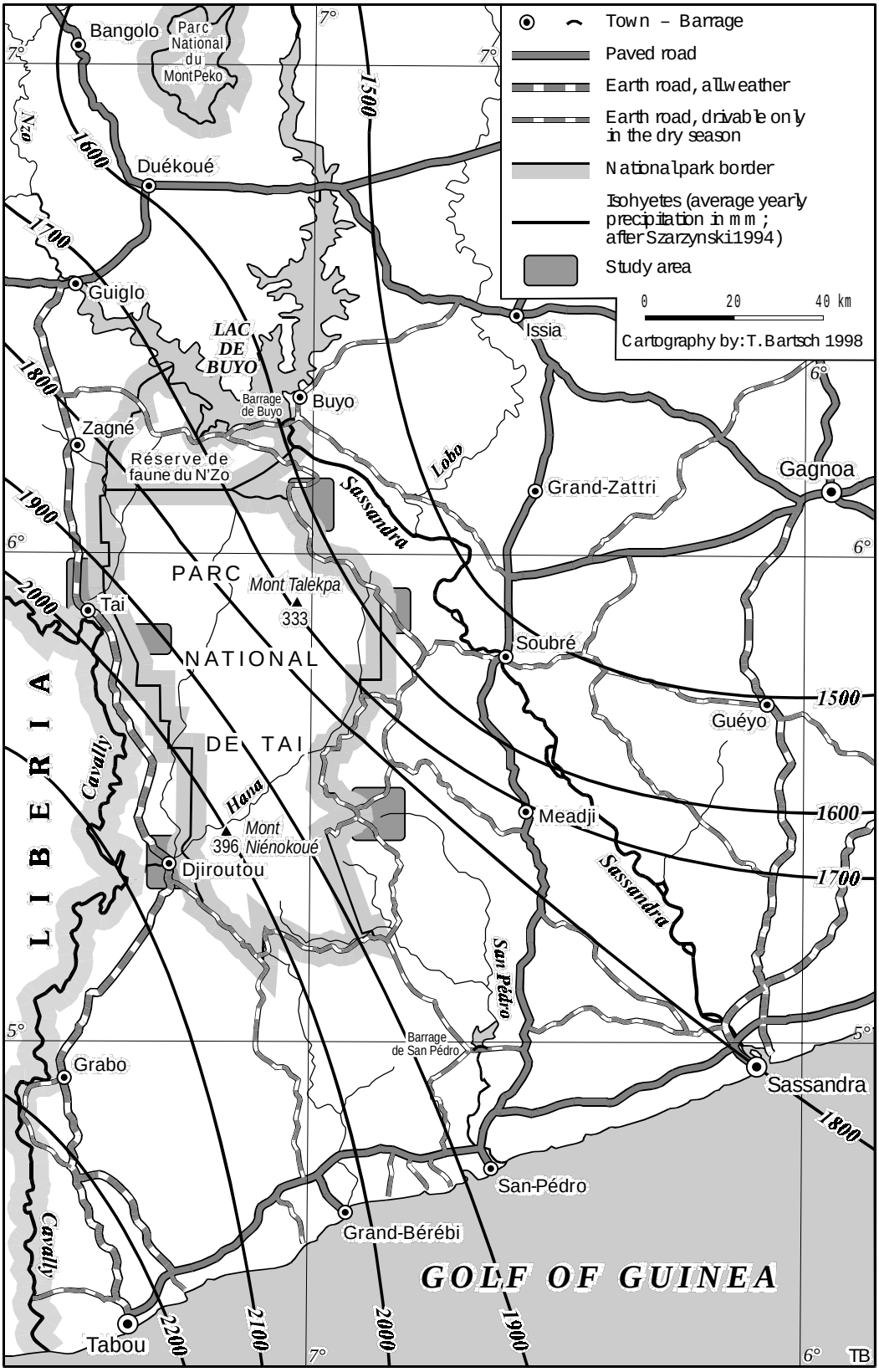
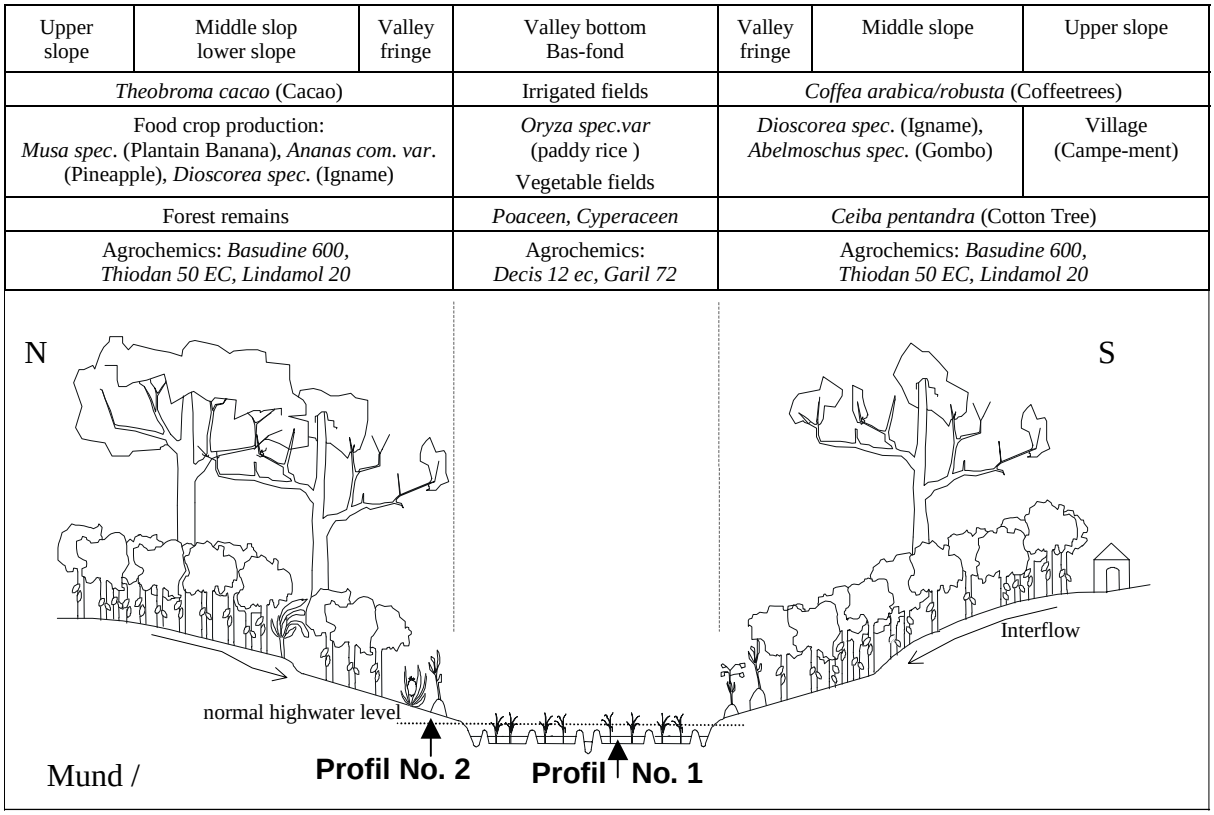


Fig. 3: Shematic toposequence of the agronomic use of one inland-valley near Sagboya / V6, SW Ivory Coast (Design and Cartography by MUND/CHRIST, 1999)



Nearly 30 years ago, more than 80 percent of the investigated region in the south-west were covered by different types of the seasonal (semi-decidue) and evergreen (ombrophile) Guinean rainforests. The dominating local forest type is a subassociation (Bas Sassandréenes) of the Guineo-congolian formation with a lot of endemic species (GUILLAUMET 1967). After the completion of a bridge over the Sassandra river near Soubré in 1970, an extensive exploitation of the rainforest was begun in the south-west of Ivory Coast. Today, nearly 30 years later, this process of exploitation has come to an end with the support of the last concessions given by the Ivorian government in 1996. According to new estimations (ANHUF 1997; GTZ/PACPNT 1998), today less than five percent of the original area of the nature forest are preserved along the eastern border of the Taï National Park. The major part of it can be found on rock outcrops and islands in the Sassandra river as well as in the inland-valleys. The natural vegetation of these inland-valleys often exists of a swampy forest, dominated by *Raphia sassandrensis* (Palmae) and *Raphia gigantea* (Palmae), *Mitragyna ciliata, Uapaca paludosa, Symphonia globulifera* and *Gilbertodendron splendidum* (GUILLAUMET 1967). Taller woody bushes and trees are often local *Diospyros* species, *Tarrieta utilis*, occasional *Ceiba pentandra*. The underwood is formed both by *Marantaceen* and different palms, as well as typical swamp plants such as *Alchornea cordifolia*, or *Cyrtosperma senegalense* and *Nephrolepis bisserrata* (GUILLAUMET 1967). Today, the vegetation cover of the bas-fond has changed fundamentally in consequence of the intensified production of cocoa, coffee, palmoil and hevea. Swampland, which is dominated by *Marantaceen* species, covers the valley

fringes and valley bottom soils. Occasionally, igname, cassava and further local food-crops such as gombo, tomatoes, cabbage and groundnuts are cultivated on this swampland area.

Morphology and Soils of the Inland-Valleys (Bas-Fond)

Since the seventies, a lot of multidisciplinary attempts at classifying the tropical inland-valleys in West Africa were made by AVENARD (1971), GILLET (1973), THOMAS (1974) and RAUNET (1985). The bas-fond are described as flat valleys with more or less broad (> 300 metres) valley bottoms with a low longitudinal slope in the area of the midstream and valley head of the dendritically branched out tributaries. The proper valley bottom soil consists of a specific mixture of colluvial and alluvial deposits, which overlap the widespread saprolitic crust, the weathered front of the basement rocks.
Particularly the valley bottom soil is modified by different processes of alluvial sedimentation or erosion, especially along the downstream part of the river. Due to the partly very low longitudinal slope a steep incised river course with pronounced terrace deposits is extremely rare in this region. Owing to the high discharge quantities, a distinct erosion edge of more than one metre is shaped in direction to the steep side slopes (fig. 4). The valley fringes are quite shortly developed with slope inclinations of 2-5° and they transfer gradually into the steep side slopes. On the middle of the side slopes steps with steeper inclinations over 10° occur frequently. This phenomenon is based on indurated plinthite layers developed in dryer times of the pleistozän. Near the crest on the upper slope the inclination profile clearly flattens and changes to a relatively peneplain type or to an undulating to rolling upland, whose expanse can stretch over several kilometres, depending on the geological structure of the basement rock. A frequent flooding, which occurs on a few days during the whole year, is significant for this type of valleys in the south-west, but at least the groundwater level can be found near the soil surface (< 50 centimetres) perennial.
The term “bas-fond” or “bassins versants”, which is used in frankophone Africa, is similar to the more common English expression “inland-valley”, while the terms “dambos” and “mbugas” are more regional notations for the type of valleys in eastern and southern Africa. However, the name “fadamas”, which originates from a region in north Nigeria and south-west Chad, is used for rather flat and broad valleys with straight slopes of less than 3° in the sudanian savanna.
In the valley bottoms stagnic to umbric gleysols are mixed with gleyic arenosols, which content an overall very low amount of gravel (GEROLD 1997). The soil texture varies from sand to silt and its stratification can hardly be a result of its alluvial to colluvial origin. As a consequence of the hydromorphic conditions, together with low soil ventilation and wetness during the whole year, the decomposition rate of plant remnants is low and the humic topsoils possess a high organic-matter content. The ph-values fluctuate between 4.3 and 5.5 under the prolonged waterlogged conditions. Towards the footslopes and on the valley fringes colluvial ferralic arenosols with very low CEC rates are associated with low base saturated gleyic arenosols. The sideslopes are dominated by a distinct interdigitation of plinthic ferralsols and plinthic cambisols with high contents of iron concretions. Deeply weathered and strongly leached ferralsols with a high plinthic content are the characteristic soil types on crests and upper slopes in south-west Ivory Coast, as well as in many other regions of tropical West Africa. A representative association of the typical soil types in the south-west of Ivory Coast is presented as a toposequence in fig. 3 and as texture diagrams in the figures 4 and 5.

Fig. 4: Soil texture diagram of a valley bottom soil

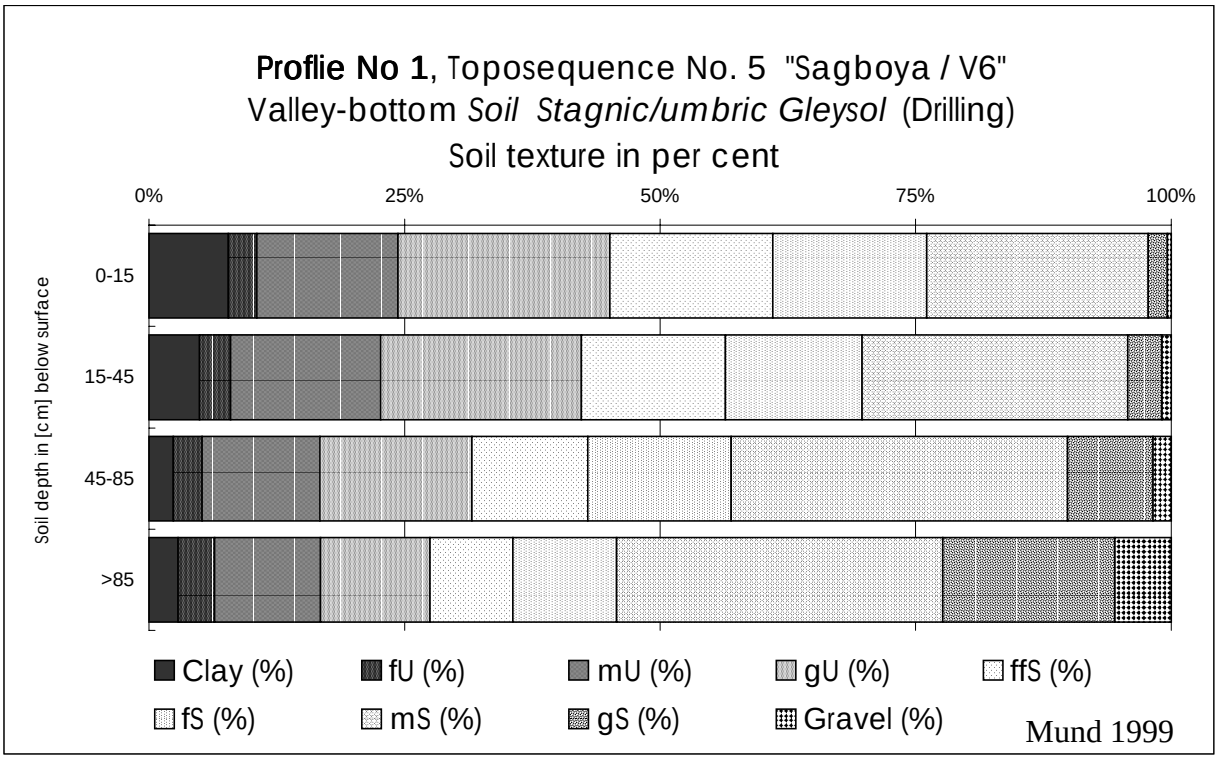
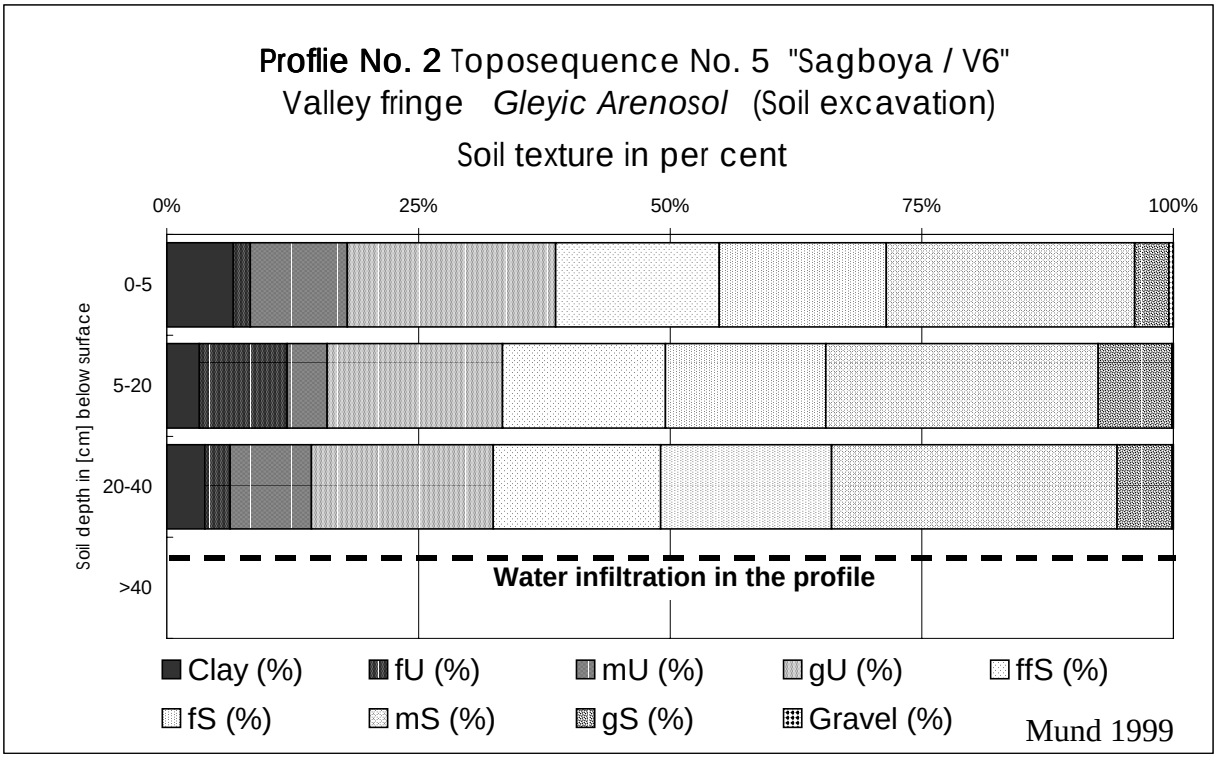


Fig 5: Soil texture diagram of a valley fringe soil



Agricultural Suitability for Irrigated Rice Growing

At first glance, the many investigated bas-fond situated in the south-west of Ivory Coast are indeed suitable for a semi-intensive smallholding cultivation of irrigated wet rice. Especially the high amounts of precipitation of over 1,600 mm, the ground water level near the surface, which exists all year round, as well as the almost continuous flooding during more than 100 to 150 days and the approximately non-seasonal inflow of lateral ground water are to be judged in a positive way. Furthermore, simple cultural and technical measures of rice cultivation, such as the small cultivated parcels of a size of 100-250 square metres or the simple ditch and drains with a low slope (approx. 2.5-5 ‰), can be done by the farmers as manual work and without machinery usage. Of course, the clearing of the chosen parcel between 0.5 and 3 hectare remains more labour-intensive compared with the traditional extensive production of igname, cassava and dry rice. But still, such an investment in a region, which, after twenty years of smallholding production of cocoa, has become a net importer of food, is definitely worthwhile in the face of the fact that the present production costs of 225 – 270 FCFA/kg (~0.5 $) confront almost all the year round the present local market prices for cheap imported rice of bad Thai and Vietnamese qualities to prices of 300 – 325 FCFA/ kg (~0.65 $). Apart from this, no alternative areas for long term fallows of the traditional field cultivation are available.

Table 1: Agrochemical products used on the neighbouring slopes of rice producing valley-bottom soil in southwest Ivory Coast

Product (common trade name)	**Active agent**	**Quantity**	**Dosing**	**Application type foging**	**Cultivation type**
Insectizides					
Basudine 600	Diazinon	600g/l	0,67l/ha	1-2x/a	Cacao
Diazol 60 EC	Diazinon	600g/l	0,65l/ha	4x/a	Cacao
Callifan 50 CE	Endosulfan	500g/l	0,5l/ha	4x/a	Cacao
Thiodan 50 EC	Endosulfan	500g/l	0,5l/ha	4x/a	Cacao
Thionex 50 EC	Endosulfan	500g/l	0,5l/ha	4x/a	Cacao
Thiosulfan 50 EC	Endosulfan	500g/l	0,5l/ha	4x/a	Cacao
Lindal 200	Lindan	200g/l	1l/ha	2x/a	Cacao
Lindamul 20	Lindan	200g/l	1,5l/ha	4x/a	Cacao
Gama 20	Lindan	200g/l	1,5l/ha	4x/a	Cacao
Ultracide	Metidathion	420g/l	1l/ha	2-4x/a	Maize
Decis 12 ec	Deltametrin	12,5g/l	1l/ha	2x/a	Rice
Garil 72 Trichlorpyr	Propanil	360g/l	5l/ha	1-2x/a	Rice
Herbizides					
Gramoxone Super	Paraquat--Dichlorid.	200g/l	1,5-3l/ha	2x/a	Cacao Rice

Although the valleys in the south-west of Ivory Coast are suitable for a smallholding finance-extensive irrigated production of rice from a geomorphological and -hydrological point of view, the investigated bottom soils can only be used, with a little technical and financial input, in a limited manner. Reasons for this are especially the concentrations of toxic (aluminium) iron, contained in the soil, as well as the low pH-values and the large fraction of sand in the migmatite-gneiss regions in direct surroundings of the Taï National Park, which make up more than 65 percent of the area. In these regions the capacity of storing water of the silty soils on the slopes confronts the repeated cycle of cultivation (> 200 days) without retention buildings with problems, despite of the higher contents of clay in the slate regions.
Additional, problems, which can develop out of a temporary interrupted interflow and can form small catchment areas in the upper reaches, occur. A hydrological estimation of minimum size of one catchment area is still to be made. However, the size of an area should not fall below 10-15 square kilometres. Otherwise not enough water would be available for the period of time the cultivation of two harvests, each period with a duration of 100 days, would need and thus, a small retention building would be necessary.
With regard to the pollutant loading of the soils of the through pesticides, bigger problems, whose detailed analysis still have to be done at the present, are still to come (tab. 6). In almost all regions, except the region in the north-east of the Taï National Park, more than 80 percent of the neighbouring slopes and plateaus are intensively cultivated with cocoa plantations. The

cocoa plants are treated with insecticides, herbicides and fungicides several times a year. An overall view of the usual products as well as their employment is presented in table 1. These products are especially combinations with *Lindan*, e*ndosulfanes* and the readily soluble *trichlorethyles*. They are principally used against damaging insects in the production of cocoa, at the moment twice a year an amount of 200 g per hectare is used. A leaching and shift of the pesticides' remains and metabolites into the bas-fond are to be expected, even though it could not be clarified yet, in which kind of dimension the remains are accumulated in toxic concentrations in the rice grain.

Prospect

The process of increasing importance of the numerous so far unused bas-fond in the south-west of Ivory Coast as suitable areas for irrigated production of rice with at least two yearly harvests, offers, on the one hand, the great chance for the diversified intensive production of food for local markets of the region to be introduced. Thus, the dependence on food imports could be reduced. On the other hand, the resistant pressure of use, caused by long term fallow systems and shifting-cultivation in the production of food, could be kept away from the borders of the national park and, eventually, could even be reduced in the remaining forests. Therefore, only a solid production of food below the present market prices can help to save the plants' acceptance of the borders of the national park. On the other hand, the intensive production of cocoa, due to the excessive use of agrochemicals, causes already today, after only 25 years, a problem for the production of food, which cannot be denied anymore. With these problems, especially the bas-fond are concerned, due to their specific pedo-morphological as well as their hydrological situation with lateral ground water. In accordance with these facts however, the chance, which the bas-fond also offer for the protection of the Taï National Park, should not be left out of consideration.

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