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Harald Lang

The Economics of Rainfed Rice Cultivation in West Africa

– The Case of the Ivory Coast –

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Meiner Mutter
zum Gedenken

Preface

Rice may be grown as an upland crop or as lowland wet rice. Demand is rising. Which type of rice cultivation deserves more emphasis in production development? Traditionally African farmers produced upland rice. In African agricultural production development, however, the emphasis during the last two decades has mainly been on irrigated lowland rice. The Asian experience seems to indicate that this is the modern and effective way to produce rice under tropical conditions.

Research in West Africa, however, indicates that in certain semi-humid and humid environments upland rice gives high yields, is profitable from the farmers' and the national economy's point of view, and may significantly contribute to the total rice output. Upland rice does not need to be produced in shifting systems. It may become - under certain edaphic and climatic conditions - a suitable crop for ecologically balanced systems of permanent farming.

This book informs about the economics of upland rice production in the Ivory Coast, where various types of upland rice are grown and where long-term research results are available. Much of the experience in the Ivory Coast is of value for upland rice production in general.

Hans Ruthenberg

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Harald Lang

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Introduction

Rice is one of the most adaptable crops in the world. It grows with millet, maize or groundnuts in the semi-humid regions, without irrigation and dependent only on rainfall as well as on river plains that are often flooded to a depth of several metres. It thrives in tropical lowlands, but is cultivated in Asia at altitudes of more than 3,000 metres above sea level. It is cultivated not only with simple hand implements by small farmers in shifting cultivation systems, but also in fully mechanised largescale farms where aerial sowing is practised.

The importance of rice in Asia is known, where about 9/10ths of the world's rice area is to be found. But rice has also acquired considerable importance in various countries in Africa. Leaving Egypt and Madagascar aside, this is particularly true of West Africa, where rice has for a long time been the staple food of the population over wide areas. In these regions, the per capita rice consumption reaches levels comparable with those in Asia. With few exceptions, these regions are almost exclusively upland rice cropping areas.

Even in those countries where most of the rice was produced by rainfed cultivation, development efforts to increase rice production in the past were concentrated on promoting wet rice cultivation. It is only in recent years that political decision makers have given more consideration to the development of rainfed rice cultivation as an alternative. The purpose of this study is to examine, from an economic point of view, to what extent and under what conditions the development of rainfed rice production is both profitable at the farm level and feasible from the macro-economic point of view and thus able to help solve the problem of supplying a growing population with rice. This analysis is based largely on data from Ivory Coast, although the basic conclusions

can be applied to other West African countries where similar natural conditions prevail.

1. Rice Production in West Africa

1.1 Extent and Significance of Rice Cultivation

In a world-wide context, Africa is an insignificant producer of rice. Taking an average of the years 1970 to 1974, only about 2.3 % of the world production of rice was attained from approximately 3 % of the world's rice area (WARDA 1975a, p. 478). About half the rice cropping area on the African continent is found in West Africa[1], although its share in production amounts to only some 30 %.

For a long time rice has been a plant which has been cultivated in West Africa. PORTERES (1950, p. 491) assumes that the species Oryza glaberrima STEUD., whose origin is presumed to be in this region, was cultivated as long as 3,500 years ago in the inland delta of the Niger. The "asiatic" rice Oryza sativa L. only came to West Africa with Portuguese sailors towards the end of the 15th century[2], and thereafter displaced the African species more and more (ANGLADETTE 1966, p. 16). Oryza glaberrima is still grown today to a limited extent in the inland delta of the Niger and in the mountain regions of the Upper Guinea Rift (MOHR 1969, p. 35), but it is becoming increasingly important in rice breeding on account of its resistance to various diseases and pests (CHABROLIN 1977, p. 12).

In 1975 more than two million hectares of rice were cultivated in West Africa. Total production amounted to 2.3 million t paddy[3] (FAO 1976a, p. 62). The importance of rice

---

1) Benin, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo and Upper Volta.

2) It is not impossible, however, that Oryza sativa came to West Africa even earlier on caravan routes via North Africa (MOHR 1969, p. 33).

3) Paddy (husked rice) is the harvest product of the rice plant, the rice grain being still enclosed by the husk.

in the various countries differs greatly, however. In Guinea Bissau, Liberia and Sierra Leone, rice is the staple food of the population. The per capita consumption of rice in these countries is over 100 kg per year, and is thus at a level that is otherwise found only in Asia. The same is true of extensive parts of Ivory Coast, Gambia, Guinea, Mali and Senegal, with the average consumption in these countries ranging between 50 and 90 kg rice per person and year[1]. In the other countries, rice has only local importance: the average consumption per inhabitant is low and amounts to 5-10 kg rice annually.

The most important rice producing countries of West Africa are Sierra Leone, Ivory Coast, Guinea, Liberia and, on account of its size, Nigeria. More than 80 % of the total production of the region comes from these countries (see Table 1.1), which are in general regions with relatively high rainfall, where in some cases rice cropping has been practised for centuries and has constituted the population's basis of life (USAID 1968, pp. 13 et seq.). Although the growth of rice production in West Africa has been about 3.8 % per annum in the past 15 years, and thus above that of the population, most West African countries are still not in a position to satisfy their needs for rice completely from their own production[2]. About one quarter of the rice consumption in the region has to be covered by imports. As we can see from Table 1.2, only Niger, Upper Volta and to a certain extent Guinea have succeeded in reducing rice imports to any notable degree since the beginning of the

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1) Mali is an exception with about 20 kg, because rice cropping is mainly restricted to the inland delta of the Niger and the extreme south of the country.

2) Niger, Nigeria and Upper Volta are now largely self-sufficient. In these countries only rice of very high quality, that is not locally produced, is imported.

Table 1.1: Development of rice production in West Africa

	Area (1000 ha)			Production (1000 t paddy)		
	1961-65	1970-72	1973-75	1961-65	1970-72	1973-75
Benin	2	4	4	1	6	7
Gambia	26	27	31	33	38	31
Ghana	33	58	72	34	57	87
Guinea	277	413	408	268	367	358
Guinea Bissau	66	30	37	48	36	30
Ivory Coast	249	286	319	220	347	404
Liberia	232	142	168	162	163	193
Mali	175	143	125	170	146	113
Mauritania	*	1	1	1	2	-
Niger	9	15	19	11	27	37
Nigeria	180	296	288	212	454	424
Senegal	76	79	74	100	81	78
Sierra Leone	273	337	367	336	464	491
Togo	23	25	23	19	17	14
Upper Volta	45	37	40	33	34	36
West Africa	1666	1893	1976	1648	2239	2303
Africa	3200	3995	4128	5480	7425	7108

- = data not available

* = < 1000

Source: FAO (1976a, p. 62); WARDA (1975a, pp. 438 et seq.).

sixties[1]. In all the other countries, the need to import rice has since risen, in some cases considerably, even though in some of them the efforts made in the past to promote rice production are now coming to fruition, and imports have been

1) In 1975 the import of rice in Ghana and Ivory Coast was negligible. This was attributable on the one hand to the good harvests in 1974/75 and on the other to the demand for rice having noticeably declined on account of the sharp rise in the consumer price (SODERIZ 1977, p. 5). In 1976/77 rice imports increased again in both countries.

Table 1.2: Development of rice consumption and rice imports in West Africa (annual averages)

	Consumption[a] (1000 t)			Imports (1000 t)			Value of imports (1000 US$)		
	1961-65	1970-72	1973-75	1961-65	1970-72	1973-75	1961-65	1970-72	1973-75
Benin	5	12	11	4,801	7,933	6,733	699	1,224	2,223
Gambia	29	35	32	8,560	10,757	12,727	1,056	1,155	3,148
Ghana	52	75	98	29,979	37,536	40,895	6,414	6,213	15,021
Guinea	202	257	256	32,920	25,670	30,400	5,237	3,933	10,533
Guinea Bissau	35	44	44	4,790	20,859	24,697	594	2,566	7,832
Ivory Coast	186	303	328	47,731	84,384	74,170	5,992	8,017	24,709
Liberia	172	134	153	32,476	48,316	37,050	5,070	8,274	13,923
Mali	-	115	115	-	20,015	41,430	-	2,563	14,518
Mauritania	7	17	30	7,000	15,900	30,000	966	1,839	6,200
Niger	9	18	24	2,015	403	301	321	79	121
Nigeria	129	275	257	1,280	2,632	2,291	282	647	1,061
Senegal	204	212	224	138,433	108,883	172,501	14,415	15,174	64,464
Sierra Leone	229	325	341	14,414	27,584	26,549	1,942	3,502	8,093
Togo	15	13	14	2,921	2,217	4,885	407	362	1,299
Upper Volta	24	22	23	3,234	1,320	*	545	180	*
West Africa	1,369	1,875	1,956	330,554	464,412	504,674	43,940	55,278	166,945

- = data not available
* = < 1000
a) Total of imports and local production

Source: FAO (1976a, p. 62) and FAO (1976b, p. 133).

declining since the beginning of the decade. We note at present for West Africa as a whole, however, that the imports are still increasing. In 1975, approximately 500,000 t of rice were imported, corresponding to a production volume of about 800,000 t of paddy.

Because of a shortage of supply on the world market, the prices of rice increased very sharply in 1973/74. During 1970/72 the average import price for West Africa was 120 US $/t, which rose to an average of about 400 US $/t in 1974, whereas towards the end of that year record figures of over 600 US $/t were reached (WARDA 1975a, p. 449). This increase of the world market price for rice led to a rapid growth in the need for foreign exchange, even in those countries that had been able to reduce rice imports (see Table 1.2). Compared with the period 1970/72, rice imports increased during 1973/75 by an average of 8.7 %, whereas expenditure of foreign exchange has more than trebled.

In the following years, the situation on the world market has stabilized again as a consequence of the good rice harvests in 1975/76 in Asia. The c.i.f. import prices (West African coast) have dropped to 200-300 US $/t rice, but are still twice as high as during 1970/72.

1.2 Types of Rice Cultivation and Their Occurrence

A whole range of different types of rice cultivation are found in West Africa, according to the variation found in the natural conditions. But cropping is not limited by natural factors alone, because socio-cultural influences and the impact of agricultural development programmes also play an important role (MOHR 1969, pp. 24 et seq.). The spread of individual forms of cropping from their original cropping areas to other regions occurred first of all through migration by the rice-growing ethnic groups who were anxious

to retain their consumption and cultural habits in their new environment (HAERINGER 1969, pp. 11 et seq.).

Today, however, the influence that predominates comes from the State. As a result of agricultural development programmes in a region, new forms of rice cropping may be adopted or rice as a new crop may be grown.

Table 1.3 presents details of the various types of rice cultivation and the main regions where they are practised in West Africa[1]. The transition from one type to another is sometimes smooth, and in practice we find many intermediate forms that cannot always be clearly categorised under any one type of cropping in this chart.

The terminology of rice cultivation is not uniform. A generally satisfactory classification of the types of rice cropping has not yet been developed. In general we differentiate roughly between wet rice (riz aquatique) and cropping on non-irrigated land (dry system, upland rice, rainfed rice, riziculture sêche or riz pluvial)(GRIST 1959, p. 113; ANGLADETTE 1966, p. 223; MOHR 1969, p. 37)[2]. This differentiation is adequate to denote the terms to be used in this study. Here the terms "rainfed rice" or "upland rice" are used to denote those types of cropping where the water supply to the plant is wholly dependent on rainfall. In contrast, "irrigated" or "wet rice" cultivation describes all forms of cropping in which measures of any kind are taken specifically to control the water supply to the plant so that the amount of water applied exceeds the rainfall. Cropping forms in which the roots of the rice plant draw on the groundwater (rainfed rice, riz pluvial sur nappe) or where the rice plants stand for a certain period of time in

1) See Appendix I.

2) Other authors differentiate according to the possibilities of water control (see JACQUOT 1973, p. 25), which usually gives rise to a different classification.

Table 1.3: Types of rice cultivation and their occurrence in West Africa

TYPE OF CULTIVATION	FEATURES	OCCURRENCE
1. Wet rice (riz aquatique)		
Irrigated rice (riz irrigué)	Complete control of the water supply and drainage. Cropped once or twice a year according to availability of water (storage capacity), mostly monoculture, transplanting method predominates. Yields 2-8 t/ha, average 3-4 t/ha, very low level of risk.	Developed only recently, no regional concentration, spread over the whole of the Sudan Savanna, smallscale irrigation projects also in the rainforest zone; about 3-4% of the rice area and 7-8% of the total production.
Mangrove rice (riz de mangrove)	Cropping on reclaimed mangrove swamps, in river estuary areas and the freshwater pool area of large rivers. Monoculture predominates, mostly transplanting method, yields 0.5-3.5 t/ha, average 1.5-2 t/ha, low level of risk on dyked land.	Coast between Gambia and Sierra Leone, in the freshwater pool area of larger rivers (Gambia, Great Scarcies, Little Scarcies) and in the Delta region of the Niger; about 5-6% of the area and 10-11% of the production.
Floating rice (riz flottant)	Cropping on the flood plain of large rivers, rice grows as the floods rise (up to more than 10 cm per day). Monoculture, direct sowing at the beginning of the rainy season, yields 0.5-3 t/ha, average 1.5 t/ha, very high level of risk.	Upper course and inland delta of the Niger (very important), Gambia and Senegal (hardly any importance), Sierra Leone and the valley of the Sokoto in Nigeria; about 10-11% of the area and 11-12% of the production.
Swamp rice (lowland rice, valley bottom rice, riz de bas-fond, riz innondé, riz de marais)	Cropping in valley bottoms with poor drainage or on strips along river banks. One or two rice harvests a year according to availability of water or cultivation of an additional crop (sweet potatoes, onions, etc.) after rice, transplanting method gaining importance, direct sowing still very common, yields 0.5-5 t/ha and harvest, average 2 t/ha, low level to very high level of risk according to the possibilities of water control.	Everywhere in West Africa, but not concentrated in any one area, frequently cultivated at the fringes of upland rice cropping areas and in the wet savanna region, about 20% of the area and 28-30% of the production.
2. Rainfed rice (dryland rice, upland rice, riz pluvial)		
Non-bunded rainfed rice (riz pluvial avec submersion)	Cropping on land that is mostly flooded towards the end of the vegetation period (up to about 40 cm). Monoculture, direct sowing at the beginning of the rainy season, yields 1-4 t/ha, average 1.5-2 t/ha, high level of risk.	Southern Senegal (Casamance), Sierra Leone, northern Ivory Coast and North Ghana; about 5-6% of the area and 4-6% of the production.
Rainfed rice (riz pluvial sur nappe)	Cropping on land where the roots of the rice plants draw on the groundwater, rotation with rainfed crops (millet, groundnuts, etc.) predominates, direct sowing at the beginning of the rainy season, yields 0.5-3 t/ha, average 1.5 t/ha, high level of risk.	Southern Senegal, North Ghana, 2-3% of the area and about 2% of the production.
Upland rice (rainfed rice, riz pluvial strict, riz de montagne)	Cropping on well-drained soils, mostly within shifting cultivation. Frequently mixed cropping, rotation essential for phytosanitary reasons, direct sowing at the beginning of the rainy season, yields 0.5-6.5 t/ha, average 1-1.5 t/ha, level of risk with favourable rainfall distribution moderate, otherwise very high.	Guinea, Sierra Leone, Liberia, West Ivory Coast, southern parts of Togo and Benin, south west Nigeria; 50-55% of the area and about 33-36% of the production.

Source: Compiled by the author from APE (no year), CHABROLIN (1977), Le BUANEC (1975a), MOHR (1969), USAID (1968), WARDA (1974a).

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water (non-bunded rainfed rice, riz pluvial avec submersion) are strictly speaking forms of wet cropping, although they are subsumed here under the term "rainfed rice cropping". However, both forms of rice cultivation are of secondary importance in West Africa compared with upland rice (riz pluvial strict).

1.3 The Problem

As a food crop, rice is becoming increasingly important in West Africa. This is true not only of those regions where it has already been cultivated for a long time and forms the basis of life of the population, but also of those countries that hitnerto have had a relatively low *per capita* rice consumption. Two basic reasons can be given for this development:

- Rice is a food preferred by the urban population, that is increasing much more quickly than the population as a whole because of the high rate of urbanisation.
- In regions where rice is not a staple food it is mostly a food consumed by people having a higher standard of living, and it reveals a relatively high income elasticity of demand.

The result of both factors is that rice replaces in particular tuber and root crops (cassava, yam) and plantains, as well as other kinds of grain (maize, millet and sorghum) as the most important foodstuff. The changes in the structure of consumption in conjunction with a high growth rate of the population have led to a situation where in many West African countries the production of rice can no longer keep pace with the growing consumption.

A priority target in the agricultural development policy of West African countries is therefore the promotion of rice cultivation and the increase of production until complete self-sufficiency is achieved (WARDA 1974a, p. 2).

In the past, almost all the attempts made to achieve this goal encouraged forms of irrigated rice cultivation. This, however, requires a high level of capital for investments in land development and irrigation, and in many parts of West Africa it represents a completely new form of land use for the farmers. Therefore, the development of irrigated rice cultivation in West Africa is expensive and usually leads only to a slow increase in rice production.

At present almost half the rice produced in West Africa is grown as an upland crop on a total area of more than a million hectares. In the key areas for upland rice cropping, i.e. in the region of the Upper Guinea Rift and the coastal strip, rainfed cultivation occupies 70-90% of the land devoted to rice, and supplies between 60 and 80% of total production. In spite of its importance, this type of cropping has only recently received more consideration by the political decision makers in these countries. This is all the more surprising since the production potential of rainfed rice was well known to agricultural research. DOBELMANN (1966, p. 1118) comments on the basis of findings principally from Madagascar: "Il n'est nullement question ... de vouloir prétendre à la diminution des surfaces irriguées, ni même à freiner les aménagements futurs. Il est encore moins question de vouloir faire la panégyrique du 'tavy' (rainfed cropping). Nous pensons seulement que la riziculture sèche, pratiquée sous une certaine forme et dans un certain milieu, peut apporter un renfort non négligeable dans la bataille de la production rizicole."

In many areas of West Africa, we find favourable natural conditions for the production of both rainfed and wet rice. The question then has to be asked whether and under what conditions irrigated or rainfed cropping forms should be promoted. The aim of this study is to investigate this problem in terms of examples from Ivory Coast and drawing on findings in other West African countries in order to

extrapolate the location factors under which rainfed rice cultivation in permanent arable farming or ley systems[1] is profitable for the farmer and feasible on the macro-economic level. The observations at the farm level, in which the various cropping methods at different levels of mechanisation are presented and analysed, is supplemented by two case studies from Ivory Coast. This is followed by the analysis of the question from the macro-economic point of view, where in this case wet rice is included as an alternative in the analysis.

1) See RUTHENBERG (1976a) for a definition of the farming systems.

2. The Economics of Rainfed Rice Cultivation at the Farm Level

2.1 Traditional Upland Rice Cultivation

2.11 Features of traditional cropping

The term "traditional" is defined as follows by SCHULTZ (1965, pp. 3 et seq.): "Farming based wholly upon kinds of factors of production that have been used for generations can be called traditional agriculture." If we adopt this definition, it is obvious that very diverse farming systems can be classified as traditional, according to the differences in the natural, ethnological and socio-economic parameters. In West Africa there are, however, a number of features that are common to all traditional farming systems in which upland rice cultivation is important:

- Traditional upland rice cropping is practised within shifting cultivation or bush fallow systems[1].
- Nearly all operations, from land clearance to harvesting, are performed manually with the help of simple tools. The use of animal power is very rare because the presence of the tsetse fly in the rainfed rice cropping regions almost always prevents traditional keeping of cattle.
- Labour and land are the most important production factors, with land still being abundant in many cases and labour representing the limiting production factor. The capital input is small and is restricted to hand tools and facilities for drying and storing the paddy.
- Most of the work is done by family labour. Hired labour is usually only employed seasonally (at times of peak

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1) One of the criteria used to differentiate the two systems is the intensity of land use. Thus RUTHENBERG (1976a, p. 15) employs the symbol R for the percentage ratio between the number of cropping years and the total years of cultivation and fallow. In this way an R value up to 33 refers to shifting cultivation. If the R value is between 33 and 66 we have fallow systems, that are specified according to the vegetation.
In keeping with the FAO's suggestion, the term "shifting cultivation" defines only those farming systems in which not only the cropping areas but also the farmstead is shifted. If this is not the case the term "fallow system" is applied (FAO/SIDA 1974, p. 17).

labour demand and for physically demanding work). Traditional forms of cooperation, like working collectively, helping neighbours, etc., are frequently practised. There is still a high degree of labour division on the basis of sex, with work involving clearing and land preparation being allotted to the men and weeding, harvesting, transport and sometimes threshing being carried out by the women.

- Yield-increasing inputs (mineral fertiliser, pesticides, etc.) are rarely applied. Similarly, dressed or cleaned seed is hardly ever used. As a rule, traditional rice varieties are grown that mostly belong to the Oryza sativa species. Oryza glaberrima is only found occasionally[1].
- Traditional upland rice cultivation is mostly practised as mixed cropping. Combinations with maize, millet or sorghum, cassava, yam and various kinds of vegetables (Hibiscus esculentus, Solanum melongena, etc.) or spice plants (e.g. Capsicum sp.) are frequently found. In some regions, shade conditions permitting, upland rice is also intersown in the first two years when perennial crops (coffee, cocoa or bananas) are being established.

Traditional upland rice cultivation in West Africa is mainly found in regions of the tropical rainforest or Guinea savanna belt, with average rainfall of about 1,500 to more than 3,000 mm per annum in a relatively long rainy season of 6 to 9 months[2]. The cropping techniques are similar in most respects:

Towards the end of the dry season, the farmers begin to clear the land. Brushwood is cut down with a matchet and some of the trees are felled, although roots and tree stumps are not removed to encourage rapid reforestation of the plot when it is no longer cultivated. Larger trees are usually left standing. After burning, towards the end of the dry season, stones and larger branches that are not destroyed by the fire are collected.

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1) In many cases the traditionally grown rice varieties scarcely differ from those which the agricultural extension service recommend to farmers for improved cultivation (see section 2.13).

2) "Riziculture de nappe" and non-bunded rainfed rice (riziculture avec submersion) are exceptions that are frequently found in the savanna region (see Table 1.3).

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Provided no loosening of the soil is necessary, rice is sown broadcast after the first rains and worked into the soil with a short-handled hoe without any further land preparation. Sometimes rice is also planted. Crops that are grown together with rice on the same plot are often sown by mixing the seeds with rice (millet, sorghum, maize, various vegetables) or mostly by interplanting them in the rice field (cassava, bananas, yam, etc.). The time for sowing rice and the mixed crops can differ considerably according to the water requirements of the different crops.

Weeding usually begins very late (5 to 8 weeks after sowing) and is carried out continuously up to about the time of coming into ear. In some places, however, weeding is completely ignored (van SANTEN 1974, p. 27). A few weeks after sowing, a fence made of such materials as branches, woven palm leaves, etc., is built to protect the rice field against bush rats (Thryonomys swinderianus). As soon as the first rice plants reach the milk stage, the fields are guarded by day until harvesting to prevent losses, particularly through birds (weaver birds). This job is often left to children. In some regions the rice fields are also guarded, for the same reasons, for about 10 days after sowing.

Harvesting is still carried out in most cases using a small knife, with which each single panicle is cut off. The panicles are bundled, and transported, dried and stored in this form. Threshing is done with sticks as required. Then the paddy is cleaned and sold or further processed for home consumption.

After the rice, sometimes a second rice crop, but mostly other food crops like groundnuts, maize, yam, sweet potatoes, etc. are grown. Cassava is very often planted as the final crop. This crop is gradually harvested according to need, and becomes overgrown in the course of time by the fallow vegetation. The period of land use and the duration of the fallow are influenced by various factors, with the

soil quality and availability of land playing an important role. Where the population density is low, the fields are often cultivated for only one year, and it is not uncommon for the subsequent fallow to last for 10 to 15 years or more. As a rule, however, a field is not used for more than 3 to 4 years, and the length of the fallow is on average 6 to 10 years[1].

2.12 Costs and returns of traditional upland rice production

The average yields of traditional upland rice in West Africa are taken to be 8 to 10 dt/ha (MOHR 1969, p. 53; ARE no year, p. 16; Le BUANEC 1975a, p. 362; CHABROLIN 1977, p. 10). As can be seen in Table 2.1, the yields fluctuate between about 6 and over 20 dt/ha[2]. The reasons for these differences in yield are:

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1) The figures fluctuate from 3-4 years to about 15 years. McCOURTIE (1973, p. 14) estimates the average fallow in Liberia to be 10-14 years. Van SANTEN (1972a, p. 20 and 1973, p. 22) gives an average of about 5 years (ranging between 2 and 9 years) for Bong County in Liberia, and for the north east of the country he states an average of 10 years, with figures between 4 and 20 years. CURRENS (1974, p. 168) estimates the fallow period in North West Liberia to be at least 10 years.

   JORDAN (1964, p. 29) estimated the length of fallow in Sierra Leone to be 3-4 years in forest regions and 6-10 years in the grass savanna area. SPENCER/BYERLEE (1977, p. 22), on the other hand, estimated averages of 7-12 years in the northern part of the country and 8-15 years in the south.

   GUINARD (1961, p. 161) estimated an average fallow of 5-10 years at the end of the fifties in West Ivory Coast. Estimates in a regional study at the beginning of the sixties are 6-8 years (BDPA, no year, p. 27). SCHWARTZ (1971, p. 210) gives an average figure of 6 years, that is confirmed by the author's personal surveys (5-6 years) (see section 2.3221).

2) See page 18.

Table 2.1: Yields and related features of traditional upland rice production in West Africa

Region	Year	Average yield (kg/ha)	Range (kg/ha)	Coefficient of variation (%)	Average annual rainfall (mm)	Quantity of seed (kg/ha)	Labour input (ME-days/ha)	Length of fallow (years)
Sierra Leone								
- Northern coastal region 1)	1971/72	580	-	-	2800-3800[e)]	-	156	-
- Southern part of country (without coast) 1)	1971/72	1450	-	-	2500-3500[e)]	-	239	8-11
- North eastern part of country (without coast) 1)	1971/72	810	-	-	2200-2900[e)]	-	286	10,4
- Western Area 2)	-	780	-	-	2500-3000[e)]	84	165	-
Liberia								
- Lofa County 3)	1972	1470	1210-1860	13,9	2640	51	269	10-20
- Foya Area 4)	1970/71	1270	560-2580	41,4		-	-	-
- Foya Area 4)	1971/72	2240	940-3920	40,1	2500	-	-	6
- Foya Area 5)	1971	1120	470-2000	-		56	208	10
- Bong County 6)	1972	970	500-2240	-	1900	34	94	5
- Country's average 7)	-	800	180-2640	-	1700-3500[e)]	54	277	10-14
Ivory Coast								
- Région de Man 8)	1959	1300	-	-	1700-1800	30-50	180-280	5-10
- Département de Biankouma 9)	1974	1740	430-2520	27,4	1800-1900	50-80	214	5-6
- Western region 10)	-	1090	120-2160	-	1800-1900	50	-	6
- Western region 11)	-	1410[a)]	-	-	1700-2300	-	-	6-8
		940[b)]	-	-		-	-	
- Central region 12)	1962/63	910	800-1490[c)]	-	1100-1300	60	229	8-9
Nigeria								
- Western Ishan District 13)	1970	2050	1530-2820[d)]	19,7[c)]	1900-2100[e)]	52	283	-
- Western State 14)	1969/70	1900	1020-2600[d)]	26,8[c)]	1400-1800[e)]	-	210	-

a) grown as a sole crop b) grown as mixed crop c) averages for the sub-regions d) averages at village level
e) estimated by the author according to WALTER/LIETH (1960) and COCHEME (1971)

Source: 1) SPENCER 1974a; 2) MITRA 1970; 3) CURRENS 1974; 4) VAN SANTEN 1972c; 5) VAN SANTEN 1972a; 6) VAN SANTEN 1973; 7) McCOURTIE 1973; 8) GUINARD 1971; 9) compiled by the author; 10) SCHWARTZ 1971; 11) BDPA no year; 12) SCI/MINISTERE DU PLAN no year, Tome 2; 13) OBOH 1970; 14) OSIFO 1971.

- The effects of climate, especially of rain. The experience gained from agricultural research shows that it is not so much the level of the annual rainfall as its distribution during the vegetation period of rice that is of crucial importance (GIGOU 1973, p. 858; HADDAD/SEGUY 1972, pp. 424 et seq.; Le BUANEC 1972, p. 1206 and 1975a, pp. 360 et seq.; De DATTA/VERGARA 1975, p. 16). Radiation is another climatic factor (De DATTA/VERGARA, pp. 17 et seq.) that plays a significant role, especially in regions with high rainfall and a long rainy season (Le BUANEC, 1975a, p. 370).
- Differences in soil quality, since soils "derived from basic rock types give distinctly higher yields than those derived from acidic rocks... The well drained upland soils used for rice growing in West Africa mostly have a low natural fertility, because they are mainly derived from acidic rocks and are, moreover, strongly leached under the high rainfall regime of the areas in which they occur" (MOORMANN et al. 1974, p. 4).

The water supply interacts closely with soil and climate, the influence on yields increasing as the uncertainty of rainfall rises (De DATTA/FEUER 1975, p. 28; HADDAD/SEGUY 1972, p. 428; Le BUANEC 1972, p. 1207).

There are no empirical data available on the influence of the intensity of farming - either of the intensity of land use (R-value) or of the intensity of the factor input. As can be seen from Table 2.1, there is no evidence on the relationship between the input of seed or labour per unit of area and rice yields at a regional level.

If we compare the returns and costs of traditional methods of upland rice production, the examples given in Table 2.2 allow the following observations to be made:

Footnote 2 from p. 16:

2) The variation in the yields of rice between the individual farms is far greater and ranges between less than 200 kg/ha and approximately 4 t/ha. No statistical data are available on the fluctuations of rice yields over time. This kind of fluctuation is the result particularly of different weather patterns over the years. Other factors like weed growth, the incidence of disease and pests, are of lesser importance and partly correlate with the climate variables. In those regions where it is grown as the main food, rainfed rice usually shows relatively slight yield variations compared with other food crops.

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Table 2.2: Costs and returns of traditional upland rice production in West Africa

	Sierra Leone 1971/72[a] southern region 1)	northern region 1)	southwest region 2)	Liberia 1971/72[b] Lofa County[3]	Foya Area[4]	Gbanga Area[5]	average for country[6]	Ivory Coast Western Region 1974/75[7]	Nigeria[c] Western Ishan District[8]	Western State Wasimi	Ilaro[9]
Yield Paddy (kg/ha)	1,450	810	1,000	1,470	1,120	970	800	1,740	2,050	1,975	2,000
Producer price (FCFA/kg)	24.2	29.0	24.4	30.3	30.3	30.3	30.3	28.0[d]	42.9[e]	35.8	35.8
Gross Returns (FCFA/ha)	35,380	23,490	24,400	44,540	33,940	29,390	24,240	48,720	87,945	70,705	71,600
Total variable costs (FCFA/ha)	8,445	14,265	10,830	3,555	2,385	1,590	4,415	7,090	3,390	26,065	19,510
- seeds	2,425	2,815	2,050	1,545	1,705	910	2,040	1,960	1,880	1,740	1,695
- wage costs of hired labour	5,060	10,445	8,355	1,310	-	-	-	4,280	-	19,770	15,495
- small implements and tools	960	1,005	425	700[h]	680	680	2,375	850	1,125	695	510
- others (fertiliser, insecticides, etc.)	-	-	-	-	-	-	-	-	385	3,850	1,810
Gross margin (FCFA/ha)	26,935	9,225	13,570	40,985	31,555	27,800	19,825	41,530	84,555	44,640	52,090
Labour requirement (ME-days/ha)	250	296	257	269	208[f]	94[f]	277	214	283	217	201
Labour productivity (kg paddy per ME-day)	5.8	2.7	3.9	5.5	5.4	10.3	2.9	8.1	7.2	9.1	10.0
Gross margin per ME-day (FCFA)	128	66	85	158	152	295	72	215	299	297	336
Return to Family Labour[g] (FCFA/Family-ME-day)	120	42	67	158	152	296	72	213	299	355	415

a) 1 Leone = 332 FCFA
b) 1 US $ = 275 FCFA
c) 1 Nig.£ = 779 FCFA
d) On the basis of the producer price 1973/74 to ensure better comparability, since the price was raised to 65 FCFA/kg in 1974.
e) Estimated by the author on the basis of the seed price, since the price data are contradictory.
f) Without threshing.
g) Since land is not a scarce factor in the farming systems analysed here and since the capital input is negligible, interest costs are ignored.
h) Estimated by the author.

Source: 1) SPENCER 1974; 2) NJOKU 1971; 3) CURRENS 1974; 4) VAN SANTEN 1972a; 5) VAN SANTEN 1973; 6) McCOURTIE 1973; 7) Compiled by the author; 8) OBOH 1970; 9) OSIFO/ANTHONIO 1970.

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- The level of the gross margin is determined primarily by the yield. A second important factor is the farm-gate price of paddy, whereas the total variable costs are hardly significant.
- The total variable costs are determined to a decisive degree by the wage costs of non-family labour. Other costs (for seed, small implements and tools) are of secondary importance. If no hired labour is employed, the total variable costs constitute only 5 to 10 % of the gross returns.
- Since in a regional comparison no relationship between labour input and yield is evident, labour productivity clearly declines with increasing labour input. The same applies, although less pronounced, to the profitability of the labour input.

Upland rice within traditional cropping systems compares frequently unfavorably with other crops with regard to the return to labour (see Van SANTEN 1974, p. 41; SPENCER/BYERLEE 1977, p. 60). This is particularly true of its competitiveness with cash crops like coffee, cocoa, oil palms, vegetables, etc., and in most cases it can be attributed to the price relations, which are unfavourable for rice in comparison with these (export) crops. Compared with food crops, on the other hand, upland rice competes considerably better, although there are no economic analyses available on this subject.

As already mentioned, labour represents the most important cost item in traditional cropping. Table 2.3 shows the details of the labour input in rainfed rice production in different cropping zones. Since rice is usually the first crop to be grown after land clearance, the labour input for this operation is considerable and, according to the type of vegetation, amounts to between 15 % and 40 % of the total labour input. Harvesting accounts for the highest proportion of labour input (25-40 %). Soil preparation, sowing and weed control each claim about 10-20 % of the total labour input. Protecting the fields from pests (construction of fences to keep out bush rats, scaring away birds, etc.) requires 20-40 days per ha, i.e. up to 20 %

Table 2.3: Labour input in traditional upland rice cultivation in West Africa (ME-days per ha)[a)]

Operations	Sierra Leone southern region[1)]	Sierra Leone northern region[1)]	Sierra Leone southwest region[2)]	Liberia Lofa County[3)]	Liberia Foya Area[4)]	Liberia Cbange Area[5)]	Liberia country's average[6)]	Ivory Coast western region[7)]	Ivory Coast western region[8)]	Nigeria Western Ishan District[9)]	Nigeria Western State[10)] Wasimi	Nigeria Western State[10)] Ilaro
Land clearance	37.5	47.2	55.5	59	59.5	42.4	79	60	50.1	48.6	81.8[h)]	70.9[h)]
- Removal of undergrowth	26.2	29.2	22.7	22	27.3	27.3	42	30	-	-	-	-
- Tree cutting			17.0	10	7.4		20					
- Burning and collection of branches, stones etc.	11.3	18.0	15.8	27	24.8	15.1	17	30	-	-	-	-
Land preparation and sowing	42.9	59.0	48.6	42	44.6	17.9	37	15	23.7	30.3	-	-
- Land preparation	-	-	23.7	-	-[b)]	-[b)]	-[b)]	-	-[b)]	-[b)]	-	-
- Sowing	-	-	24.9	-	-	-	-	-	-	-	9.6	19.3
Weeding	30.6	56.5	48.9	52	44.6	-[c)]	32	45	48.6	53.4	43.2	33.9
Fencing	43.2	37.8	-	-	14.9[d)]	7.4	20	-	7.8	11.0	-	-
Guarding[e)]			21.0	27	-	-	35	-	21.1	25.6	-	-
- after sowing	-	-	-	-	-	-	-	-	6.0	8.6	-	-
- before harvest	-	-	-	-	-	-	-	-	23.1	17.0	-	-
Harvest and post harvest operations	95.0	95.6	-	-	-	-	74	80	50.3	117.6	78.3	76.8
- Harvest and transport	84.2	85.0	51.9	89	44.6	27.3	47	25	36.3	82.4	60.0	67.7
- Threshing and cleaning	10.8	10.6	-	-	-	-	27	55	14.0	35.2	18.3	9.1
Total labour requirements for field work[g)]	195.2	247.7	204.9	242	208.2	95.0	215	145	166.5	225.7	194.6	191.8
Total labour requirements	249.2	296.1	225.9[f)]	269[f)]	208.2[g)]	95.0[g)]	277	200[h)]	209.6	286.5	212.9[h)]	200.9[h)]

a) Transfer of values to man-hours is not possible because of lack of information.
b) Land preparation before sowing is usually not practised.
c) Weeding was practised in only about 30 % of the holdings. The labour averaged 12.30 ME-days/ha.
d) Including construction of a guard's hut.
e) Per acre values are not transfered to values per ha because of important scale-effects.
f) without threshing and cleaning.
g) Without guarding and threshing.
h) without guarding.

Source: 1) SPENCER 1970a; 2) NJOKU 1971; 3) CURRENS 1974, p. 134; 4) VAN SANTEN 1972, p. 24; 5) VAN SANTEN 1973, p. 25; 6) Mc Courtie 1973, p. 36; 7) GAUDY 1959, p. 28; 8) compiled by the author; 9) OBOH 1970; 10) OSIFO/ANTHONIO 1970, p. 312.

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of the total labour input, although the data for these activities are uncertain, since guarding fields is frequently undertaken by children, and moreover considerable economies of scale can be expected. The total labour input amounts to about 200-300 days/ha, varying only slightly between the different regions.

2.13 The profitability of applying biological and technical innovations within traditional upland rice production

New varieties and mineral fertiliser are currently the most important technical improvements in traditional upland rice cropping[1]. The use of pesticides and herbicides is not common. Improved dressed seeds and mineral fertilisers are not generally supplied to the farmers seperately but in the form of the so-called "extension packages" combined with more careful cropping methods (row sowing, early and continuous weeding, etc.). The majority of the improved rice varieties that are recommended for use in traditional holdings by the agricultural extension service are varieties that have been derived by selection or hybridisation from the traditional varieties grown in a region[2]. The

1) The problems associated with introducing and extending technical innovations to traditional small farmers cannot be dealt with in further detail here. A detailed discussion can be found, for example, in ALBRECHT 1969; Von BLANCKENBURG 1967; PAYR 1977; ROGERS 1962 and 1969; RUTHENBERG 1969, 1972 and 1977a; SCHULZ 1973.

2) This applies, for example, to the varieties Anethoda in Sierra Leone, LAC 5 and LAC 23 in Liberia, Morobérékan and Paté Blanc in Ivory Coast and Parawan in Ghana (CHABROLIN 1977, pp. 11 et seq.). Some of these varieties have gained importance beyond their region of origin, e.g. the variety OS 6 from the former Belgian Congo that is widely grown today in Nigeria. Appendix II provides information about the most important rice varieties in West Africa.

yield potential of those varieties is between 30 and 40 dt/ha, and even without mineral fertiliser they outyield the traditional varieties (see Table 2.4). They largely possess those positive characteristics of the traditional varieties that make them suitable for labour-extensive cropping in small farms[1].

Table 2.4: The effect of mineral fertiliser application on traditional and improved rice varieties in Liberia[a]

	1971/72		1972/73	
	Trad. Varieties	LAC 23	Trad. Varieties	LAC 23
Yield without fertiliser (kg paddy/ha)	1,255	1,690	1,219	1,545
Yield with fertiliser (NPK 34-34-34)	1,725	2,330	1,570	1,690
Yield increase due to mineral fertiliser application (%)	37.5	37.9	29.8	26.9

a) Results from experiments on a total of 288 demonstration farms in smallscale holdings.

Source: Improvement of Upland Rice in West Africa (no year, p. 5)

A fundamental disadvantage of these varieties is that their yield response to mineral fertiliser is low, averaging 30 to 80 % according to soil quality, cropping intensity and variety. Higher nitrogen doses in particular usually bring

1) These features are, for example, lower demand for high soil fertility, resistance to diseases and pests, resistance to short periods of drought and low grain loss in the ripening stage. The introduction of very high yielding Asian varieties for rainfed rice cropping in West Africa failed because among other things they did not in some cases have these qualities, in particular the resistance to drought and *Piricularia oryzae*.

about an increase in vegetative growth of these varieties and not a higher grain production. This is illustrated in Table 2.5.

Table 2.5: The effect of nitrogen application on an improved upland rice variety in Ivory Coast[a)]

Fertiliser NPK (kg/ha)	Yield of Grain			Yield of Straw		
	Average kg/ha	Range kg/ha	Level of significance	Average kg/ha	Range kg/ha	Level of significance
0-45-60	1452	1039-2095	-	2392	1667-3619	-
21-45-60	1684	1101-2521	n.s.	3290	2632-5024	***[b)]
42-45-60	1826	1398-2448	n.s.	4115	3429-5000	***

a) Experiment that was repeated 10 times (50 m²/plot) with the variety Morobêrêkan on the agricultural research station Bouaké/Ivory Coast 1964.

b) Statistical significance of the difference between the averages on the 5% (*), 1% (**) and 0.1% (***) level.

Source: Calculated by the author based on STATION EXPERIMENTALE AGRICOLE DE BOUAKE (1965, pp. 24 et seq.).

The profitability of using mineral fertiliser depends on the nature of the production function and on the price relation between fertiliser and rice. Because of the different cropping conditions under which rainfed rice is cultivated in West Africa, it is essential that the fertiliser recommendations by agricultural extension services should correspond to the specific conditions of the various regions. This, however, cannot be achieved at the present time due to the lack of facilities in agricultural research in West Africa. Recommendations for mineral fertiliser application as guide lines for extension services apply, therefore, mostly to large regions or even to whole countries (Le BUANEC 1973, p. 6). Moreover, economic considerations are scarcely taken into account in this process, but this seems

to be wholly justified if the low level of fertiliser application and the variety of cropping conditions between holdings is oorne in mind[1].

Table 2.6 shows some examples of the profitability of mineral fertiliser application in traditional upland rice production in West Africa. The criterion for evaluating the profitability of mineral fertiliser in small holdings is usually not the change in the gross margin but the relation between marginal gross returns due to fertiliser application and the costs of fertilisers, which constitues a threshold for fertiliser application to the traditional farmer. The level of this threshold depends on the personal attitude of the individual farmer. According to RUTHENBERG (1977a, p. 134), the relation in West Africa should be at least 2:1 before traditional small farmers can be expected to adopt such an innovation. But Table 2.6 demonstrates that this is not so in all cases. The low profitability of mineral fertiliser application can mostly be attributed to the low yield response of the varieties grown[2]. The increase in

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1) If economic considerations are indeed taken into account, the optimum level of fertiliser application per hectare is usually established. The argument against this is that the limiting factor in many holdings is not land but capital, and thus the fertiliser input per unit of money invested ought to be optimised (WILSON et al. 1973, p. 7). Since the yield response of the varieties available at present is relatively low, i.e. the marginal returns to fertiliser application rapidly decrease, the optimum level is reached at relatively low quantities of fertiliser (N, P_2O_5 and K_2O each 20-30 kg/ha). If the criterion "optimisation per invested unit of money" is applied, this mostly leads to even lower quantities of fertiliser applied.

2) It is on this point that one of the main arguments against using mineral fertiliser in traditional cropping is founded. Upland rice is generally cultivated as the first crop on newly cleared land on which - especially in the tropical rainforest region - the supply of nutrients does not represent a critically yield-limiting factor, at least in the case of the varieties currently being grown (Le BUANEC 1973, p. 7). If, on the other hand, more pronounced nutrient deficiencies occur, small fertiliser doses scarcely have any effect (ANGLADETTE/DESCHAMPS 1974, p. 296).

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Table 2.6: Profitability of mineral fertiliser application in traditional upland rice production in West Africa

	Sierra Leone 1968[1]		Sierra Leone 1971/72[2]				Liberia 1971/72[3]		Ghana 1967[4]		
			Northern region		Coastal region						
	Trad. cropping	Fertiliser application (22-22-0)	Trad. cropping	Fertiliser application	Trad. cropping	Fertiliser application	Trad. cropping	Fertiliser application (30-30-30)	Trad. cropping	Fertiliser application (22-22-22)	Fertiliser application (45-45-45)
Yield (kg/ha)	1,140	1,800	800	1,440	580	920	995	1,230	1,200	1,835	1,940
Farm-gate price (FCFA/kg)	24.4[c]	24.4[c]	29.0[c]	29.0[c]	29.0[c]	29.0[c]	30.8[d]	30.8[d]	16.7[e]	16.7[e]	16.7[e]
Gross returns (FCFA/ha)	27,815	43,920	23,200	41,760	16,820	26,680	30,645	37,885	20,040	30,645	32,400
Costs of fertilisers (FCFA/ha)	-	2,950[f]	-	6,600	-	7,280	-	7,150	-	3,610	7,220
Increase in gross margin due to mineral fertiliser (FCFA/ha)[a]	13,155		11,960		2,580		90		6,990		5,140
Return-cost ratio[b]	5.5		2.8		1.4		1.0		2.9		1.7
Labour input (ME-days/ha)	257	277	307	314	165	171	-	-	-		-
Labour productivity (kg paddy/ME/day)	4.4	6.5	2.6	4.6	3.5	5.4	-	-	-		-
Gross margin per additional working day (FCFA/ME-day)	658		1,709		430		-			-	

a) Assuming that there are no variable costs other than those of fertilisers.
b) Additional gross returns related to the costs of fertilisers.
c) 1 Leone = 332 FCFA.
d) 1 US $ = 275 FCFA.
e) 1 £ = 252 FCFA.
f) subsidised

Source: Compiled by the author from 1) NJOKU (1971, pp. 144 et seq.), 2) SPENCER (1974a, pp. 12 et seq. and 1975b, pp. 32 et seq.), 3) WILSON et al. (1973, pp. 3 et seq.), 4) DJOKOTO (1968, pp. 106 et seq.).

labour input due to mineral fertiliser application (transport and application of fertiliser, more intensive weed control, more effort for harvesting and threshing, etc.) is slight compared to the total labour input (3 to 7 %). Even in the case of relatively minor increases in the gross margins, the return to the additional labour input is high, and in some cases is several times more than the average return to labour. On the other hand, it has to be borne in mind that these tasks usually occur at times of labour peaks, in which the marginal return to labour is higher than the average even without application of technical innovations.

In almost all West African countries, fertilisers are subsidised by the Government, which means that the costs of fertiliser per hectare, in terms of the corresponding amount of paddy valued at farm-gate prices, are reduced from 200-300 kg to 50-100 kg. This kind of price policy considerably improves the profitability of mineral fertiliser application at farm level, which is illustrated in the examples given in Table 2.7. Through heavy subsidies in Sierra Leone, e.g., fertiliser costs as a proportion of the gross returns per hectare are reduced from 15-30 % to a mere 2-9 %. In this way, the farmer's risk[1)] as regards the purchase of inputs is reduced, and in regions with a high yield potential this risk is negligibly small.

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1) The variation of yields is usually slight in regions with traditional upland rice cultivation. When yield-increasing inputs are applied, the liquidity problems are particularly significant in these cases, since rainfed rice represents the most important subsistence crop and only a small proportion of the production is sold. In regions of the Sudan savanna, however, that are subject to considerably higher yield fluctuations and where rainfed rice is grown mostly as a cash crop, the profitability of rice production, in other words the variation of gross margins over the year, is crucial as an evaluation criterion.

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Table 2.7: The effect of fertiliser subsidies on the profitability of mineral fertiliser application in traditional upland rice production in Sierra Leone

	Coastal region		Northern region		Southern region	
	1971/72	1974/75	1971/72	1974/75	1971/72	1974/75
Yield without fertiliser (kg/ha)	580		810		1,230	
Yield increase due to fertiliser (NPK 50-50-0)	375		650		800	
Producer price (FCFA/kg Paddy)[1]	27.5	61.0	28.9	61.0	27.4	61.0
Increase in gross returns (FCFA/ha)	10,320	22,865	18,790	39,630	21,900	48,775
Costs of fertilisers (FCFA/ha)						
- without subsidy	7,373	17,210	7,375	17,210	7,373	17,210
- with subsidy	2,455	2,455	2,455	2,455	2,455	2,455
Increase in gross margin due to fertiliser application (FCFA/ha)						
- without subsidy	2,945	5,655	11,415	22,420	14,525	31,565
- with subsidy	7,865	20,410	16,335	37,175	19,455	46,320
Return-cost ratio						
- without subsidy	1.4	1.3	2.5	2.3	3.0	2.8
- with subsidy	4.2	9.3	7.7	16.1	8.9	19.9
Additional labour input (ME-days/ha)	16		39		20	
Gross margin per additional working day (FCFA/ME-day)						
- without subsidy	184	353	292	575	726	1,578
- with subsidy	492	1,276	419	953	972	2,316

1) 1 Le = 332 FCFA

Source: Calculated by the author based on SPENCER (1975b, pp. 28 et seq.).

2.2 Mechanised Rainfed Rice Cultivation

The mechanisation of rainfed rice cropping, i.e. the use of animal power or tractors, demands the transition from bush fallow systems to forms of permanent arable cropping or ley systems, since the use of implements for land preparation is almost impossible unless the land has been completely cleared. A central problem in these cropping systems is the maintenance of soil productivity.

2.21 Mechanised rice production within permanent upland cultivation systems: results of research in Ivory Coast

The long-term experience from cropping experiments on agricultural research stations is available in Ivory Coast, and this experience permits conclusions to be drawn with regard to the change in soil fertility as a result of permanent arable cultivation. From an economic point of view, time-series analysis of crop yields would have been of particular importance, but this was not possible due to the lack of data. However, development of yields over time are discussed below, taking three experiments as examples.

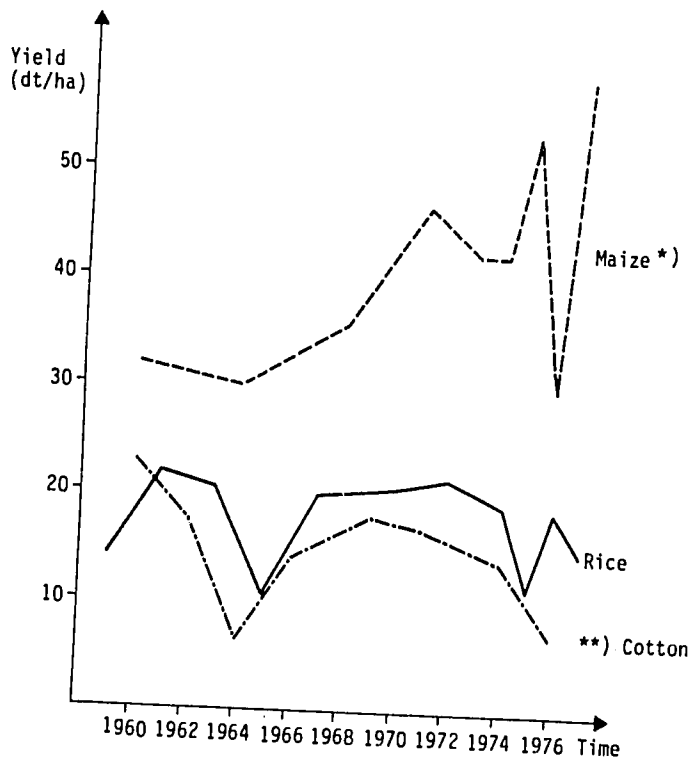
2.211 Permanent upland cultivation under humid conditions

This experiment has been carried out since 1959 in West Ivory Coast in a region with an average annual rainfall of 1700 mm[1]. After almost two decades of permanent arable cultivation without fallow and with a land-use intensity of 150 %, no reduction in yield of any of the crops grown

1) The details of the experiment and the climatic conditions are given in Appendix IV.

is apparent, although the quantity of mineral fertiliser applied is relatively low and no organic fertiliser application is practised apart from ploughing harvest residues into the soil. As can be seen from Diagram 2.1, the maize yields could even be raised through plant breeding, shifting to a hybrid variety.

Diagram 2.1: The yield development of maize, rice and cotton in permanent upland cultivation in West Ivory Coast 1959-1977



*) Cultivation of hybrid varieties (H 507) since 1971.

**) In 1975 the yield was very low because sowing was too late. The yield was not measured and is therefore ignored.

Source: RCI/MINISTERE DE LA RECHERCHE SCIENTIFIQUE/IRAT, Division d'Agronomie, Rapport Annuel 1974, 1975 and 1976.

The average maize yields of 41.7 dt/ha are very high, whereas rice yields of 18.1 dt/ha are relatively low. It has already been mentioned that one of the main reasons for these low yields is the dense cloud cover and the incidence of mist during the rainy season in this region, so that radiation is severely limited. The varieties grown, Morobérékan and Iguapé Cateto (see Appendix II), have a yield potential of 40-50 dt/ha that has never been reached even in years with very favourable climatic conditions. However, the yields are very stable, the coefficient of variation over time being only 22 % (maize 25 %). On the other hand, at 35 % the coefficient of variation of cotton yields is considerably higher. The average yield is 15.2 dt/ha seed cotton, which is, as in the case of maize, relatively high compared with rice.

After eight years of cropping, a part of the previously cultivated area was left fallow in 1967. A comparison of the soils of this part with the cultivated area after a further seven years of permanent cropping revealed no differences in soil texture (clay 26 %, sand 23 %). The permanently cropped plots are somewhat deficient in carbon, nitrogen and exchangeable salts, with the exception of potassium, a fact that can be attributed to the effect of fertiliser application. This applies to phosphorous too. The clear decrease in the pH value with permanent cultivation (4.9 compared with 5.4) can partly be attributed to the fact that no organic fertiliser was used. In the long term, the deficiency in organic matter represents one of the main agricultural problems (RCI/MINISTERE DE LA RECHERCHE SCIENTIFIQUE/IRAT 1974, Fascicule I, p. 70). Severe weed infestation is a further problem that is particularly important in commercial production. Soil erosion, on the other hand, is not an important problem in this experiment, and this can be related to the relatively small plots (0.2-0.4 ha) and the very gentle slope of the land. Thus the conclusions drawn from this experiment as regards soil erosion are very restricted.

2.212 Permanent upland cultivation under semi-humid conditions

A similar experiment has been carried out since 1960 at the agricultural research station Bouaké in the central part of Ivory Coast. The average annual rainfall is 1,200 mm, spread over two rainy seasons[1].

An initial analysis of the results[2] was carried out after 10 years of permanent arable cropping with green manuring. Le BUANEC (1972, pp. 1198 et seq.) draws the following conclusions:

- Since the land was always ploughed in the same direction, and the soil pushed down the slope of the valley, after only a few years narrow terraces were formed.
- No erosion problems have occurred, except in a few small areas at the foot of the slope, which were slightly affected by the surface run-off.
- The soil fertility potential could be maintained on the rest of the land. The soil texture and the content of organic matter and phosphorous, the pH value, the ion-exchange capacity and the total exchangeable salts remained the same.
- By applying improved cropping methods as well as biological and technical innovations, yields of yam and cotton could be raised by 35 %, while those of rice and maize could be increased by 60 and 85 % respectively within 10 years time (see Table 2.8).

No information is available yet about the effects of cultivation without green manuring since 1971. However, other experiments carried out in the region indicate that the yield potential of the soil can also be maintained with permanent cropping even in the absence of fallow or a fodder crop in the rotation (GERDAT 1975).

If we consider the development of the yields, this fact is also confirmed in the case under review (see Table 2.8).

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1) Appendix IV gives a detailed description of the experiment and of the climatic conditions.

2) Unless otherwise stated, all data is taken from Le BUANEC 1972, pp. 1191 et seq.

Table 2.8: The development of yields of a continuous cropping experiment in the central part of Ivory Coast 1960 - 1976
(Yields in dt/ha and coefficients of variation as a %)

Crop	Average yield		Coefficient of variation		Yields at the beginning of experiment average 1960-61	Yields after 9 years' cropping with green manuring average 1967-69	Yields after a further 7 years' cropping without green manuring average 1974-76
	1960-69	1971-76	1960-69	1971-76			
Rice	13.8	20.6	47.2	59.2	12.0	19.5	25.3
Maize	25.9	32.5	51.1	30.0	20.9	38.8	26.8
Cotton	12.0	10.6	36.9	17.0	10.3	13.9	10.4
Yam	138.3	99.3	33.9	43.2	121.8	167.7	107.6

Source: Le BUANEC 1972, p. 1207 et seq.; RCI/MINISTERE DE LA RECHERCHE SCIENTIFIQUE/IRAT; Rapport analytique exploitation, 1970, 1971, 1972, 1973, 1974 and 1975.

Grown in rotation systems without green manuring, yields of maize and rice are 25 % and 50 % higher than those in the rotations where green manuring is practised, although the yields are lower in the case of cotton and yam.

If we further compare the yields at the beginning of the experiment with those obtained after 8-10 years cropping with green manuring, and the yields after a further 6-7 years without it, the yield level seems to decline on account of the absence of green manuring. But in the case of rice, a yield of 35.8 dt/ha was achieved in 1975, which is the highest average yield to-date.

The interpretation of yield development is, however, difficult for the following reasons:

1. Climatic factors are conducive to the sharp from-year-to-year variations in yields making the comparison of averages, even over long periods of time, more difficult.
2. Soils are not homogeneous. The upper parts of the slope have a higher clay content and usually produce higher yields, although statistically significant differences exist only in the case of rice (Le BUANEC 1972, p. 1207).
3. The cropping methods are not uniform. Every year a section of the land is used for various experiments (tilling, application of herbicides, etc.). Moreover crop varieties grown have been changed. The yield increase of maize, and to a certain extent of rice, must be attributed partly to the use of higher yielding varieties. In a similar way, the decrease in yield of yam can be explained by the fact that in recent years the varieties cropped have been mainly of the type Discorea alata, which is much more suitable for mechanised cropping than Discorea cayenensis, but which has a lower yield potential.

Without further discussion of this problem in any more detail, we can nevertheless draw the conclusion from the experiments that permanent arable cultivation can be carried on under the given natural conditions in this regions without jeopardising the long-term yield potential of the soil[1] provided that:

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1) This is confirmed by long-term experiments in other regions of West Africa with similar natural conditions (see ROOSE 1967, COLONNA 1967, HADDAD/SEGUY 1972, BØ 1975 quoted in GRETZMACHER 1977).

- The necessary measures are taken to control soil erosion[1] (no cultivation of land with more than 3-7 % slope according to soil texture, contour ploughing, establishment of protective strips against erosion, the creation of a permanent soil cover by mulching techniques, etc.);
- nutrients losses and their removal by the crops are replaced in the soil by applying mineral fertiliser;
- by means of a sufficient supply of organic matter, the humus content of the soil is maintained and a drecrease in the pH value is prevented;
- diseases, pests and above all weed growth are effectively controlled.

These conditions can, however, not always be met outside agricultural research stations, and this endangers the success of mechanised cropping systems in the long run. GREENLAND and HERRERA (no year, p. 22) remark in this context that "in spite of many examples of mechanised development, combined with adequate inputs of fertilisers and pesticides, these techniques have nowhere been commercially successful", and draw the conclusion: "This is an eloquent testimony to their unsuitability for the agricultural development of these areas. What is required is not the translation of equipment and the methods shown to be appropriate to arable farming in the very different conditions of the northern temperate zone, but the devising of methods adapted to the humid tropics."

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1) Compared with other crops, rice produced excellent results in intensive cropping systems with regard to soil erosion (HADDAD/SEGUY 1972, p. 459). The factor C (the influence of the vegetation on soil erosion) comes to only 0.2-0.4 in the equation according to WISCHMEIER, whereas for maize or millet, for example, it is 0.4-0.9, for cotton 0.5-0.7 and for groundnuts 0.4-0.8 (RODSE 1977, p. 135).

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2.213 Permanent cultivation at different levels of technology

At the agricultural research station Bouaké, a continuous cropping experiment has been carried out since 1967 in which the influence of mineral fertilisers and stable manure under different methods of land preparation (hand hoe, ox-teams and tractor ploughing) on the yield development in permanent arable cropping is being investigated[1].

Because of the uncertain rainfall in the region, climate is a decisive factor determining yield[2]. If we consider the yields over time (Table 2.9), we can see that the variation of yields usually decreases as the level of inputs is increased, i.e. the more fertiliser applied[3] and the higher the degree of mechanisation, the smaller the relative yield variations[4].

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1) The experiment is described in Appendix VII.

2) Taking this experiment as an example, a method is presented in Appendix VII in which the yield uncertainty caused by the climate can be taken into account in the evaluation of the profitability of improved cropping techniques.

3) The decrease in the variation of yields on account of the application of mineral fertiliser is surprising, since we would expect that with irregular rainfall distribution the yield uncertainty caused by climate would be increased, because mineral fertiliser application:
   - encourages more vegetative growth of plants and thus raises the water requirements and shortens the period during which the plants can survive without yield losses (DOBELMANN/FALAIS 1968, p. 49);
   - leads to increased root growth in the top soil layers, in the case of shallow land preparation, and thus the plant's ability to cover its water requirements from deeper soil layers in lengthy dry periods is reduced (BERTRAND 1971, p. 385);
   - promotes weed growth and therefore increases the competition for water and nutrients.

4) Similar experience has been recorded from Senegal (BIGOT 1974).

Table 2.3. Average yields and yield variation of rice, maize, cotton and yam under different methods of land preparation in the central region of Ivory Coast 1967 - 1974
(Yields in dt/ha and coefficient of variation as a %)

Method of land preparation	Fertiliser quantity a)	Yam		Maize		Cotton		Rice	
		$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)
Hand-hoe	F_o	78.4	38	4.4	81	2.5	82	5.8	91
	F_1	112.5	43	22.7	53	6.7	58	11.6	86
	F_2	136.5	43	37.7	74	10.4	34	11.9	94
Ox-ploughing without manure	F_o	80.2	44	4.7	130	2.3	98	4.7	89
	F_1	116.5	41	18.9	64	5.9	65	13.2	91
	F_2	136.5	25	36.8	80	9.6	35	12.3	85
Ox-ploughing with manure	F_o	80.5	41	6.1	89	2.8	80	6.2	88
	F_1	147.4	30	24.8	89	8.9	39	12.2	86
	F_2	193.8	27	39.1	80	10.8	33	15.1	86
Tractor-ploughing	F_o	86.7	42	5.3	77	2.4	85	4.5	97
	F_1	141.3	38	33.3	94	8.0	28	12.3	83
	F_2	173.7	34	41.8	82	11.1	16	13.7	84

a) Fertiliser doses see Appendix VII.

Source: Compiled by the author from RCI/MINISTERE DE LA RECHERCHE SCIENTIFIQUE/IRAT, Rapports annuels, Division d'Agronomie, 1967 - 1974.

Because of the sharp fluctuations of yield over time, 7 to 8 years are too short to make solid statements on the development of yields. However, we recognise the tendency for yields to decline in the absence of mineral fertiliser or to remain constant at a very low level. With a slight mineral fertiliser application yields could be maintained at a medium yield level and could be raised slightly if th mineral fertiliser doses were doubled.

The difference in yields resulting from applying average and high fertiliser doses is evident for all crops, with the exception of rice, which produces just a small yield increase, with the variety playing an important role. The application of stable manure combined with the use of animal power produces yields that are higher than when mineral fertiliser is applied, and which reach levels similar to that achieved in semi-mechanised cropping. This fact underlines the importance of the supply of organic matter to maintain or improve the yield potential of soils.

With the exception of yam, mechanisation has no influence o the level of yield. Low yields in climatically unfavourable years cannot be avoided by means of deeper tillage operatio This is largely to be attributed to the ridging practised f yam cultivation, which even with the use of a hand hoe guar tees sufficient loosening of the soil and renders intensive soil preparation for the following crops superfluous (BIGOT, 1977, p. 243).

2.22 The profitability of mechanised rainfed rice productic

2.221 Investment in land development

The use of mechanical implements for land preparation presupposes the complete clearance of the land. Roots and the larger stones must be removed, laterite accumulations and termite mounds have to be destroyed and levelled. In addi-

tion a vehicle road network is required, but usually this does not exist and has to be constructed. The higher the level of mechanisation, the more care must be given to land development, and the higher the indirect investment in infrastrucutre.

With the use of animal power, clearance work can be carried out manually. If fairly large areas are to be cleared for mechanised cropping, the use of heavy equipment (caterpillar tractors) is normally indispensable[1]. The amount of investment in land development fluctuates widely according to topography, vegetation and the intensity of the land clearance.

Clearance by hand alone is only practicable if the trees have not grown too big. Experiments in Senegal indicated a labour input of 629 man-days/ha with a stand of 400 trees/ha of which 60 % had a trunk diameter of over 5 cm (Le GRAZ 1970, p. 4). If the felled trees are left on the field and burnt, the labour input is reduced to 394 man-days/ha. At an average cost of 250 FCFA/man-day, this would correspond to an investment of 98,500 to 157,300 FCFA/ha. In Ivory Coast, using a rope winch, the costs amount to 7,500 to 30,000 FCFA/ha (CFDT 1973, p. 80; CIDT 1974, p. 22). The productivity of a group of workers of 3-5 men comes to about 2.7 - 3.3 ha per month (CIDT 1975a, p. 24).

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1) This applies not only to the quality of clearance work, but also to its duration. When animal power is used, clearance work can sometimes last for several years, since cropping with ox-teams can be carried out on plots that have not been completely cleared. If tractors are to be used, clearance work with caterpillar tractors has the advantage of removing more effectively the obstacles to mechanical operations (and thus the danger of damage to equipment is reduced) and of enabling mechanised agriculture to be started in the first year after clearance, a fact which guarantees better use of machinery.

The costs of clearance by using heavy caterpillar tractors amount to 90,000 to 160,000 FCFA/ha. Table 2.10 illustrates the individual details of costs.

Table 2.10: Costs of mechanised land development in Ivory Coast (FCFA/ha)

	1974[1]		1975[2]		1974/75[3]	
	Savanna	Forest	Savanna	Forest	Northern Region	Western Region
Soil surveys	4,500		8,000			
Topographical work	10,000		10,000			
Felling trees, removing roots	41,000	69,000	44,800	74,500		
Pushing vegetation together on contour dams	22,000	29,000	23,800	31,000	66,400	96,000
Loosening the subsoil	15,000	18,000	16,700	19,500	20,000	20,000
Harrowing with heavy disc harrows	9,700		11,500		6,000	6,000
Digging of wells	3,500		3,500			
Total costs	105,700	143,700	118,300	158,300	92,400	122,000

Source: 1) AVB 1975, pp. 17 et seq.
2) VIRICELLE no year, pp. 18 et seq.
3) CIDT 1975a, p. 23.

Van SANTEN (1972b, p. 4) gives a figure of 605 US $/ha (166,300 FCFA/ha) for Liberia in 1971; in which, however, almost 75 % represent overheads which are not given in any specific detail. The costs of mechanised land clearance in the savanna region of North Ghana are considerably lower because of the less dense vegetation cover and come to 27,300 - 44,300 FCFA/ha (WARDA 1977, pp. 16 et seq.). WINCH (1976, p. 185) estimates the costs to be only 19,000 FCFA/ha.

Investment in land clearance represents fundamental improvements which add to the value of the land. If we assume an unlimited use of the land, the annual costs are simply the interest costs on capital invested in land development (REISCH/ZEDDIES 1977, pp. 64 et seq.). With the exception of the cost of maintaining the road network, the maintenance costs (e.g. erosion control by contour ploughing) cannot be separated from the normal production costs.

The advantage of an investment in land development has to be justified by an economic evaluation at the farm level[1]. In these evaluations we would have to bear in mind that, given the small farmers' ideas on profitability, the time horizon could be considerably less than the useful life of the investment, or, expressed in other words, that the actual equivalent of future incomes is underestimated and therefore high discounting rates have to be used (see also section 3.31).

Investment in land development, however, is frequently heavily subsidised or wholly financed by the Government, as in the case of Ivory Coast and partly in Ghana, Liberia and Sierra Leone. In such cases, economic considerations with regard to investments in land development are without or only of secondary importance for the individual farmer.

2.222 The profitability of rainfed rice production using animal power

The use of ox-teams in West Africa is found mainly in savanna regions with rainfall between 600 and 1200 mm/year. Upland rice is only of secondary importance in these areas (see MOHR 1969, pp. 36 et seq.). In those regions, however, where upland rice is an important crop, cattle are usually

1) Methods are suggested by HAX 1970; KÜHNE 1966; SABEL 1965 and SCHNEIDER 1971.

not kept. Only in the last few years in these regions, as for example in West Ivory Coast, have ox-teams been introduced in agricultural development projects, and the corresponding farming systems with permanent cultivation have started to be developed. There are scarcely any empirical investigations into the use of animal power in rainfed rice production in West Africa.

Apart from investment in land development, the capital requirements for the purchase of machinery, equipment and draught animals, if they are not raised by the farmers themselves, are in the order of 170,000 to 200,000 FCFA per ox-team. The price of N'Dama cattle in 1974/75 in Ivory Coast was about 130 FCFA/kg live-weight, i.e. about 30,000 to 32,000 FCFA/animal (230-250 kg). The cost of animal training amounts to about 20,000 FCFA/pair, and this is taken over by the Government (PROJET DE DEVELOPPEMENT RURAL no year, p. 7).

Multi-purpose equipment has proved practically feasible for land preparation. The purchase price is 30,000 to 40,000 FCFA for these "multiculteurs", 25,000 to 30,000 FCFA for a seed-drill (one or two rows), 50,000 to 60,000 FCFA for an ox-cart, and about 5,000 to 7,000 FCFA for a yoke, draw-chain, etc., coming to a total capital investment of 110,000 to 140,000 FCFA per ox-team. In contrast to traditional farming, where fixed costs are insignificant, annual depreciation costs of 15,000 to 20,000 FCFA for these implements have to be taken into consideration. In addition an annual rate of animal losses of 8-10 % can be expected in the case of draught oxen[1)] (CIDT 1975a, p. 19), and costs of 3,000 to 5,000 FCFA have to be paid annually for veterinary services (CIDT 1975a, p. 21). The total fixed costs

1) There is no depreciation cost for draught oxen, since they can be sold for at least their purchase price at the end of their period of use, if they have been properly kept.

amount to 23,000 to 31,000 FCFA per ox-team and year, which is, with a cropping area of 3-6 hectares per ox-team, 3,830 to 10,330 FCFA/ha[1]. The interest costs on capital invested[2] amount to 4,300 to 5,000 FCFA per team or 720 to 1,630 FCFA/ha. The interest cost on the investments in land development is usually small, due to the fact that clearance work is done mainly by hand.

Table 2.11 gives an idea of the costs and returns of rainfed rice production with draught oxen. For the economic evaluation, average yields at the regional level, and for comparison the average yields of the better holdings, have been used. If we compare the gross margins here with those of semi-mechanised cropping (see Table 2.14), we see that they are almost the same in the central region of Ivory Coast but lower in the West Region because of the higher average yields in semi-mechanised cultivation. The variable costs associated with the use of draught animals come to only 25-45 % of the costs of mechanisation for semi-mechanised cropping. However, if we include the fixed costs in our consideration, the differences are slighter[3], and tractor hiring becomes more competitive. Assuming constant yields, the effect of mechanisation on the return to labour is dependent on:

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1) The average cropping area per ox-team in 1973/74 (1974/75) was 3.4 ha (4.0) in the north and 4.1 ha (4.5) in the central and western regions. The planned cropping area per team is 6 ha (CIDT 1975a, p. 27).

2) The rate of interest for calculation purposes is 5 %. For the sake of simplicity, the interest costs were calculated on 50 % of the purchase price.

3) In the example from the western region, rates for tractor hire are very favourable, resulting in the high competitiveness of semi-mechanised cropping. But if tractor hire is not subsidised, the use of draught animals is in any case more favourable.

- the amount of labour saved by the various forms of mechanisation, and
- the level of wage costs, and the opportunity costs of labour in relation to the costs of mechanisation.

The use of animal power is usually less profitable than mechanised cultivation in as far as it involves a considerably higher input of manual labour. This is particularly true in the initial stage of expanding the use of draught animals, when the input of manual labour is still high because of the lack of experience with this cropping method. Nevertheless, animal traction can be advantageous, because it enables mechanical weed control to be carried out, since weeding represents a considerable part of the total labour input in semi-mechanised cropping[1].

Rainfed rice is highly profitable compared with other crops in the rotation, as Table 2.12 illustrates[2]. The corresponding break-even yields[3] concerning returns to land can certainly be achieved for yam in the central region of Ivory Coast[4], and the yield level is about equal to that of rice. For maize and groundnuts, however, due to the given price conditions, break-even yields are much higher than average yields even at very low rice yields of 10 dt/ha. In the case of cotton too, a yield level considerably

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1) The use of tractors for mechanical weed control is limited, because at this time high rainfall scarcely allows them to be employed.

2) This applies also if the yield uncertainty caused by climate is taken into consideration (see Appendix VII).

3) The break-even yields (prices) of two or more crops are the corresponding yield (price) levels when, assuming given production costs, the gross margins of the crops compared are equal. See REISCH/ZEDDIES 1977, pp. 20 et seq. concerning the method used.

4) If we assume a producer price of 15 FCFA/kg, as was paid in some cases in 1974/75, yam is far more profitable than all other crops. A price of 10 FCFA seems to be more realistic, since the demand for yam in Ivory Coast is limited, and the price elasticity is therefore very high.

Table 2.11: Costs and returns of rainfed rice production using draught oxen in Ghana and Ivory Coast

	Ivory Coast 1974/75[1]				Ghana 1973/74[2]
	Central Region		Western Region		Northern Region
	(A)[a]	(H)[b]	(A)[a]	(H)[b]	
Yield (kg/ha)	1,500	2,000	1,800	2,500	1,500
Producer price (FCFA/kg)	65		65		40.6
Gross returns (FCFA/ha)	57,500	130,000	117,000	162,500	60,900
Total variable costs[c] (FCFA/ha)	27,470 (28,070)		27,470 (28,570)		13,535 (17,245)
- seeds	7,875		7,875		2,200
- mineral fertiliser	14,875		14,875		1,585 (5,165)
- small implements etc.	400		400		1,035
- hired labour	-		-		5,580
- ox-team	4,320[e]		4,320[e]		3,135
- land development[d]	(600)		(1,100)		(130)
Gross margin[c] (FCFA/ha)	70,030 (69,430)	102,530 (101,930)	89,530 (88,430)	135,030 (133,930)	47,365 (43,655)
Labour requirement (ME-days/ha)	115	128	137	148	260
Gross margin per ME-day (FCFA)	609 (604)	801 (796)	654 (645)	912 (905)	182 (168)
Labour productivity (kg paddy/ME-day)	11.3	15.6	13.1	16.9	5.8

a) Average yield
b) High yield level
c) Without interest costs for running capital.
d) Interest costs (5 %) for capital investment in land development.
e) Costs of concentrates for 14 working-days (4 kg/day x 8 FCFA/kg) and maintenance and repair costs for implements.

Source: 1) CIDT 1975a, p. 30; 2) WINCH 1976, p. 76.

Table 2.12: Break-even yields with regard to return to land of the most important crops in farming using animal power compared with different yield levels of rainfed rice in Ivory Coast (prices 1974/75)

	Average yield (dt/ha)	Producer price (FCFA/dt)	Gross margin (FCFA/ha)	Break-even yield compared with rainfed rice at a yield of 10 dt/ha	15 dt/ha	20 dt/ha	25 dt/ha
Yam	120	1,000	88,350	69	102	134	167
Maize	18	2,000	33,270	20	36	53	69
Groundnuts	14	2,200	21,340	21	36	51	66
Cotton	10	6,500	51,450	8	13	18	23

Source: Calculated by the author.

higher than 1 t of rice is necessary to achieve equally high gross margins. However, it must be borne in mind that in those regions where cotton can be grown in the same year after maize or groundnuts, the return per unit of land from these crops increases. Thus, for example, assuming a rice yield of 20 dt/ha and an average maize yield of 18 dt/ha, the break-even yield of cotton would be only 13 instead of 18 dt/ha seed cotton.

If we consider the profitability of rainfed rice as far as returns to labour are concerned (Table 2.13), it is apparent that yam becomes less favourable on account of the high labour requirements, but maize and groundnuts compete better, whereas the competitiveness of cotton changes only slightly. It cannot be overlooked, however, that in the case of the other crops too the labour requirements change with different yield levels, a fact that was assumed in Table 2.11 for rice. This causes a somewhat smaller variation of break-even yields.

Table 2.13: Break-even yields with regard to returns to labour of the most important crops in farming using animal power compared with different yield levels of rainfed rice in Ivory Coast (prices 1974/75)

	Gross margin (FCFA/ha)	Labour requirements (ME-days/ha)	Gross margin per ME-day (FCFA)	Break-even yield compared with rainfed rice at a yield of 10 dt/ha	15 dt/ha	20 dt/ha	25 dt/ha
Yam	88,350	220	402	107	165	208	232
Maize	33,270	85	391	16	27	35	40
Groundnuts	21,340	90	237	18	29	37	42
Cotton	51,450	135	381	9	15	19	21

Source: Calculated by the author.

The use of average gross margins per ME-day is, however, of limited value and can sometimes lead to false conclusions when evaluating the competitiveness of these crops for labour, if the labour requirements of the crops differ over the course of the year. What is vital for optimal factor allocation is not the average return to labour but the return to labour in those periods when labour is in short supply. This problem has to be investigated in each individual holding and can only be solved by means of simultaneous planning methods.

But nevertheless we can draw the conclusion from this analysis, that rainfed rice cultivation is a profitable enterprise with regard to both, returns to land and labour compared to other crops in farming systems using animal power.

2.223 The profitability of semi-mechanised rainfed rice production

The term "semi-mechanised cultivation"[1] refers to those activities where ploughing, seedbed preparation and sometimes sowing is performed by tractors, with all other field work such as weed control and harvesting being carried out manually.

Apart from the investment in land development that is frequently subsidised or completely borne by the Government, there are no further investments at farm level, since the machine work is carried out mostly by the Government, co-operatives or private entrepreneurs. Except for the interest costs on the capital invested in land development, the burden of fixed costs in semi-mechanised farms does not differ from that of farms in the traditional sector, and as a rule it is negligible. The application of yield-increasing inputs in semi-mechanised rice production is limited to improved seeds (dressed and cleaned seed, sometimes varieties with a higher yield potential) and mineral fertilisers. Chemical plant protection is usually not practised. Compared with traditional cropping, yield increases of between 30 % and about 100 % are attained, as illustrated by Table 2.15. The mechanisation of land preparation has no influence on yields (see also section 2.213 and Appendix VII).

Under favourable climatic conditions, average yields of about 20 dt/ha can be achieved, and indeed with relatively

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1) If we define mechanisation as "any mechanical means used in the process of agricultural production" (KLINE et al. 1969, p. 1), strictly speaking the use of hand tools represents a semi-mechanised method of cropping. In the case under review, the term "semi-motorised cropping" would be more precise, but it is not used because the term "semi-mechanised cultivation" generally predominates.

w mineral fertiliser doses of 30-50 kg/ha N, 20-30 kg/ha O_5 and 20-40 kg/ha K_2O. As Table 2.14 demonstrates, semi-chanised rainfed rice cultivation under these conditions economically profitable at the farm level. The total riable costs as a proportion of gross returns amount to -30 %. If only average yields of 10-15 dt/ha are attained, is proportion rises to 40-50 % and, without Government bsidies for the input of machinery or fertiliser, to over % as, for example, in Sierra Leone and Ghana.

:cause of the higher yields, the gross margins are higher ıan those from traditional farming (see Table 2.2), and ıey are comparable to the gross margins achieved in farming ıstems using animal power (Table 2.11).

ıt when we draw these comparisons we must bear in mind the lfference in fixed costs. With mechanical land clearance, ıe annual interest costs on the capital investments in ınd development is approximately 6,000 - 8,000 FCFA/ha, ıich is nearly equal to the average fixed costs of animal-raction farming. If the Government finances the investment ı land clearance, semi-mechanised farming becomes more dvantageous. The labour productivity of semi-mechanised arming is considerably higher compared to traditional up-and rice cultivation, because of the higher yields and the ower labour input.

he labour input for field work in upland rice cropping is 0-100 ME-days/ha, and the total labour requirements are 50-160 ME-days/ha (Table 2.16). Non-bunded rainfed rice ultivation on the other hand, is carried out with a less ntensive use of labour, amounting to about 50-80 ME-days/ a. This is mainly attributable to the lower labour input or weed control, which is also one of the factors under-ying the lower level of yield.

Table 2.14: Costs and returns of semi-mechanised rainfed rice production in West Africa

	Liberia[1]	Ivory Coast				Nigeria[4]		Sierra Leone[5]	Ghana[6]	
	Foya Area	Central Region[2]		Western Region[3]		Abeokuta/ Ondo Circles	Oyo North Division	Bolilands[c]	Northern Region[d] Improved varieties	Northern Region[d] Traditional varieties
	1971/72	1972/73	1974/75	1972/73	1974/75	1970	1970		1973/74	
Yield (kg/ha)	2,350	1,800		2,300		2,050	710	1,395	1,250	1,050
Producer price (FCFA/kg)	30.3	28.0	65.0	28.0	65.0	35.8	35.8	29.0	40.6	40.6
Gross return (FCFA/ha)	71,205	50,400	117,000	64,400	149,500	73,390	25,420	40,455	50,750	42,630
Total variable costs[a] (FCFA/ha)	21,170 (29,490)	24,900 (30,850)	41,300 (47,975)	24,565 (31,750)	39,590 (47,505)	11,030	9,490	11,570 (25,505)	26,340 (33,710)	24,233 (27,275)
- seeds	2,335	2,700	5,200	3,375	7,875	1,310	1,165	1,920	4,485	4,480
- mineral fertiliser	13,240	9,300	12,300	7,890	14,875	3,445	310	1,310	2,630	930
- tractor hiring	5,095	12,500	23,300	8,000	10,000	680	6,975	na 5,740	(9,050) 11,040[h]	(3,025) 11,710[i]
- small implements, tools etc.	500	400	500	400	420	na	na	(19,675)	na	na
- hired labour	-	-	-	4,900	6,420	730	1,040	690	2,115	1,780
- land development[b]	(8,320)	(5,950)	(6,675)	(7,185)	(7,915)	4,865	-	1,910	6,070	5,330
Gross margin[a] (FCFA/ha)	50,035 (41,715)	25,500 (19,550)	75,700 (69,025)	39,835 (32,650)	109,910 (101,995)	na	na	na	(950)	(950)
Labour input (ME-days/ha)	141[e]	95[f][g]		117[f]		62,360	15,930	28,885 (14,950)	24,410 (17,040)	18,400 (15,355)
Gross margin per ME-day[a] (FCFA)	355 (296)	268 (206)	797 (727)	382 (321)	994 (927)	210[f]	104[f]	78[e]	43[e][g]	48[e][g]
Labour productivity (kg paddy/ME-day)	16.7	18.9		19.7		297	153	395 (216)	709 (537)	494 (431)
						9.8	6.8	17.9	29.1	21.9

Footnotes see page 51

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Footnotes for Table 2.14:

a) Without interest costs for capital. Non-subsidised values in parenthesis.

b) Interest costs (5 %) of total costs of land development.

c) "Bolilands are extensive low swamp grasslands in the central and northern part of Sierra Leone. Fertility is low and the area floods up to about half a metre for periods ranging from four weeks to three months" (SPENCER 1975a, S. 13). This type of rice cropping can be classified therefore as non-bunded rainfed rice cultivation (see Table 1.3).

d) Cropping on the so-called "valley bottom lands" (Fadamas) and in river valleys, which are inundated for several weeks towards the end of the rainy season. This type has to be classified therefore as non-bunded rainfed rice cultivation, too (ESPIG et al. 1975, p. 49).

e) Sowing, weeding and harvesting done by hand.

f) Land preparation and sowing done by tractor, all other operations by hand.

g) Threshing partially mechanised.

h) 15 % of the area harvested by combines.

i) 20 % of the area harvested by combines.

Source: Compiled by the author from 1) VAN SANTEN 1972a, pp. 29 et seq.; 2) AVB 1975, pp. 17 et seq.; 3) Author's survey; 4) OSIFO 1971, pp. 39 et seq.; 5) SPENCER 1974b, pp. 6 et seq. and 1975a, pp. 14 et seq.; 6) WINCH 1976, pp. 62 et seq.

Table 2.15: Yields from traditional and semi-mechanised upland rice cultivation in Liberia and Ivory Coast

	Liberia 1970/71[1)]		Liberia 1971/72[1)]		Ivory Coast[2)] 1974/75	
	T[a)]	M[b)]	T[a)]	M[b)]	T[a)]	M[b)]
Size of sample	16	13	15	21	30	29
Average yield (dt/ha)	15.3	28.1	22.4	33.5	17.4	23.0
Range (dt/ha)	5.6-25.8	4.0-55.4	9.4-39.8	12.6-68.6	4.3-28.8	13.6-32.0
Variety	trad.	Socotera 107	trad.	Socotera 107	trad.	Morobêrê-kan
Mineral fertiliser (kg/ha N-P-K)	-	29-17-17	-	29-17-17	-	45-23-23

a) Traditional cropping; b) Semi-mechanised cropping

Source: 1) VAN SANTEN 1972c, pp. 2 et seq.;
2) Compiled by the author.

From Table 2.17 we get an idea of the profitability of rain-fed rice compared with other crops in semi-mechanised agriculture in the central region of Ivory Coast. There are no fundamental differences in the break-even yields with regard to returns to land compared to animal traction farming (Table 2.12). The conclusions apply also to semi-mechanised cultivation. This problem is dealt with in more detail in sections 2.34 and 2.45.

Table 2.16: Labour input in semi-mechanised rainfed rice cropping in West Africa (ME-days/ha)

	Liberia[1)] Foya Area	Ivory Coast Central Region[2)]	Ivory Coast West-Region[3)]	Ghana[4)] Northern Region[a)b)]	Sierra Leone[5)] Bolilands[b)]
Labour for seed-bed preparation (burning the stubble, collecting stones, etc.)	-	11.5	20.7	-	17.5
Sowing (broadcast)	3	-	-	1.7	
Fertiliser application	2	5.2	2.1	1.5	
Weeding	62	53.7	50.6	9.7	10.8
Fencing	-	3.8	5.3	-	-
Guarding the fields	19[d)]	18.8	17.3	-	-
Harvest and transport	12	37.7	39.2	18.6	42.0
Threshing and cleaning	62	33.0	17.7	22.1	7.6
Total labour for field work [c)]	79	111.9	116.9	31.5	70.3
Total labour input	160	163.7	151.6	53.6	77.9

a) Data converted to ME-days (6^h/ME-day).

b) Non-bunded rainfed rice cultivation (see Table 1.3).

c) Without further processing or guarding the fields.

d) Data per acre have not been converted to per hectare, because there are considerable economies of scale.

Source: 1) VAN SANTEN 1972a, p. 29; 2) BONNEFOND 1971, Vol. 2, pp. 44 et seq.; 3) Compiled by the author; 4) WINCH 1976, p. 65; 5) SPENCER 1975a, p. 19.

Table 2.17: Break-even yields with regard to returns to land of the most important crops in semi-mechanised farming compared with various yield levels of rainfed rice in Ivory Coast (prices 1974/75)

	Average yield	Producer price	Gross margin	Break-even yield compared with rainfed rice at a yield of				
	(dt/ha)	(FCFA/dt)	(FCFA/ha)	10	15	20	25	30
				dt/ha				
Yam	125	1,000	86,300	65	96	127	158	189
Maize	19	2,000	17,100	24	39	55	70	86
Cotton	6.5[a)]	6,500	22,600	7	12	17	21	26

a) Average yields of 10 dt/ha seed cotton are given for cotton cropping with animal traction (see Table 2.12). This higher yield can be attributed to the fact that ox-teams were mainly introduced in Ivory Coast by the Compagnie Ivorienne pour le Développement des Fibres Textiles, that is principally interested in raising cotton production and concentrates its extension work on this activity.

Source: Compiled by the author.

2.224 The profitability of fully mechanised rainfed rice production

Fully mechanised rainfed rice cultivation in West Africa is confined to just a few largescale farms in Liberia, Ivory Coast and Nigeria. An exception to this is North Ghana, where a fairly large number of holdings have developed since the end of the sixties that practise fully mechanised rainfed rice cropping on farms of about 150 to in some cases over 400 ha. In this region, however, the type of farming is non-bunded rainfed cropping on land that is flooded up to 50 cm for several weeks towards the end of the rainy sea-

son and on which rice is continuously grown[1]. In contrast, upland rice has to be included in a rotation, and therefore, in this type of farming, there is usually the problem of finding other farm enterprises that can be integrated into a highly mechanised farming system and which are economically feasible.

The cultivation methods are the same as those of mechanised grain production in temperate climates. At the beginning of the rainy season the soil is ploughed and the seedbed is prepared with disc implements. Sowing is carried out using seed-drills with spacings of 30-60 cm between the rows (60-80 kg/ha). Sometimes broadcasting is practised. Mineral fertiliser doses are usually low: 40-60 kg/ha N, 30-60 kg/ha P_2O_5 and 20-60 kg/ha K_2O. Multinutrient fertilisers are mechanically applied before the first or second harrowing; nitrogen fertiliser is manually applied as top dressing between sprouting and coming into ear. Weed control with herbicides is mostly supplemented by hand hoeing. Mechanical weed control has proved impractical while the rice plants are young (RENAUT 1972, p. 233), and later it is scarcely possible because the high rainfall makes the land too wet to use tractors. Chemical weed control consists almost exclusively of contact herbicides. A mixture of Propanil (3-3.5 kg/ha) and Phytohormones (0.7-0.8 kg/ha 2,4-D and MCPA), if correctly applied, can effectively control weed growth after germination. Pre-emergence herbicides are not suitable (RENAUT 1972, p. 335), because shortly after application their effect decreases sharply and because there are problems that occur with irregular rainfall distribution. Harvesting is done with combine harvesters. Depending on the moisture content of the grains, the paddy has to be dried after harvest (usually air drying).

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1) As yet there is no information on whether this form of land use can be practised over quite long periods of time without endangering the yield potential of the land.

In some regions, yield losses through bush rats and weaver birds are very high. Therefore, the fields are fenced and are guarded for some days after sowing and before harvesting.

Table 2.18 presents examples form West Africa of the costs and returns of fully mechanised rainfed rice production. Some of the figures are actual data (Liberia, Ghana 1973/74), and some are model calculations based on information from largescale farms. The yield level of approximately 20 dt/ha is on average not higher than in semi-mechanised cultivation on smallscale farms. If rice is cultivated on the same field for several consecutive years, there is the danger of yields declining drastically (5-10 dt/ha), especially in regions with high rainfall, because of increased weed growth and the occurrence of diseases (mainly Piricularia oryzae) and nematodes (Van SANTEN 1974, p. 51).

The total variable costs are on average about 40-50 % of the gross returns, and they are much higher than in the case of semi-mechanised cultivation. The losses in the examples in Liberia are due to the high wage costs for bird scaring and the costs of chemical plant protection. In the other examples the gross margins are positive, and after deducting the fixed costs there is a profit of 20,000-30,000 FCFA/ha with average rice yields of 20 dt/ha[1].

Depending on the level of yield, the fixed costs per hectare[2] amount to about 30-70 % of the gross margin. This level of the fixed costs is influenced decisively by the efficiency of the agricultural machinery, since most of the capital

1) In Northern Ghana the profitability of fully mechanised rice cropping in 1974/75 could be guaranteed only because mineral fertilisers were subsidised. Without fertilisers being subsidised, cropping would only be profitable if the use of tractors were technically highly efficient and if the level of yield were over 20 dt/ha (FISCHER et al., Vol. 1, pp. 28 et seq.).

2) see p. 58

Table 2.18: Costs and returns of fully mechanised rainfed rice production in West Africa

	Liberia[a] 1970[1]	Liberia[a] 1971[2]	Ivory Coast 1974/75[3]	Ivory Coast 1971/72[4]	Ghana, Northern Region[b] 1974/75[4]	Ghana, Northern Region[b] 1973/74[5]	Ghana, Northern Region[b] 1974[6]
Yield (dt/ha	21.6	16.0	20.0	20.2		20.6	30.2
Producer price (FCFA/kg)	36.4	34.4	65	35.8	49.0	40.6	49.0
Gross returns (FCFA/ha)	78,625	58,240	130,000	72,315	98,980	83,635	147,980
Total variable costs (FCFA/ha)	135,530	124,665	63,645	36,035 (41,300)	48,230 (76,985)	35,790	38,195
- Seeds	6,275	6,275	7,350	3,460	5,315	4,200	6,010
- Fertiliser	16,810	12,900	16,350	5,480[f]	5,180[f]	5,705[f]	5,180[f]
- Herbizides, Pesticides	27,725	10,095	5,845	-	18,060[g]	-	-
- Variable machinery costs	13,485	14,945	23,140	3,965	5,110	13,120	13,650
- Hired labour	43.255[d]	77,410[d]	6,960	17,305	7,430	3,415	11,585
- Other costs (sacks, tools, etc.)	24,675[e]	.	2,450	4,110	4,840	3,475	-
- Interest costs on running capital[c]	3,305	3,040	1,550	1,715	2,295	875	1,820
Gross margin (FCFA/ha)	-56,905	-66,366	66,355	36,280	50,750	47,834	109,785
Fixed costs (FCFA/ha)			36,270[h]	18,250[i]	34,470[i]		5,130[k]
- Depreciation (machinery, implements and buildings)			18,510	7,530	15,830		21,280
- Maintenance and repair (machinery, implements and buildings)			5,930	5,490	11,190		12,400
- Other costs (admininistration, insurance, taxes etc.)			11,630	5,230	7,450		1,450[l]
Profit[m] (FCFA/ha)			30,085	18,030	16,280		74,655
Interest costs for capital investments in machinery, implements and buildings[n] (FCFA/ha)			1,370	1,140	2,330		3,750
Interest costs for capital investments in land development[o] (FCFA/ha)			7,190	1,440	1,880		2,110

a) 1 US $ = 275 FCFA.
b) 1 NC = 292 FCFA (1970/71) and 276 FCFA (1974/75).
c) 5 % for 6 months.
d) Guarding the fields.
e) Drying and storing.
f) Subsidised by the Government (50-80 %).
g) Aerial spraying included.
h) 370 ha of rice, performance of the machinery 90 ha/tractor and 185 ha/combine.
i) Supposing a performance of the machinery of 80 ha/tractor and 200 ha/combine.
k) Supposing a performance of machinery of 120 ha/tractor and 200 ha/combine.
l) Administration costs excluded.
m) The Profit is over-estimated, because there was no information on costs of borrowed capital.
n) 5 % p.a. from 50 % of the purchase price.
o) 5 % p.a. of the total investment in land development.

Source: 1) McKAY 1970; 2) McKAY 1971; 3) Compiled by the author, 4) FISCHER et al. 1975, Vol. 2, pp. 24 et seq 5) WINCH 1976, p. 101; 6) WARDA 1977, pp. 75 et seq.

Best Available Document

(80-90 %) is invested in machinery and implements (90,000-170,000 FCFA/ha). The efficiency of the machinery (tractors, combine harvesters and implements) is in turn dependent on:

- natural factors like climate, soil type, topography;
- the shape and size of plots and their spacial distribution;
- the quality of land clearance, and
- the technical and organisational efficiency of the utilisation of machinery.

The natural conditions are very important in rainfed farming. The level and distribution of rainfall and soil composition determine the period when sowing is possible[1)] and the days available for field work, especially for land preparation and harvesting. Together with the other factors they also influence how much time individual tasks take to complete, and thus at the same time they largely determine the variable costs of machinery. The shorter the time in which rice can be sown, the greater the need for more power, i.e. the greater the capital investments per hectare and the greater the production risks and losses, if timely operations are not adhered to.

Footnote 2) from page 56:

2) In the example in Ivory Coast, where upland rice is cropped as part of a ley-system, 90 % of agricultural machinery and implements and 50 % of all other overheads were attributable to rice production.

1) If the cultivation period is short, the time span for harvesting can be increased by using a combination of different varieties with different vegetational periods. But the length of time for sowing is frequently limited by the period in which a sufficient water supply to the rice is guaranteed (during coming into ear up to milk ripeness) and soil conditions allow the use of combines at the time of harvest.

2.3 Traditional and Semi-mechanised Upland Rice Production Under Favourable Climatic Conditions in West Ivory Coast

This case study is based on surveys that were carried out between February 1974 and March 1975 in five villages of the Sous-préfecture Biankouma, about 30 km north of Man (see map 1, Appendix III). A detailed description of the method of the investigation is given in Appendix V.

2.31 The study area

2.311 The natural conditions

The region where the survey was carried out is in the mountainous area of "Monts du Toura", an eastwards-running spur of the "Dorsale guinèen". It lies within the northern border zone of the tropical rainforest, in the transitional area to Guinea Savanna. Rainfall is 1,700-1,800 mm/year and occurs in one rainy season lasting from March to October, reaching its maximum of 300-350 mm in September[1]. Thus with regard to rainfall the western region is one of the most favourable rainfed rice cropping areas in Ivory Coast for varieties with a vegetation period of 110-150 days (GIGOU 1973, pp. 871 et seq.). The average annual temperature is 24.8°C, and there are only slight variations within the year. The pronounced relief pattern of this hilly landscape encourages the formation of microclimates. Soil erosion damage due to rainfall is high: the R-value on the Wischmeier scale is 800-900 (ROOSE 1977, p. 133).

Most of the soils on the plateaux and on the slopes belong to the ferralitic soils, which are usually deep, and from the point of view of their composition provide favourable

1) For data on climate see also Appendix IV.

conditions for arable cropping. The clay content is 30-50 %, and organic matter represents 4-8 %, which is relatively high. The pH-value ranges between 4.5 and 6. The content of exchangeable salts is low, and there is a general lack of phosphorous. The hydromorphic soils in the valley bottoms are pseudoglei or glei soils on a mostly very sandy substratum, and these soils are less suitable, therefore, to irrigation farming (BDPA 1966, Vol. 3, p. 17).

2.312 The socio-economic conditions

Compared with the national average, the area round the town of Man is relatively densely populated, with approximately 50 persons per km². Since the population is concentrated along the main roads, the population density in the survey area is even higher.

On account of its remoteness, the region has scarcely been economically developed. There is almost no industry (BORCHERT 1972, p. 122). Agriculture is characterised by smallholdings operating in the traditional manner. Rice is the staple food and is grown under rainfed conditions almost exclusively for subsistence[1]. Other foodcrops, like maize, cassava or plantains, are of secondary importance. The most important cash crop is coffee. Livestock-keeping (sheep, goats, poultry) is practised exclusively to supply domestic needs, and cattle are rarely kept. The land is cultivated by small family holdings. Private ownership of land is unknown, but transferable rights (inheritance, sale) can be acquired by the cultivation of perennial crops.

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1) In 1968, about 15 % of rice production was sold. This proportion may have risen slightly in recent years, particularly on account of the development of wet rice cultivation.

3.313 The development of mechanised farming

In the survey region, a development project was started at the end of the '60s whose aim was to test concepts for modernising the rural areas by setting up model villages. The main objectives of the project were as follows (RCI/MINISTERE DE L'AGRICULTURE 1966, p. 5):

- replacing the traditional shifting cultivation system by means of mechanisation and transition to permanent farming with crop rotations;
- improvement of the income of the agricultural population by raising farm and net cash incomes;
- changes in the traditional social structures by founding cooperatives;
- improvement of living conditions in the villages by building up an infrastructure (road building, digging of wells, etc.) and by granting credit for brick-houses.

The project objectives thus corresponded essentially with the targets stated in the five-year plan 1971-75 for agricultural development policy at the farm level (see RCI/MINISTRE DU PLAN 1971, p. 138).

The implementation of the project was the task of the "Service de Prévulgarisation"in the Ministry of Agriculture, and was taken over in 1975 by the Société pour le Développement de la Riziculture (SODERIZ).

The phase of mechanised farming began in 1969/70 with the foundation of a "Coopérative pour l'Utilisation du Matériel Agricole" (CUMA). This farm machinery cooperative was equipped with two tractors wit their implements (disc plough and disc harrow, drill machine, slasher and trailer). By 1971, 220 ha of land had been mechanically cleared by the Government and about 30 ha manually by the farmers. Because the mechanised operations were discontinued in two villages on account of the farmers' unwillingness to pay, only about 200 ha of this land were cultivated in 1974/75 with tractors. Participation by the farmers in the project is voluntary,

but if they do join, they are obliged to comply with the instructions of the extension staff[1]. In 1974/75 the CUMA had 122 members.

2.32 The organisation of farms

2.321 The resource base

2.3211 Labour

Since no permanent hired labour is employed, the supply of labour to the farms is determined fundamentally by family size (r = 0.875***). The basic social unit of the Yacouba is the simple family, consisting of the head of family, wife or wives, children and sometimes other people who are mostly close relatives of the head of family. The labour force of the semi-mechanised holdings is on average 4.5 ME[2], and is therefore significantly higher compared to the traditional holdings (3.2 ME) on account of the farmers' larger families[3].

Table 2.19 shows that above all the older farmers with their generally larger families (because of the fairly high level of polygamy) are more represented among the semi-mechanised holdings.

Labour force per unit area is the same in both groups (0.65 ME/ha cultivated area) and decreases as the farm size in increases (r = -0.547***).

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1) This form of organisation thus has features in common with contract agriculture and "production under close supervision" (see RUTHENBERG 1973, pp. 238 et seq.).

2) See Appendix V for calculations.

3) It was also possible to observe this in similar projects in the central west region of Ivory Coast, in which "les attributions de champs sur bloc de culture semi-motorisée se sont en effet localisées plutôt dans les groupes disposant d'une main d'oeuvre abondante" (RCI/MINISTERE DE LA RECHERCHE SCIENTIFIQUE 1977, p 12).

Table 2.19: Demographic features and labour supply on traditional and semi-mechanised holdings in West Ivory Coast

Feature	Regional average[a]	Traditional holdings $\bar{x}$	Traditional holdings CV(%)[b]	Semi-mechanised holdings $\bar{x}$	Semi-mechanised holdings CV(%)	Difference
Number of persons per household	6.2	6.9	33	10.8	53	**
Number of wives per farmer	-	1.3	46	2.3	51	***
Age of the farmer (years)	-	40.6	24	46.9	20	**
Labour force (ME)	3.0[c]	3.2	34	4.5	48	**

a) Results of the agricultural census in 1974 in the Département Biankouma (RCI/MINISTERE DE L'AGRICULTURE 1976).

b) Coefficient of variation (standard deviation as a percentage of the mean value).

c) Number of persons between 15 and 59 years old.

Source: Compiled by the author.

2.3212 Land

According to the traditional concept of law no one can acquire private ownership of land, but only usufructury rights to use the land for certain periods of time. Since all other land is communal property, the fallow is not considered as a part of the holding. For this reason, the farm area comprises only the land cleared for arable farming and the stands of perennial crops[1] and is therefore variable to a certain extent from year to year.

1) Cassava and plantains are considered as arable crops.

The farm size of traditional holdings amounts to 4.9 ha, of which about two-thirds are devoted to perennial crops and only one-third is thus used for arable farming (cf. Table 2.20). Because of the larger area used for perennial crops, the mean value lies above the average for the region. The difference can be attributed to the fact that coffee and cocoa cropping in the Département Biankouma noticeably declines from north to south, and the survey area lies on the southern border of the Département.

Table 2.20: Land use in traditional and semi-mechanised holdings in West Ivory Coast (ha)

	Regional average[a)]	Traditional holdings		Semi-mechanised holdings		Difference
		$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	
Cultivated area	3.7	4.9	67	7.2	54	*
Prennial crops	2.1	3.3	96	4.1	73	n.s.
Field crops	1.6	1.6	52	3.1	72	**
Mechanised area	.	-	-	1.9	53	-
Theoretical farm size b)	10.5	12.2	57	10.2	72	n.s.

a) Results of the agricultural census 1974 for the Département Biankouma (RCI/MINISTERE DE L'AGRICULTURE 1976).

b) Traditional rice area x (fallow period +1) + area of perennial crops + mechanically farmed area. On account of the traditional concept of land ownership, this is a theoretical value.

Source: Compiled by the author.

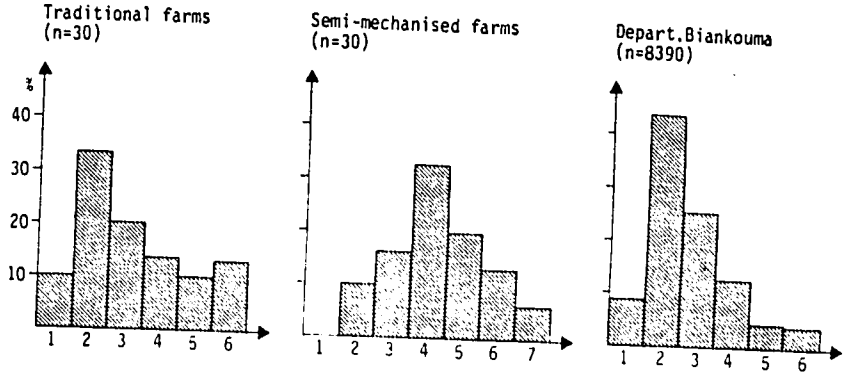
The cooperative holdings with an average farm size of 7.2 ha are significantly larger than the traditional holdings. About one-quarter of the area is used for mechanised cultivation and 17 % for traditional farming. Perennial crops occupy 57 % of the total cultivated area.

If we include the fallow in our consideration, and assume that for traditional rice cropping only fallow land is clear-

ed, the result is a theoretical farm size of 12.2 ha for traditional holdings campared with 10.2 ha for cooperative holdings.

The distribution of farm size in Diagram 2.2 shows that only 40 % of the traditional holdings, compared with approximately three-quarters of the semi-mechanised holdings, cultivate more than 5 ha. In the Département Biankouma, however, only 22 % of farms are larger than 5 ha.

Diagram 2.2: Farm size distribution in traditional and semi-mechanised holdings in West Ivory Coast

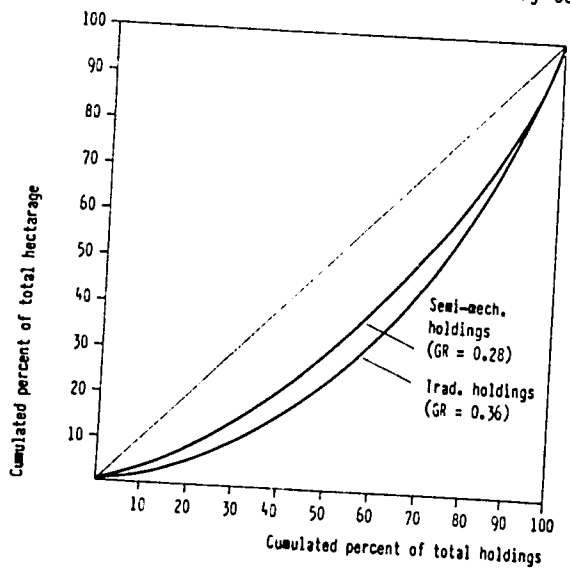


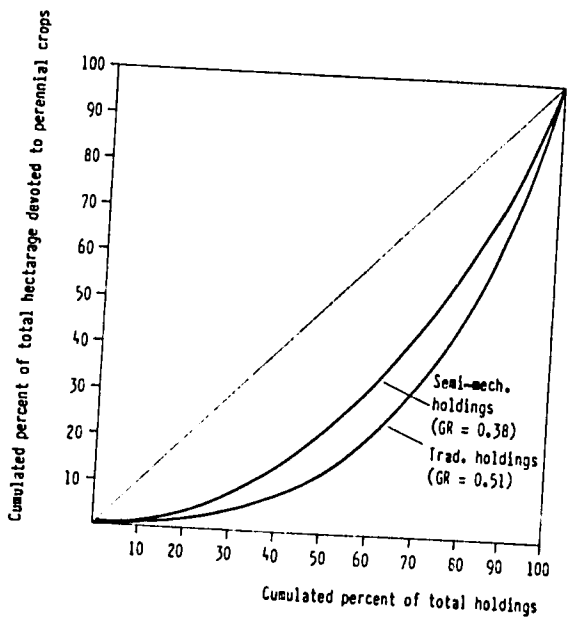
Class	1	2	3	4	5	6	7
Farm size (ha)	<1.0	1-2.99	3-4.99	5-7.49	7.5-9.99	10-14.99	>15

The part of the area devoted to perennial crops greatly influences the variation in farm sizes within the two groups. Diagram 2.3 shows that the distribution of perennial crop areas compared with the total land area is considerably more uneven. The Gini-ratio (GR)[1] in the semi-mechanised holdings

1) The Gini-Ratio is a measure of disparity and is difined as the ratio of the area between the diagonal and the Lorenz curve to the total area below the diagonal. See PIESCH (1975, pp. 28 et seq.) for the calculation method.

Diagram 2.3: Relationship between number of holdings, cultivated area and area devoted to perennial crops in traditional and semi-mechanised holdings in West Ivory Coast





Source: Compiled by the author.

rises from 0.28 to 0.38, and for the traditional holdings by as much as 0.36 to 0.51 with, in this case, half of all the holdings cultivating only about 13 % of the total perennial crop area (semi-mechanised holdings 22 %).

2.3213 Capital and livestock

The capital goods with which farms are equipped are usually simple hand tools (machetes, hoes, knives, etc.) and containers for transport (bowls, sacks). Two of the farmers owned coffee peeling machines. The total value of equipment[1] comes to an average of about 6,400 FCFA per holding, and is not significantly different for the two groups. But the capital stock per unit of area is 1,700 FCFA/ha in the traditional farms, and thus almost twice as high as in the semi-mechanised farms (910 FCFA/ha)[2].

Livestock-keeping is limited to poultry, sheep, goats and pigs, and is carried on solely to cover subsistence needs. Cattle-keeping is rare[3]. About three-quarters of the holdings keep poultry (6.9 units/farm). A third have either goats, sheep or pigs, and the average of all farms is only 1.2 animals/farm. Only 10 % of all holdings keep more than three types of animal. The total value of the livestock amounts to about 12,000 FCFA per farm.

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1) Buildings, cycles and motocycles were not taken into account, since they are not used predominantly in the agricultural sector.

2) Agricultural machinery and implements are owned by the cooperative (CUMA) and not by the individual farmer.

3) One head of the semi-mechanised holdings owned a herd of 25 cattle that were entrusted to a herdsman.

2.322 Land use

2.3221 Cropping methods

The type of land use is the traditional bush-fallow system, with upland rice being grown as the first crop after clearance. Towards the end of the dry season[1], the undergrowth is cut down with a machete, bushes and smaller trees are felled, larger trees and root-stock are left standing. When this has been done, the fields are burned and debris not destroyed by fire is then collected. When the rainy period begins, rice is sown and worked into the soil with a small hoe. Sowing is spread over a period of about 3 months, in order to minimise the risk to subsistence and to reduce the labour peak at harvest time. The main variety grown is Morobérékan, and traditional varieties are of secondary importance. In only a part of the area rice is grown as a sole crop, and as a rule maize or cassava are interplanted. After sowing, the fields are guarded until emergence, to protect the seeds from birds. Mineral fertiliser application is not practised[2].

Weed control begins about 5 to 6 weeks after sowing and lasts into September. To protect the plants from bush rats (Thryonomys swinderianus), the rice fields are often surrounded by a fence of palm leaves or branches. As soon as the first panicles reach the milk stage, bird scaring begins again. Harvesting is carried out with a small knife, with the stalks being cut off about 20 cm below the panicle. The panicles are bundled, and transported, dried and stored in this form. When required, the paddy is threshed with sticks and then cleaned.

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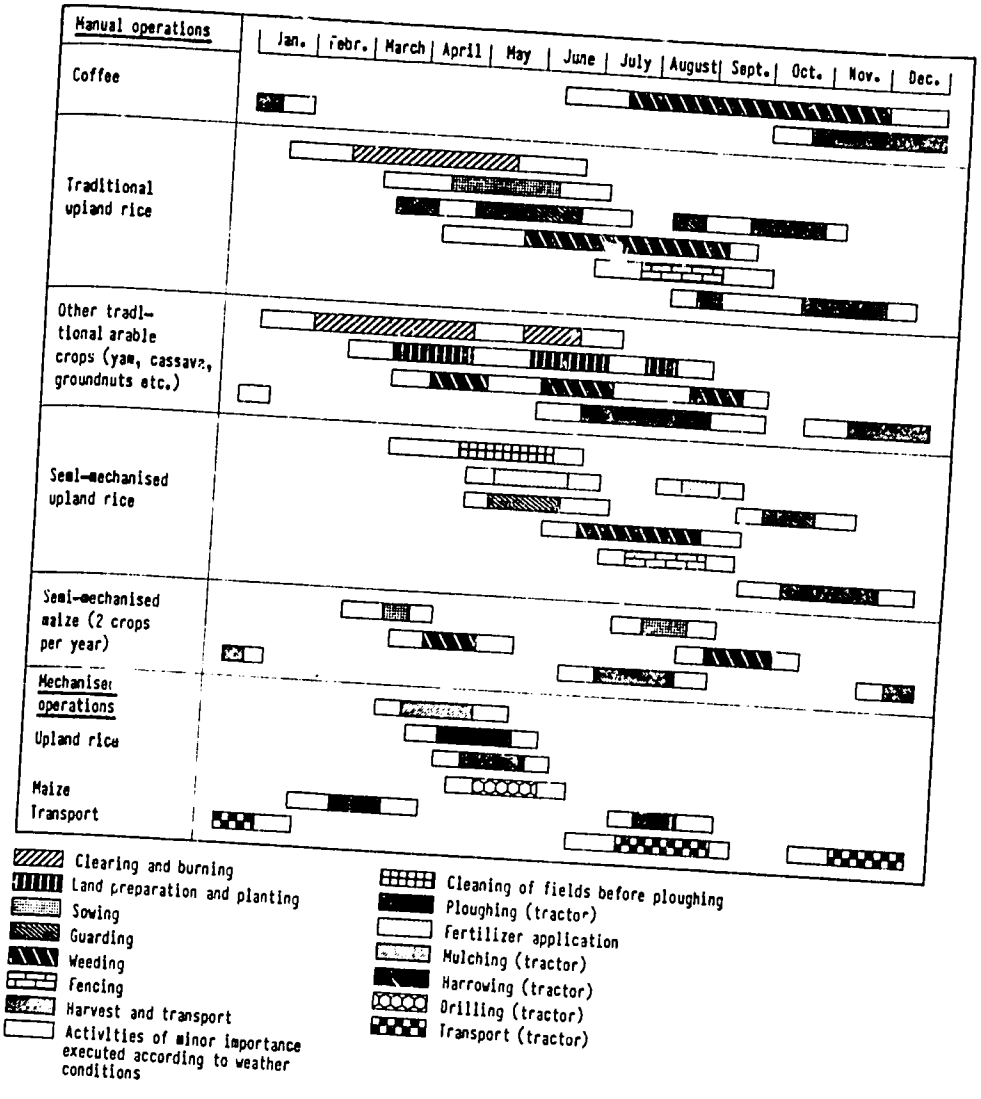
1) Diagram 2.4 illustrates the seasonal pattern of field work.

2) Some farmers in the cooperative holdings take some of the mineral fertiliser intended for mechanised cultivation to their traditionally cropped fields. Since this practice is not allowed by the agricultural extension service, the exact quantity cannot easily be established, but the amount is probably very small.

Diagram 2.4: Pattern of field work throughout the year in traditional and semi-mechanised holdings in West Ivory Coast



Source: Compiled by the author.

In the following year rice is sometimes cultivaced again, but more frequently other food crops like groundnuts, yam, sweet potatoes, etc., are grown. Cassava is mostly the final crop. It is harvested when needed and with time overgrown by the fallow vegetation. Two to a maximum of four years of cropping are followed by a bush fallow of three to ten years.

Coffee production is practised with a very low level of labour input. New coffee plantations are frequently established through intercropping with food crops (mainly rice) in the first one to two years. Areas are only occasionally cleared specifically for coffee cropping. Robusta coffee (Coffea canephora) is practically the only variety grown, and local varieties are scarcely found any more. Crop husbandry is limited to a single cutting of brushwood (desherbage) and serves to make harvesting easier rather than to increase the yield. Other measures like pruning, use of insecticides, fertiliser application, etc., are not practised.

This traditional form of land use is also followed by the cooperative holdings outside the areas of mechanised cultivation.

The following rotation was the original plan for mechanised cropping, and had been recommended by agricultural research for permanent upland farming: first year rice, second year maize, followed by cotton in the same year, third year rice, and in the fourth and fifth years a legume fallow (Stylosanthes gracilis). This rotation has, however, been modified several times:

- The use of the Stylosanthes fallow for cattle-keeping proved impracticable, and green manuring was rejected by the farmers.
- Cotton cropping was abandoned because of low yields and poor quality (rain during the harvest).
- After a short natural fallow of one year the dense vegetation (Pennissetum purpureum, Rottboelia exaltata) is a major obstacle to mechanised cultivation, even when slashers are used.

- Many farmers are of the opinion that a fallow in the mechanised crop rotation is unnecessary because mineral fertilisers are used.

Since 1973 a four-year rotation has been recommended, with three years of upland rice and two maize crops in the fourth year. However, this rotation has only been adopted by about half of the farmers. 10 % of them grow a higher and 40 % a lower proportion of rice, with about a quarter of the farmers following a rice-maize rotation.

In the case of semi-mechanised rice cropping, land preparation and sowing are done by tractor. The land is mulched, then ploughed, and harrowed once. A drill machine is used for sowing (row spacing 20 cm, 70-80 kg seed per ha). Weeding and harvesting are carried out manually by the farmers themselves, as in traditional farming. Not all farmers apply the recommended quantities of mineral fertiliser (NPK 40-20-20), since some of the fertiliser is also used for maize and the traditionally cropped fields. Harvesting lasts into December. Because of the low grain losses of this variety, yield losses as a result of delayed harvests are kept within tolerable limits.

For maize cultivation the land is simply ploughed once with a disc plough without previous mulching. All other operations are carried out by hand. About 30 kg seeds are used per hectare, and small quantities of mineral fertiliser are applied only in a few cases. The variety cultivated, CJB (Composite Jaune de Bouaké), has a vegetation period of about 110 days, and it is harvested in July. Directly after the harvest maize is grown once again, and the harvest lasts into January.

2.3222 Yields and yield relationships

In 1974/75, the average rice yield from traditional cropping was 18.3 dt/ha[1]. If we compared traditional and semi-mechanised farms, we would expect the yields from the co-operative farms to be higher because methods like row sowing, using dressed seeds and early weeding that are recommended for mechanised cropping are employed on some of the area traditionally cultivated, but Table 2.21 illustrates an insignificant yield difference of 2 dt/ha. There is no significant correlation between yield per hectare and cultivated area[2]: the correlation coefficients are r = 0.146 for the traditional holdings and r = -0.043 for the semi-mechanised holdings.

Table 2.21: Yields per hectare from traditional cropping in traditional and cooperative holdings in West Ivory Coast 1974/75

	Traditional holdings		Cooperative holdings		Difference
	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	
Upland rice (paddy) dt/ha	17.4	27	19.4	17	n.s.
Coffee[a] kg/ha	218	52	183	38	n.s.

a) Quantity sold in relation to the coffee area. Since non-fruit-bearing stands are included, the actual yield is somewhat higher.

Source: Compiled by the author.

1) See Appendix V for how these data were derived.

2) The calculation of the unweighted arithmetic mean is, therefore, sufficient.

The total average of coffee yields amounted to 200 kg/ha dried beans. Yields in the traditional farms are 20 % higher than those of the cooperative holdings. The variation of coffee yields between the farms is higher than in the case of rice yields. What is also striking in both crops is the greater variation of yields in the traditional farms compared with the cooperative farms.

The climatic conditions in 1974/75 were favourable for upland rice cultivation, but not for coffee production. The long-term average rice yields in traditional upland farming are about 14-15 dt/ha, with the coefficient of variation in the order of 15-20 %[1]. With regard to climate, the survey area is a marginal region for coffee production (BDPA, Vol. 3, pp. 17 et seq.). The long-term average yield is about 250 kg/ha, with considerably higher variations than upland rice (CV > 30 %).

The average yield for semi-mechanised upland rice cropping amounted to 23.0 dt/ha in 1974/75, and compared to traditional farming, the difference of 4.7 dt/ha is highly significant. The coefficient of variation is 22 %, i.e. the variation of yield among the cooperative holdings corresponded roughly to that of traditional cropping.

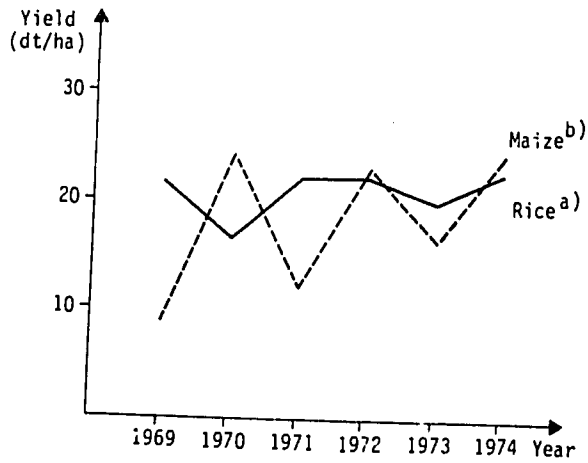
The maize yields in semi-mechanised cropping came to 30.5 dt/ha for the first crop and 22.6 dt/ha for the second. The yield difference could be attributed largely to the lower level of inputs of the second crop, when no mineral fertiliser is used and weeding is mostly neglected. For this reason the variation in yields of the second crop is substantially higher (CV 34 % as aginst 25 % for the first crop).

Diagram 2.5 shows the development of yields since the beginning of mechanisation. From 1969 to 1974, the average

1) Estimates by the author on the basis of results from long-term experiments at the agricultural research station Man.

rice yield was 20.9 dt/ha, and that of maize was 18.5 dt/ha for the first crop. Over time, rice yields vary only slightly compared to maize yields, and for both crops, there is neither a decline nor an increase of yields observed.

Diagram 2.5: The development of yields in semi-mechanised cultivation (Terroirs de l'Ouest 1969 - 1974)



a) Average yields of the project area "Mangouin"

b) First crop, average yields of the total project area

Source: RCI/MINISTERE DE L'AGRICULTURE, Terroirs de l'Ouest, Annual reports 1969 to 1974

To identify the most important factors influencing crop yields, regression analyses were carried out using linear, quadratic and Cobb-Douglas functions. Unfortunately, a soil survey could not be made, and because of the fact that the level of fertiliser application was at least theoretically equal in all farms, the analysis is limited to the length of the fallowing and the labour input as factors influencing yields. The functions which best explain the relationship are shown in Table 2.22.

Table 2.22: Factors influencing yields in upland rice and coffee production in West Ivory Coast in 1974/75

Traditional upland rice production (n=41)	$Y = 2.088 \cdot x_1^{0.436}$ **	$r^2=0.220$ F= 10.690
(n=41)	$Y = 0.535 \cdot x_1^{0.480}$ ***	$r^2=0.328$ F= 8.931
Semi-mechanised upland rice production (n=29)	$Y = 2.535 \cdot x_3^{0.562}$ **	$r^2=0,528$ F= 30.191
(n=29)	$Y = 7.543 + 0.301\ x_3$ ***	$r^2=0.637$ F= 49.102
Coffee production (n=53)	$Y = 70.827 + 8.126\ x_4$ ***	$r^2=0,668$ F=102.446

Y = Yield in dt/ha (coffee kg/ha)
x_1 = Length of fallow in years
x_2 = Total labour input (ME-days)
x_3 = Labour input for weeding (ME-days)
x_4 = Labour input for crop husbandry practices (ME-days)

Source: Compiled by the author.

In the case of upland rice, the Cobb-Douglas function gave the best fit. In traditional cropping only a small part of the yield variation can be explained by the length of the fallow and the labour input[1]. Soil quality in particular could have played an important role in this case. On the other hand, the conditions in semi-mechanised farming are

1) Differentiating the total labour input according to the various cultural operations certainly raises the multiple coefficient of correlation to 0.472, but the function loses its statistical significance.

much more homogeneous, where only soils of better quality were selected for mechanised cultivation, and land preparation and the input of seed and mineral fertiliser scarcely vary between farms. But more than 50 % of the yield variation can be explained just by the labour input for weeding. The importance of weed control as a factor affecting yields in semi-mechanised rice cultivation is confirmed by the results of experiments on demonstration farms as illustrated in Table 2.23.

Table 2.23: The influence of mineral fertiliser and weed control on the yields of semi-mechanised upland rice in West Ivory Coast[a] (yields in dt/ha)

	Without mineral fertiliser	With mineral fertiliser (NPK 42-36-36)
Without weed control	0.7] [b]	1.7]
Low level of weed control	14.0]	18.2]
Efficient weed control	17.7]	25.4]

a) Results from demonstration farms in 1973/74.

b) ⟵ = classification according to the Duncan-test

Source: Compiled by the author based on RCI/MINISTERE DE L'AGRICULTURE, Terroirs de l'Ouest, Rapport annuel, 1973.

In semi-mechanised cropping the yields remain very low where no weed control is practised. If no mineral fertiliser is used, intensive weed control does not bring about a significant rise in yields. If mineral fertiliser is applied, however, its effect is only significant with efficient weed control[1].

1) Thus the experiment confirms a number of observations in other regions in West Africa: "In the absence of efficient weed control, other inputs such as high-yielding, disease and insect resistant varieties, fertilisers and water control will be useless" (DADEY 1973, as quoted in MOODY 1974, p. 2).

As far as coffee yields are concerned, weeding is of crucial importance: the labour input explains two-thirds of the yield variation among farms. As can be seen from the function in Table 2.22, the increase in yield per ME-day for crop husbandry is approximately 8 kg coffee, which would correspond to a return to labour of 1200 FCFA per working-day.

A quantitative analysis of the yield relationships must, however, be interpreted with caution. First, essential explanatory factors (soil quality, etc.) are omitted, secondly the efficiency of the labour employed is not considered, and thirdly there are relations like that between labour input for weeding and the intensity of weed growth which become more important, the better the soil quality is, particularly in semi-mechanised farming. Over time, climate is also another fundamental factor affecting yields.

2.2.2.3 Crop areas

Because climatic conditions permit "double cropping"[1], the annual cultivated area can exceed the actual cultivable area of the holdings. This difference is very small in the case of the traditional holdings, since only 4 % of the land is used twice a year, and amounts to 0.6 ha in the cooperative holdings, where double cropping occurs on 7 % of the traditionally and 26 % of the mechanically cropped area.

Rice and coffee are the two most important crops, and they are grown in almost all the holdings (97 %). They cover 92 % of the total area in traditional holdings and 76 % in semi-mechanised holdings.

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1) "Double cropping" describes a method whereby a second crop is planted in the same year on the same field after or shortly before the harvest of the first crop.

Table 2.24 demonstrates that the difference in the total cultivated area between the two groups is to be attributed to the more and intensive arable cropping on the cooperative holdings. On account of the mechanisation of land preparation, these farms are in a position to cultivate a larger area with increased intensity of land-use. This is not, however, to be ascribed to the expansion of upland rice cropping, but largely to the growing of maize. If the rice area of the holdings is related to family size and labour force, it can be seen that the area of rice per person (0.20 ha) and per ME (0.45 ha) does not differ between the two groups. As rice is mainly grown for subsistence and not as a cash crop, this is not surprising.

Table 2.24: Crop areas in traditional and semi-mechanised holdings in West Ivory Coast 1974/75 (averages in ha)

	Traditional holdings		Semi-mechanised holdings		Difference
	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	
Total cultivated area	5.0	67	7.8	53	**
- perennial crops (coffee)	3.3	96	4.1	73	n.s.
- arable crops	1.7	52	3.7	73	***
Traditional farming	1.7	52	1.3	83	n.s.
- upland rice	1.3	55	0.6	115+)	***
- cassava	0.2	112+)	0.3	94	n.s.
- others (groundnuts, yam, etc.)	0.2	-	0.4	-	
Semi-mechanised cultivation					
- upland rice			2.3	56	-
- maize			1.3	53	-
			1.0	-	-

+) High coefficient of variation caused by a large number of zeros.

Source: Compiled by the author.

2.323 The labour economy

2.3231 Labour input per holding

The average labour input on the traditional holdings for field work, including the processing of the harvest, came to 390 ME-days[1] compared with 532 ME-days on the cooperative holdings[2] (Table 2.25). In both groups, rice claims the highest proportion of labour input: approximately two-thirds of the total labour input in the traditional farms and more than half in the semi-mechanised farms is devoted to upland rice cropping: only 31 % and 21 % respectively of the labour input goes on coffee production.

Table 2.25: Total labour input in traditional and semi-mechanised holdings in West Ivory Coast 1974/75 (ME-days)

	Traditional holdings		Semi-mechanised holdings		Difference
	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	
Total labour input	390	35	532	41	***
Perennial crops (coffee)	122	80	113	56	n.s.
Traditional upland rice	244	35	103	90+)	***
Other traditional arable crops	23	124+)	61	86+)	***
Semi-mechanised upland rice	-	-	178	34	-
Semi-mechanised maize	-	-	74	66	-

+) High coefficient of variation caused by a large number of zeros.

Source: Compiled by the author.

1) See Appendix V for calculations.

2) Assuming an average of 6 to 6.5 hours of work per day (including getting to and from work), the labour input expressed in man-hours comes to 2340-2540 in the traditional holdings and 3200-3450 on the semi-mechanised holdings.

The other traditional arable crops, apart from rice, on the cooperative holdings account for 12 %, which is twice as high as on the traditional holdings. Since these crops occupy 8-9 % of the total cultivated area, this might be attributable to the fact that yam, which is a labour-demanding crop, is widely grown on the cooperative farms. The semi-mechanised farming requires about half of the total labour input, approximately 70 % of which is accounted for by rice and 30 % by maize.

In the case of both traditional and cooperative holdings family labour constitutes almost two-thirds of the total labour input. As Table 2.26 illustrates, cooperation between neighbours[1)] becomes less important on the semi-mechanised holdings, and hired labour is employed instead. Bearing in mind that, on average, the help received from neighbours must be more or less compensated on other holdings through family labour, only hired labour represents non-family labour in the true sense of the word. Thus the share of family labour in the total labour input is 80-85 %.

The dominating influence of rice cropping on the seasonal work pattern can be seen clearly in Diagram 2.6. It is apparent that the seasonal work pattern is not fundamentally influenced by mechanisation. In both groups there is a labour peak in April/May because of clearance and cultivation

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1) We differentiate roughly between two forms of cooperation between neighbours: the "sociétés d'entraide" and the so-called "groupes de jeunes". In the first case, farmers, their wives or any other group of people cooperate to carry out certain jobs communally. The work done by individual members is on a mutual basis. With the second kind of help, young people of a certain age group join together when demanded by the leader either of a family group (ligneage) or of the whole village. The group usually does not receive a wage, but simply receive drinks and one or two meals (mostly with meat), depending on the length of time worked.

Table 2.26: Input of family and non-family labour in traditional and semi-mechanised holdings in West Ivory Coast 1974/75 (ME-days per holding)

	Traditional holdings			Semi-mechanised holdings		
	$\bar{x}$	CV(%)	% of total labour	$\bar{x}$	CV(%)	% of total labour
Family labour	245	31	62.8	341	38	64.1
Help from neighbours	83	56	21.3	79	64	14.8
Hired labour	62	120+)	15.9	112	78	21.1

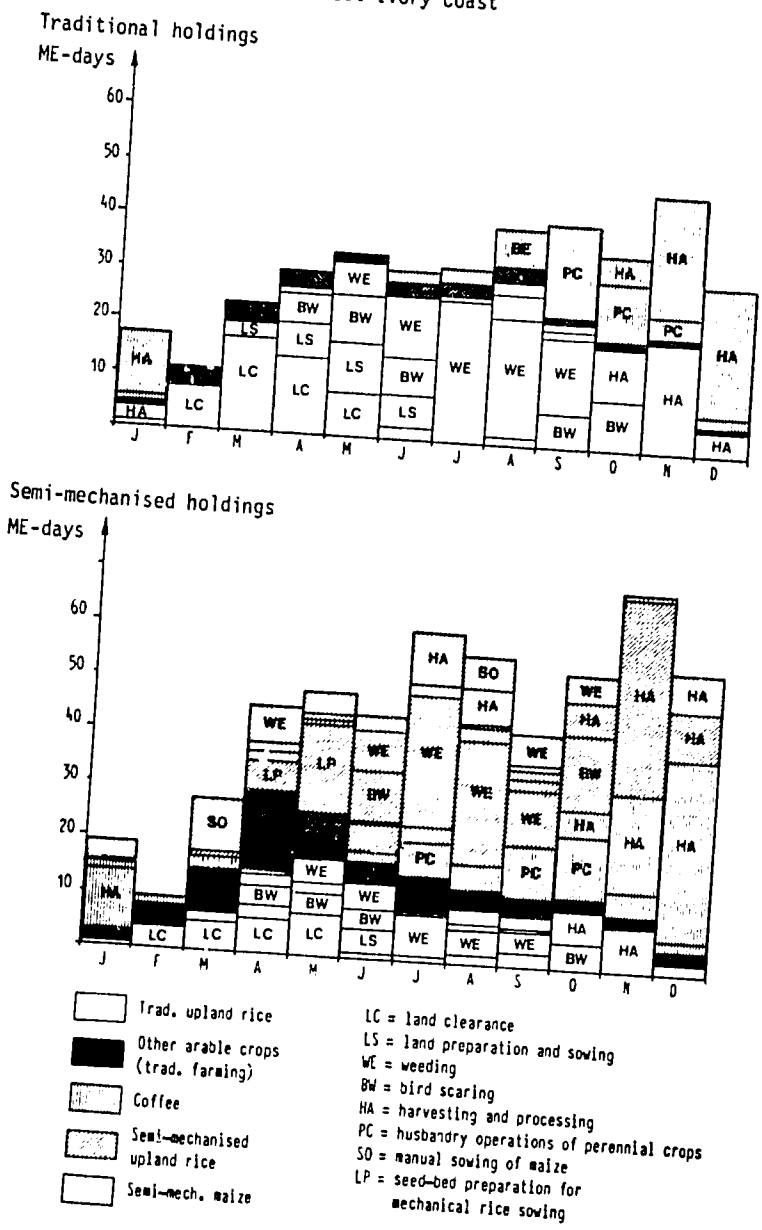
+) High coefficient of variation caused by a large number of zeros.

Source: Compiled by the author.

work for arable crops, and another peak in November when the rice harvest and the beginning of the coffee harvest coincide. On traditional farms, a further labour peak occurs in August/September, when weeding the stands of perennial crops is started. On the other hand, the corresponding labour peak on the cooperative farms occurs somewhat earlier (July), when the upland rice is weeded and the harvest of semi-mechanised maize commences. Because of this labour bottleneck, the sowing of the second crop cycle is delayed, with the consequent effect on maize yields[1].

1) With unduly late sowing, the flowering will be towards the end of the rainy season which increases the probability of dry periods, with their negative effects on maize yields.

Diagram 2.6: Pattern of field work in traditional and semi-mechanised holdings in West Ivory Coast



Source: Compiled by the author.

2.3232 Labour input per unit area

2.32321 Labour input in traditional farming

In traditional rice cropping, there are no significant differences in the labour input between traditional and cooperative holdings. Table 2.27 illustrates that the labour input for field work is on average 168 ME-days per ha. In traditional holdings, the highest input relates to weeding (35 %), followed by clearance work (29 %) and harvesting (21 %). In contrast to this, the labour input for land clearance is higher than for weed control in the cooperative holdings, which on the other hand cultivate more areas with abundant fallow vegetation (and longer fallow periods) on which weed growth is comparatively slight.

Table 2.27: Labour input per hectare in traditional upland rice cropping in West Ivory Coast (ME-days/ha)

	Traditional holdings		Semi-mechanised holdings		Difference
	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	
Land clearance	47.8	37	53.4	3.8	n.s.
Sowing	21.4	44	26.8	59	n.s.
Weeding	58.0	59	45.8	44	n.s.
Fencing	7.4	57	8.4	61	n.s.
Guarding*)	33.5	49	23.2	51	**
Harvest	35.1	47	37.9	39	n.s.
Total field work (excluding guarding)	167.1	39	168.8	36	n.s.
Total field work (including guarding)	200.4	43	192.7	39	n.s.

*) Was not converted to a hectare basis, since the labour input is largely independent of the area.

Source: Compiled by the author.

Another reason for the low labour input for weed control in the semi-mechanised holdings could be that weeding is started considerably earlier. In semi-mechanised cropping, one of the vital areas of extension work is early weed control, which is also increasingly practised in the cooperative holdings on traditional upland rice plots, as illustrated in Table 2.28.

Table 2.28: Interval between sowing and the beginning of weed control in upland rice cropping in traditional and semi-mechanised holdings in West Ivory Coast (% of fields)

	< 20	21-30	31-40	41-50	> 50 days
Traditional farming					
- traditional holdings	5.3	10.5	26.3	34.2	23.7
- semi-mechanised holdings	19.0	33.3	28.6	4.8	14.3
Semi-mechanised farming	24.1	34.5	24.1	10.3	6.9

Source: Compiled by the author.

Guarding the fields after sowing and before the beginning of harvest requires an average of 34 ME-days in the traditional holdings. The lower number of days devoted to this activity in the cooperative holdings can be attributed to the fact that at about the same time the semi-mechanised rice areas also have to be guarded, and the amount of labour available for these tasks is only limited to family members[1]. The labour input for rice threshing and cleaning comes to about 0.8 ME-days/dt paddy, and would thus be equivalent to about 14-16 ME-days/ha.

1) This example demonstrates clearly the problem of estimating the labour requirements of a crop on the basis of data collected in a farm survey. The difference between

(see page 85)

As the area cropped increases, the total labour input per hectare decreases, and this relation is considerably closer in the traditional holdings (r = -0.722***) than in the semi-mechanised holdings (r = -0.282). This indicated that economies of scale are only of limited importance in semi-mechanised holdings on account of the smaller cropping areas.

Differences between the two groups with regard to labour input are more obvious in the case of perennial crops. The labour input for crop husbandry of coffee is almost 50 % higher in the traditional holdings than in the cooperative holdings, and the total labour input per hectare, including the processing of harvest, is more than 30 % higher. Nevertheless, coffee cropping in almost all farms is characterised by a very low labour input per unit area, and reveals features of a collecting activity. One of the reasons for this unwillingness to intensify can be attributed to the higher production risk of coffee compared with upland rice. This behaviour of traditional farmers can often be observed where climate leads to yield uncertainty (RUTHENBERG 1976a, pp. 289 et seq.).

As in upland rice farming, the labour input per hectare for coffee production decreases, as the area increases. The correlation coefficient in both groups is about the same (r = -0.569*** and -0.601***).

The high degree of variation in labour input in both traditional rice and coffee production can be attributed to a number of reasons, that will not be treated here in any further detail[1].

Footnote 1 from page 84:

the estimated and the actual labour requirements for a particular activity will usually be the greater as social and traditional aspects play a part in farm work.

1) COLLINSON (1972, p. 205 et seq.) gives a detailed description in this aspect.

Table 2.29: Labour input in coffee production in traditional and semi-mechanised holdings in West Ivory Coast (ME-days/ha)

	Traditional holdings		Semi-mechanised holdings		Difference
	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	
Crop husbandry	20.4	56	14.0	51	*
Harvest	22.4	72	17.2	69	n.s.
Total labour input	52.5	63	36.3	62	*

Source: Compiled by the author.

2.32322 Labour input in semi-mechanised cropping

The total labour input for field work in semi-mechanised upland rice cropping amounts to 116.6 ME-days per ha, and thus comes to about 70 % of the labour input in traditional rice production. The input for weeding is 50.5 ME-days per ha, which is not higher than in traditional cropping[1]. However, this is 43 % of the total labour input, in contrast to only 30 % in non-mechanised farming. The labour input for harvest is 39.2 ME-days per ha, and is on average hardly more than in traditional cropping, although the yields are considerably higher. It can therefore be concluded that there are considerable economies of scale in this area. Even after several years of permanent cultivation, the labour input of 20.7 ME-days per ha for land preparation

1) It could be expected that the labour input for weeding in semi-mechanised cropping would be higher on account of the increasing weed growth in permanent cultivation than on the traditionally cropped areas. On the other hand, the labour requirements are reduced through more rational cropping practices like row sowing and the early start of weed control (see also Table 2.28).

(burning the debris, removing roots, stones, etc.) before and/or after ploughing is relatively high, and the variation is the highest (CV = 54 %) compared to all other activities (weeding, harvesting, etc.), where the coefficients of variation range between 22 and 29 %, which are considerably lower than in traditional farming.

A decrease in labour intensity with increasing cropping area can be discerned in semi-mechanised farming also. The correlation coefficient (r = -0.624***) is much higher than on traditionally cultivated areas.

Compared with rice, maize cultivation is practised with a low level of labour input per unit area, especially in the second cropping cycle, when work is reduced to essential operations only. Here too the farmers' behaviour is similar to that in coffee production, namely the trend towards reduction of labour input in cropping with a higher yield uncertainty. On average, the total labour input for field work amounts to 64.8 ME-days per ha, of which about 35 % is devoted to weed control (22.7 ME-days per ha), 28 % to harvesting (18.1 ME-days per ha) and 25 % to sowing (16.2 ME-days per ha).

2.3233 The influence of semi-mechanisation on the division of labour and employment in the holdings

The mechanisation of farm enterprises or the holding as a whole usually has some influence on the employment situation of the rural population. Basically two factors are significant: the effects of mechanisation on the traditionally practised division of labour (between the sexes and with regard to family labour, help by neighbours and hired labour as a proportion of the total input for individual crops and husbandry practices) and the effects on the employment of non-family and family labour.

The division of labour according to sex is in line with observations in other regions of West Africa (CLEAVE 1974, pp. 170 et seq.): the cultivation of cash crops (coffee) is performed predominantly by men and subsistence crops are cultivated mainly by women, with the physically demanding work (e.g. land clearance and land preparation) and burning and fencing being the duty of men. On the other hand, women have the task of sowing, weeding and harvesting. This type of division of labour is not fundamentally influenced by mechanisation. In maize production, however, it can be seen that especially the farmers themselves are prepared to take more part in typically female activities (sowing, weeding and harvesting).

If we consider the importance of the three labour categories with regard to individual crops or husbandry practices (Table 2.30), we see no basic differences between the two groups, apart from the already mentioned increasing extent to which hired labour is employed in the cooperative holdings. Help from neighbours is concentrated on subsistence crops, expecially upland rice, and has scarcely any importance in the case of cash crops (coffee and semi-mechanised maize), where hired labour is increasingly being employed.

The mechanisation of land preparation on part of the holding has similarly scarcely any effect on the employment situation of the family labour (see Table 2.31). The total labour performance of family members in the agricultural sector does not differ significantly between the two groups[1]. However,

1) Various authors raise the question to what extent it is practical to evaluate the employment effect of technical innovations in family holdings by means of the variation in total working time per family labour unit. They are of the opinion that income usually represents a far better basis of evaluation, especially when little non-familiy labour is employed (see BODENSTEDT et al. 1977, pp. 5 et seq. and pp. 38 et seq.; TURNHAM 1971, p. 69; HUNTER 1973, p. 121).

Table 2.30: Importance of family and non-family labour as a proportion of the total labour input per crop in traditional and semi-mechanised holdings in West Ivory Coast (average as a %)

	Traditional holdings			Semi-mechanised holdings		
	Family labour	Help from neighbours	Wage labour	Family labour	Help from neighbours	Wage labour
Traditional upland rice						
- Land clearing	59	31	10	61	21	18
- Sowing	44	35	20	59	13	29
- Weeding	18	64	17	41	28	32
- Harvesting	63	28	9	57	29	15
Semi-mech. upland rice	60	38	2	65	28	7
- Weeding	-	-	-	53	27	21
- Harvesting	-	-	-	41	27	32
Semi-mechanised maize	-	-	-	46	46	9
- Weeding	-	-	-	68	11	22
- Harvesting	-	-	-	59	13	28
Coffee	-	-	-	84	9	7
- Crop husbandry	74	7	18	70	5	25
- Harvesting	55	11	34	44	8	49
	83	7	10	90	4	6

Source: Compiled by the author.

Table 2.31: Employment of family labour in traditional and semi-mechanised holdings in West Ivory Coast (days per person)

	Traditional holdings		Semi-mechanised holdings		Difference
	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	
Farmer	104	36	114	21	n.s.
- work on own holding	86	36	102	20	*
- work on other holdings	18	78	12	93	n.s.
Other family members	103	34	98	41	n.s.
- work on own holding	76	38	80	46	n.s.
- work on other holdings	27	49	18	38	**

Source: Compiled by the author.

in the semi-mechanised holdings we can see that farmers tend to concentrate their family labour force more on their own holdings. This is particularly true of the farmers themselves, who spend much more time working on their own farms than in the traditional holdings. The importance of neighbours' cooperation is accordingly reduced.

The total working time per family member in the agricultural sector is on average 100-110 days per year, and in comparison with other regions of West Africa this is relatively low (CLEAVE 1974, pp. 32 et seq.), even though comparisons in this area are not without problems, since the length of the working-day can vary considerably[1].

1) In the survey the classification of the working time according to man-hours was proved to be very expensive (see Appendix V). If we assume an average of 6 to 6.5 hours of work per day, including going to and returning from work, we get an average annual work rate of 600-700 hours per adult. But even on the basis of hours of work a comparison with other data is not without problems, since the activities are not always identical.

2.33 Returns and cash income

2.331 Farm income and farm family income

For an economic evaluation of the holdings, we use the farm income tc measure the profitability of the input of production factors and the farm family income as an index of the level of income of the population. In this respect, total income figures are not a suitable measure for farm comparison, and therefore have to be converted to values which reflect the differences in the level of farm resources.

If we first consider the gross returns (Table 2.32), the importance of arable farming is very apparent: in the traditional holdings 65 % of the gross returns are earned from 33 % of the land area, and only 32 % is derived from perennial crops (67 % of the land area). In the cooperative holdings, about three-quarters of the gross returns result from arable farming (43 % of the land area), with half of the gross returns being produced solely from semi-mechanised cropping on 26 % of the land area. In both groups rice is the most important crop, and produces 55-56 % of the gross returns.

There are also differences in the compositon of the total costs: the biggest proportion in both groups is certainly accounted for by wages (50 % and 36 % of the total costs), but the costs of material inputs and machine hire in the traditional holdings come to only 23 %, whereas they are over 50 % of the total costs in the cooperative holdings.

The farm income of the cooperative holdings amounts to 398,000 FCFA, and is thus on average 50 % higher than in the traditional holdings. But if we relate the farm income to the area cultivated or the labour employed, we see that in the traditional holdings the productivity per unit of area is higher[1], while in the semi-mechanised holdings the

1) The difference is significant at the 8 % level.

Table 2.32: Costs and returns of traditional and semi-mechanised holdings in West Ivory Coast (FCFA)

	Traditional holdings $\bar{x}$	CV(%)	Semi-mechanised holdings $\bar{x}$	CV(%)	Difference
Gross returns[a)]	287,150	50	473,540	43	***
- from traditional arable farming	185,160	59	126,580	88[e)]	*
- from semi-mechanised farming	-	-	234,390	46	-
- from perennial crops	92,130	89	104,580	72	n.s.
- other sources[b)]	9,860	92	14,270	72	n.s.
Total costs	53,180	69	117,960	54	***
- material inputs (seed, fertiliser, etc.)	7,570	66	36,260	57	***
- machine hire	4,950	110	23,510	49	***
- depreciation (perennial crops, tools, etc.)	12,910	81	14,020	66	n.s.
- wages[c)]	26,390	50	42,150	36	**
- others	1,360	174[e)]	2,020	73[e)]	n.s.
Farm income	260,360	50	397,730	44	**
- per ha cropped	63,270	48	54,440	28	n.s.
- per ha gross area (including fallow)	27,350	68	49,820	49	***
- per ME-day	633	32	735	19	*
Farm family income	233,970	52	355,580	43	**
- per ME	74,300	52	85,340	40	n.s.
- per ME-day of family labour	704	39	857	27	*
- per resident[d)]	36,360	58	37,700	49	n.s.

a) Value of production at farm-gate prices. See Appendix V for calculation.
b) From stock-keeping, collecting, etc.
c) Including wages paid in kind.
d) Family members and other relatives living with the family.
e) High coefficients of variation because zeros occur.

Source: Compiled by the author.

labour productivity is higher. If the fallow areas are included, the productivity of the land in the mechanised holdings is almost twice as high as in the traditional holdings.

This applies also to the farm family income, which is identical with the family income for the majority of holdings since there is little income from off-farm sources[1]. It is true that the farm family income per unit of family labour in the cooperative holdings is about 15 % higher than in the traditional holdings, but the difference of 11,000 FCFA/ME is not significant. If the farm family income is related to the employment of family labour, returns per working-day in the semi-mechanised holdings are 20 % higher, and in both groups are above the farm income per ME-day, a fact caused by the relatively low wage level of hired labour.

If we relate the farm family income to the number of people in the household of the farmer, we get a rough idea of the living standard of the population. The farm family income per resident is nearly equal in both groups (36,000-38,000 FCFA), and was not affected by mechanisation.

In comparisons on a national level, the per capita gross national product is usually used as an index of the standard of living. At the farm level, a corresponding figure is obtained if the gross returns are related to the number of people belonging to the farmer's household. The gross

1) Income from non-agricultural activities (working as craftsmen, trading, etc.) is obtained in only one-fifth of the holdings. This income is 50,000 to 100,000 FCFA. Apart from this non-farm income, we ought to consider transfer payments by members of the family living away from the village, if we want to establish the total income of a family, but hardly any details could be got from the farmers. On average, the total family income could be raised by about 15,000 to 20,000 FCFA per holding as a result of these factors.

returns per resident amount to an average of 41,600 FCFA in the traditional holdings and 43,800 FCFA in the semi-mechanised holdings, which is only slightly below the *per capita* gross national product of 48,300 FCFA in the agricultural sector in 1974[1].

Compared to the gross national product per inhabitant of 122,400 FCFA, the productivity of agriculture is clearly lower than in other sectors.

2.332 The distribution of the farm family income

As we can see from Diagram 2.7, the differences in income distribution between traditional and semi-mechanised holdings are relatively small. One third of the holdings with the highest farm family income produces about 48-52 % of the total farm family income, while one third of the lowest income group produces only 14-18 %. The distribution of farm family income, that is considerably more homogeneous than that of the land area (cf. Diagram 2.3), illustrates how the smaller holdings were able to increase their farm family income by raising the intensity of cropping.

It is also noticeable that the traditional holdings are more heterogeneous than the semi-mechanised holdings. However, it cannot be concluded here that the introduction of technical innovations has led to a levelling of income, since there is no information on the situation before the introduction of mechanisation[2]. Instead, we must assume that those holdings that joined the cooperative were already somewhat more homogeneous in relation to other agricultural holdings (see SCHULZ 1968).

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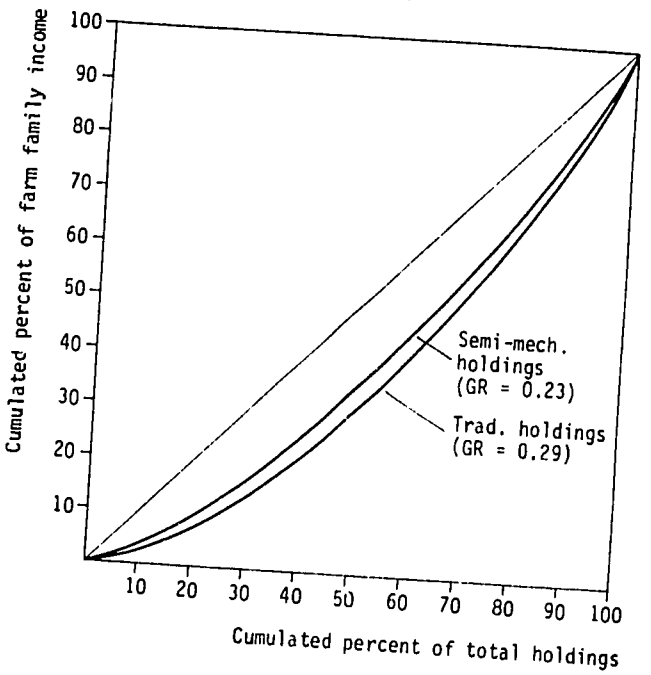
1) Calculated by the author according to the MINISTERE DE LA COOPERATION 1976, pp. 38 et seq.

2) We cannot, of course, ignore the fact that mechanisation could have led to some homogeneity. At least it has not given rise to substantial disparities in income.

Diagram 2.7: Relationship between number of holdings and farm family income in traditional and semi-mechanised holdings in West Ivory Coast 1974/75



Source: Compiled by the author.

2.333 Relationship between farm income and the input of land and labour as production factors

Simple and multiple regression analyses using linear and Cobb-Douglas functions were carried out in order to demonstrate the influence of the production factors on farm income. The analyses were restricted to the factors land and labour, because capital is of minor importance and also closely correlated with the other production factors. Moreover, it was not intended to quantify production functions

of the holdings, but simply to give an idea of dependencies and relations.

Table 2.33 presents the results of the analyses. It can be seen that in both groups the farm income is greatly affected by the level of labour input, and in fact explains about 75 % to 86 % of the variation of farm income. In the case of the semi-mechanised holdings, the area cultivated also produces very good results, whereas the labour force of the holdings explains only a meagre part of the variation of farm income, particularly in the traditional farms.

In the traditional holdings, the higher multiple coefficients of correlation of the Cobb-Douglas functions compared with the linear functions illustrate clearly the diminishing marginal returns to land and labour. On the other hand, the differences between linear and Cobb-Douglas functions are less evident in the cooperative holdings (labour input) or exactly reversed (labour force, farm size), which leads to the conclusion of practically constant marginal returns.

2.334 Net cash income from farming

In family holdings like those considered here, where the main part of the agricultural production is consumed in the household, the level of the net cash income of the holding is another important index for economic evaluation.

The total cash income from the sale of agricultural produce is on average 117,500 FCFA for the traditional holdings, compared with 195,800 FCFA for the cooperative holdings. This difference cannot, however, be attributed to more commercially oriented production, since the sales as a proportion of the gross returns come to about 40 % in both groups.

As Table 2.34 demonstrates, coffee is the most important cash crop and accounts for 71 % and 52 % of the cash income

Table 2.33: Relationship between farm income and the input of land and labour in traditional and semi-mechanised holdings in West Ivory Coast

Traditional holdings (n=30)	r^2	F	Semi mechanised holdings (n=30)	r^2	F
$Y = 11.590 + 45.988^{*} ME$	0.150	4.953	$Y = 132.540 + 59.063^{***} ME$	0.543	33.328
$Y = 114.188 + 29.221^{***} HA$	0.563	36.138	$Y = 109.219 + 36.978^{***} HA$	0.783	100.978
$Y = -64.858 + 834.2^{***} MED$	0.758	87.503	$Y = 10.196 + 728.7^{***} MED$	0.823	130.294
$Y = 79.592 + 13.328 ME + 27.517^{**} HA$	0.574	18.201	$Y = 75.783 + 19.695 ME + 29.929^{***} HA$	0.815	59.429
$Y = -60.613 + 1.339 HA + 806.1^{**} MED$	0.758	42.264	$Y = 26.798 + 16.777^{**} HA + 451.3^{***} MED$	0.865	86.524
$Y = 63.259 \cdot ME^{1.099^{**}}$	0.283	11.042	$Y = 137.214 \cdot ME^{0.686^{***}}$	0.406	19.146
$Y = 83.533 \cdot HA^{0.709^{***}}$	0.652	52.406	$Y = 78.924 \cdot HA^{0.786^{***}}$	0.707	67.541
$Y = 21.2 \cdot MED^{1.567^{***}}$	0.864	178.098	$Y = 161.1 \cdot MED^{1.241^{***}}$	0.861	173.964
$Y = 53.276 \cdot ME^{0.5080^{*}} \cdot HA^{0.622^{***}}$	0.702	31.842	$Y = 73.042 \cdot ME^{0.209} \cdot HA^{0.675^{***}}$	0.730	36.553
$Y = 44.0 \cdot HA^{0.090} \cdot MED^{1.422^{***}}$	0.867	88.258	$Y = 454.1 \cdot HA^{0.186} \cdot MED^{1.017^{***}}$	0.873	92.546

Y = farm income (FCFA), ME = labour force of the holdings (ME), HA = farm size (ha), MED = total labour input (ME-days)

Source: Compiled by the author.

Table 2.34: Cash income and expenditure of traditional and semi-mechanised holdings in West Ivory Coast 1974/75 (FCFA)

	Traditional holdings $\bar{x}$	CV(%)	Semi-mechanised holdings $\bar{x}$	CV(%)	Difference
Total cash income	117,460	77	195,800	48	*
- sale of coffee	82,860	105	101,080	72	n.s.
- sale of rice[a)]	25,730	78	54,020	49	***
- sale of maize	1,240	276	23,030	72	***
- other cash income from farming and stock-keeping	7,630	108	17,670	107	*
Total cash expenditure	23,680	114	82,550	48	***
- wages	14,370	138	29,290	79	**
- machine hire	4,950	110	23,510	49	***
- material inputs[a)] tools	3,010	52	27,740	36	***
- others	1,360	274	2,020	73	n.s.
Net cash income	93,780	72	113,240	60	n.s.
Net cash income per ME	30,125	72	26,775	58	n.s.

a) "Repayments" of short-term credit for purchased inputs (seed, fertiliser) that had to me made in kind in keeping with the cropping contracts were evaluated as purchases and sales.

Source: Compiled by the author.

in the two groups, whereas rice[1)] accounts for only 22 % and 28 %. In the semi-mechanised holdings, maize is also of some importance (12 % of the cash income), and moreover

1) About 16 % of the rice production in the traditional holdings was sold. The higher degree of commercialisation at 21 % in the semi-mechanised holdings can be attributed to credit for purchased inputs, that is paid for in kind, in keeping with the cropping contracts. If these payments in kind are not evaluated as sales, rice sales as a proportion of the total production are only 12 % in the co-operative holdings.

it is sold in July/August, at a time when the farmers are in need of cash for payment of wages, school fees, etc., whereas most of all the other cash receipts are in the period November to March[1].

Average cash expenses in the traditional holdings amount to 23,680 FCFA (about 20 % of cash income). Most payments (60 %) are to cover wage costs. The total cash expenses in the cooperative holdings are approximately four times as high, and come to 42 % of the cash income, with wage costs, machine hire and the purchase of material inputs each accounting for about one-third of the cash expenses.

Despite the net cash income in the cooperative holdings being on average about 20 % above that in the traditional holdings, the difference of 20,000 FCFA is not statistically significant. On the other hand, if we consider the net cash income per unit of family labour, the semi-mechanised holdings are even less profitable than the traditional holdings.

The level of the net cash income in all holdings is closely correlated with the area devoted to perennial crops: the correlation coefficients are $r = 0.847^{***}$ in the traditional holdings and $r = 0.779^{***}$ in the semi-mechanised holdings. The correlation between rice sales and net cash income, however, is only slightly positive and not significant ($r = 0.282$ and $r = 0.263$).

The greater variation of the net cash income compared with the farm family income leads to the conclusion that there are obviously some more factors connected with commercialisation which influence the net cash income. The bigger the

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1) Liquidity problems, in the sense of meeting payment obligations on schedule, scarcely occur, because a large proportion of the costs are not paid for until after the harvest (machine hire, fertiliser, some wages in coffee cropping) or do not arise until then (e.g. coffee peeling).

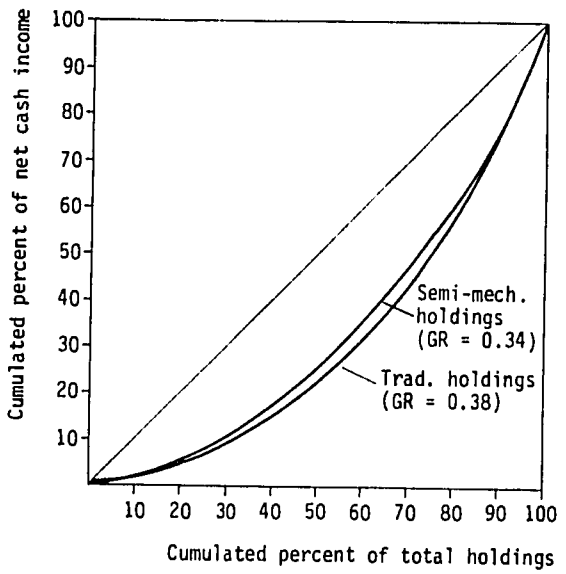
proportion of the total cropping area devoted to rice, the smaller the degree of commercialisation of the holdings (r - -0.677*** and r = -0.581***). In contrast, perennial crops show a positive relation to commercialisation, and the coefficient of correlation is highly significant in traditional holdings (r = 0.751***), but not so in the semi-mechanised holdings (r = 0.297), where semi-mechanised maize production still plays a certain role.

2.335 The distribution of net cash income

There is scarcely any difference in the distribution of net cash income between the traditional and semi-mechanised holdings. If we compare Diagrams 2.7 and 2.8, we can see that the net cash income is distributed considerably less equally than the farm family income. This is to be expected on account of the close relation to the perennial crop area, which is distributed very unequally[1]. 30 % of the holdings with the smallest net cash income account for only 9-11 % of the total net cash income, whereas 10 % of the best holdings account for one-quarter.

1) Cf. Diagram 2.3. Coffee is the most important cash crop in both, traditional and cooperative holdings, but it is surprising that those semi-mechanised holdings with limited perennial crop areas did not compensate this disadvantage by an intensification of mechanised farming.

Diagram 2.8: Relationship between the number of holdings and net cash income in traditional and semi-mechanised holdings in West Ivory Coast 1974/75



Source: Compiled by the author.

2.34 The economic importance of upland rice in farming systems under favourable natural conditions - a model analysis

Simultaneous planning is a suitable analytical instrument for the economic evaluation of production activities and farm enterprises, because complex production and cost relations in the holdings can largely be taken into account by these methods. With the help of simple linear planning models for traditional and semi-mechanised holdings the following examines the profitability of upland rice in these farming systems under the prevailing natural and economic conditions.

2.341 Assumptions in the model

Due to the fact that perennial crops play an important role in the agricultural systems under consideration, it would have been suitable to use dynamic models in the analysis. This, however, was not possible on account of time limitations and also because the available data was not sufficient to estimate the change of coefficients over time. Moreover, the primary intention is not to arrive at normative conclusions about optimal farm organisations, or even to establish farm development plans; instead the attempt is made to demonstrate the influence of the price changes of agricultural products and purchased inputs on the allocation of farm resources, and to assess the impact of technical innovations.

The economic target of the farmers, and therefore the objective function of the model, is to maximise net cash income of the holding, provided that the subsistence of the household is guaranteed (security constraint).

Average figures from the survey are employed to estimate the coefficients of the model. As far as subsistence requirements are concerned, rice (235 kg paddy/person) is differentiated from other subsistence crops that are combined as one activity (0.05 ha/person). A fixed relation of 1:2.2 between labour force of the holding and familiy size is assumed in calculating the subsistence requirement of the household.

Traditional upland rice production activities differ both in yields and labour requirements according to the time of sowing and the position in the rotation. Therefore, four production methods are identified in the model: cropping in the first or second year after land clearance, each differentiated according to the sowing time: March to mid-April and the end of April to the beginning of June (see Appendix VI). Other subsistence crops are only grown in the second

or third year after land clearance, with a distinction being made between extensive cropping (mainly cassava) and intensive production (high proportion of yam).

Since cocoa production is of practically no importance, only coffee is considered as a perennial crop, for which two activities are identified: cropping with low labour input and average yields of 160 kg/ha, and traditional cultivation with careful crop husbandry and average yields of 350 kg/ha.

In order to consider the fact that some farmers practise intensive cropping in semi-mechanised farming, both production with low labour input and labour-intensive production activities have been formulated for semi-mechanised upland rice and maize cultivation.

As regards the labour resource, the year has been divided into 7 periods corresponding to the seasonal pattern of field work. The working days available for field work have been estimated with weather conditions, social factors, etc., being borne in mind (see Appendix VI). The employment of hired labour is limited to a maximum of 25 % of the family labour input in the individual periods and to 45 % for the whole year. Moreover, the rice production activities facilitate the transfer of labour from period IV to period III, taking into consideration that the first weeding can be delayed, with the consequence of yield losses.

Because most of the farmers do not regard land as in short supply, it is not considered as a limited resource, except in the case of mechanised cultivation, with a maximum of 2 ha per holding. For mechanised cropping an agronomic constraint is included, according to which not more than 75 % of the area cultivated mechanically can be planted with rice.

Cash expenses of the production activities are identified in the objective function. Sales of rice, maize and coffee are considered as separate activities, whereas income from other subsistence crops is ignored, because they are rarely sold and only in very limited quantities.

To estimate the effects of technical innovations, which are at present not used by the farmers but partly offered by the Extension Service, the following activities have been formulated (see also Appendix VI):

- modern coffee production with selected cuttings, the use of mineral fertiliser and insecticides and intensive crop husbandry (yield 950 kg beans/ha);
- rice cultivation by hand with dressed seeds and the use of mineral fertiliser, cultivated in pure stand with row sowing and intensive weed control;
- semi-mechanised cultivation of early-maturing rice varieties with a vegetation period of 110 days that permits a second maize crop in the same year.

Additionally, the growing of improved varieties with a higher yield potential as a factor influencing the profitability of rice production is also investigated.

2.342 Results of the model

2.3421 Profitability of upland rice production under the prevailing natural and economic conditions

If we compare the actual organisation of the holdings in 1974/75 (see section 2.32) with the results from the model, we find in the case of traditional farms that there is no difference in the area of upland rice (see Table 2.35). The farm size in the optimal solution is somewhat less, because only the intensive production activities are realised for coffee and other subsistence crops. This raises coffee production, and 95 % of cash income is due to coffee sales. The amount of rice sold is very small, in fact much less

Table 2.35: Actual and optimal farm organisation of traditional and semi-mechanised holdings in West Ivory Coast 1974/5

	Traditional holdings (labour force 3.2 ME)		Semi-mechanised holdings (labour force 4.5 ME)	
	Optimal organisation	Actual organisation	Optimal organisation	Actual organisation
Total cultivated area (ha)	4.36	5.0	7.17	7.8
- traditional upland rice (ha)	1.30	1.3	0.94	0.6
- other subsistence crops (ha)	0.28	0.4	0.34	0.7
- coffee (ha)	2.78	3.3	3.39	4.1
- semi-mechanised upland rice (ha)	-	-	1.50	1.3
- semi-mechanised maize, 1st cycle (ha)	-	-	0.50	0.6
- semi-mechanised maize, 2nd cycle (ha)	-	-	0.50	0.4
Labour input (ME-days)	555	390	803	532
- family labour (ME-days)	492[a)]	328[a)]	691[a)]	420[a)]
- hired labour (ME-days)	63	72	112[b)]	112
Sale of rice (kg paddy)	108	396	2,237	831
Sale of maize (kg maize)	-	-	2,090	1,152
Sale of coffee (kg beans)	971	552	793	674
Net cash income (FCFA)	126,440	95,760	233,160	116,820

a) Including assistance from neighbours, since work arrangements are on a mutual basis.
b) Maximum limit in the model.

Source: Compiled by the author.

than was actually sold in 1974/75, because of the lower average yields of rice assumed in the model. As a result of intensive cultivation, particularly in the case of coffee, the input of familiy labour increases by 50 %, though the employment of hired labour does not change[1]. But the net cash income rises by only 32 %.

In the optimal solution of semi-mechanised holdings, the farm size is also smaller than the survey average, the difference being determined by the higher labour intensity involved in the production of coffee and the other subsistence crops. In contrast to traditional farms, however, only a third of the land devoted to coffee is cropped intensively, a fact that could be attributed to non-labour-intensive coffee production making better use of the scarce labour in period III (marginal value 1,560 FCFA/ME-day) than with intensive cultivation. Rice is the most important cash crop, and accounts for approximately 50 % of the cash income, about 40 % coming from coffee and just over 10 % from maize. Semi-mechanised upland rice is extended up to the limits imposed by agronomic constraints and cultivated intensively, whereas maize is produced with a low level of inputs in both cropping cycles. In the optimal solution traditional upland rice is to be grown to a much greater extent than has actually happened. By intensifying cropping, the net cash income can be doubled, with the input of family labour increasing by 65 %.

Accordingly, it would be advantageous in both cases to increase the labour intensity: in the traditional holdings with regard to coffee production, and mainly in rice cropping in the cooperative holdings. As revealed by the survey results, the farmers are in fact tending to follow these

1) Hired labour is used up to the limits set in the periods II, III and VI, the marginal values being 421, 574 and 720 FCFA/ME-day. The total labour resource does not act as a constraint.

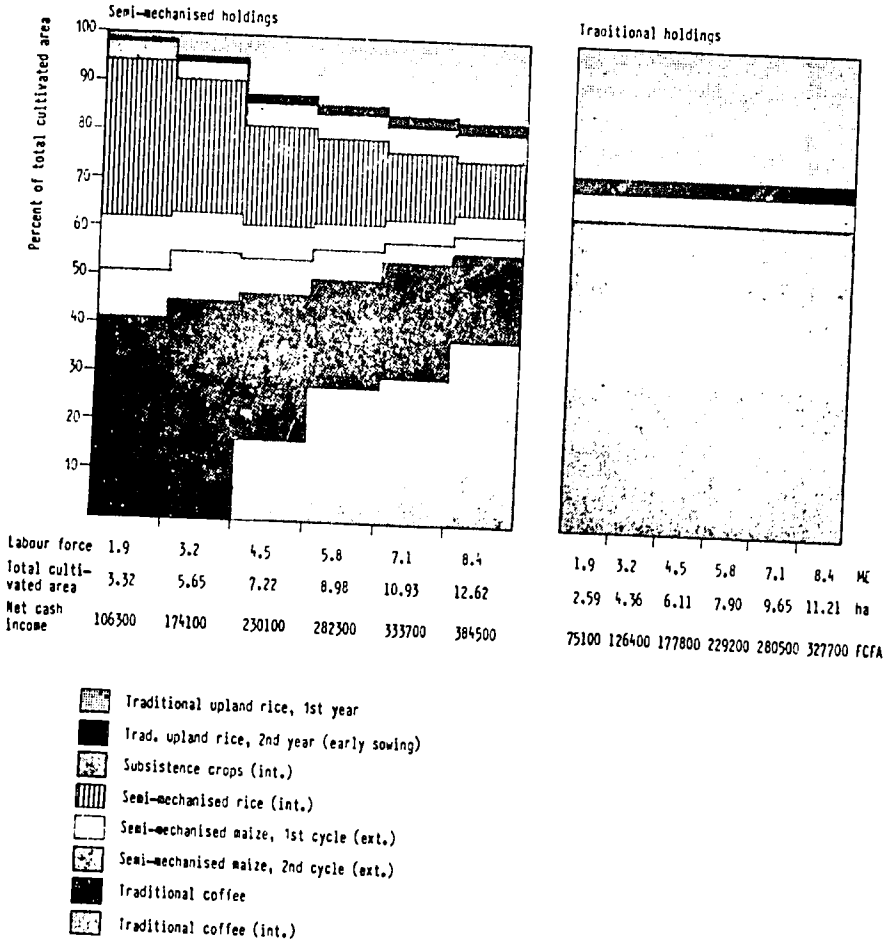
principles. In the traditional holdings coffee is produced with a much higher labour intensity than in the cooperative holdings, where the labour input in semi-mechanised rice production is again relatively high compared with other arable crops (see section 2.3232).

The total labour input per holding in the optimal solution is generally still very low. In the traditional holdings the reason for this can be seen in the fact that, with increasing input of labour, the increase in net cash income is on average only 187 FCFA/ME-day, and therefore lower than the wage level for hired labour. From this it can be concluded that marginal returns to labour are rapidly diminishing,as already observed when the relation between labour input and farm income was analysed (cf. section 2.333). In the semi-mechanised holdings, on the other hand, the net cash income rises by an average of 430 FCFA/ME-day. In this case, the unwillingness of farmers to increase their input of family labour can be attributed to the following reasons:

- The additional net cash income per working-day is not a sufficient incentive for these farmers to invest more family labour, i.e. they prefer to spend time on alternatives other than farming, or
- the farmers do not recognise the advantage of semi-mechanised farming as a means of increasing cash income, i.e. traditional behaviour persists and farmers do not adapt themselves to changing conditions.

If we compare the results of the models in Diagram 2.9, it is apparent that the net cash income can be increased by mechanising production on a part of the land. Since the semi-mechanised part of the holding is limited to a maximum of 2 ha, the increase in net casn income declines with increasing labour force from 42 % (1.9 ME) to 17 % (8.4 ME). This area constraint becomes effective with a labour force of 3.2 ME. As the labour force is increased, the marginal value of the mechanised land rises from 0 to 24,000 FCFA/ha, whereas the marginal value of a unit of family labour

Diagram 2.9: Changes in the optimal organisation of traditional and semi-mechanised holdings with increasing labour force



Source: Compiled by the author.

decreases from 56,000 to 39,000 FCFA/ME[1]. At the same time coffee production is intensified and traditional rice cropping is extended: thus the proportion of the area devoted to semi-mechanised rice growing is reduced from 32 % to 12 %, and that of maize from 11 % to 4 %.

In contrast, the organisation of the traditional holdings does not change as the labour force increases, because land is not considered as a constraint in the model, and all other limiting factors change proportionally to a change in the labour force. The marginal value of labour is 39,500 FCFA/ME, and it remains unchanged with increasing labour force of the holdings.

Despite the fact that labour is of decisive importance, the stability of the solutions is very high, even if the working-time per unit of labour is changed. If the available amount of labour in the traditional holdings decreases, the coffee area is disproportionately reduced, but intensive cultivation is nevertheless retained. However, with an increase of the working-time per unit of labour up to 30 %, the solution remains stable. With increasing availability of labour in semi-mechanised holdings, coffee production is intensified, while the total cultivated area changes only slightly.

So far in this analysis, yield uncertainty of the various crops has not been considered. Only in the case of traditional rice production is it assumed in the model as a security constraint that farmers sow a maximum of only 10 % of the land area by the middle of April. If this assumption did not apply, the proportion of the early sown upland rice would rise to 30-40 %. Consequently, the area devoted to

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1) In order not to act as a constraint, a land resource of 0.75 ha/ME for mechanised farming would be necessary. The resulting increases in the objective function values are 3 % (3.2 ME) to 20 % (8.4 ME).

rice and coffee would expand, but the resulting increase in net cash income comes to only 5-10 %, which does not appear to justify the higher production risk. The greater yield uncertainty of coffee due to climate, however, might make upland rice relatively more encouraging than actually appears in the model. It was not possible to include this aspect in the analysis because of the lack of sufficient data[1].

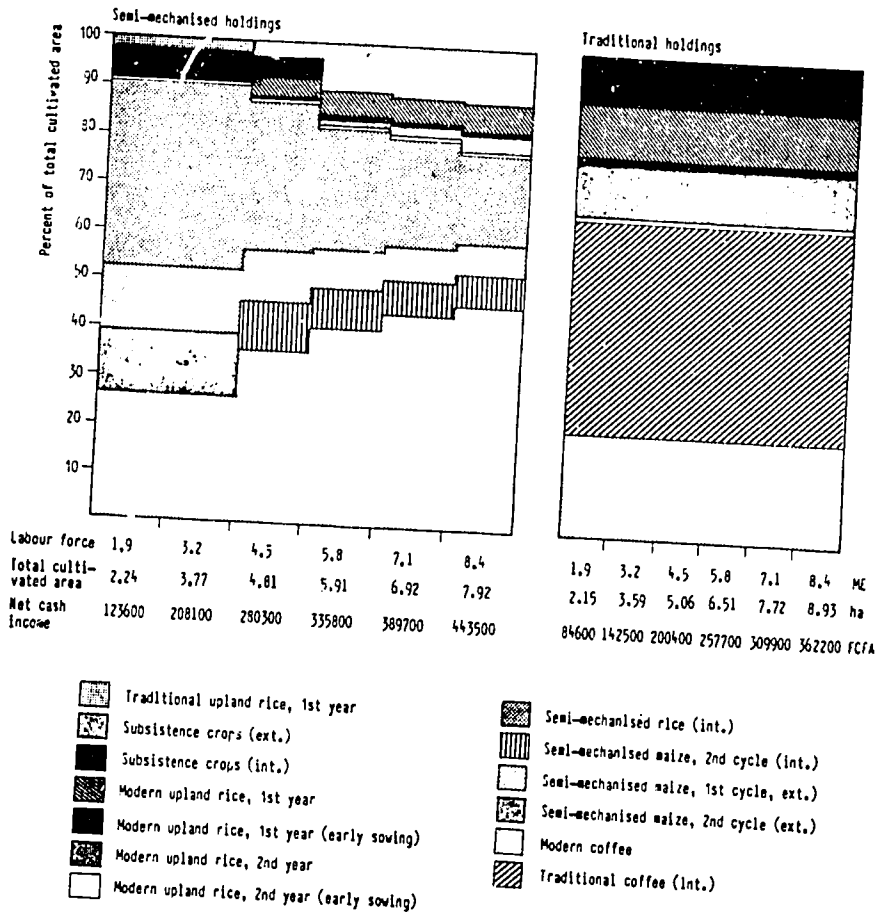
2.3422 The impact of technical innovations in rice and coffee production on the optimal organisation of traditional and semi-mechanised holdings

The intensification of rice and coffee production by introducing mineral fertilisers, improved seeds and selected cuttings, together with improved husbandry practices, brings about a reduction in the cultivated area in traditional holdings, where the coffee and rice areas are reduced by 15 % and about 30 % respectively, and traditional upland rice cropping is completely replaced by modern production techniques (see Diagram 2.10). The share of rice and coffee in the total cultivated area remains virtually unchanged, but that of the remaining subsistence crops increases slightly. Modern coffee production occupies one third of the coffee area. Rice is grown exclusively for subsistence, whereas coffee production is increased by 30 %.

These changes in farm organisation, however, bring about only insignificant increases in farm profits. The net cash income in the optimal solution is only 13 % more than in the traditional holdings. Even if we bear in mind that the family labour input is reduced by about 10 % and the aver-

1) For the treatment of risk in linear planning models, see ANDERSON et al. 1977, BOUSSARD 1976, BOUSSARD/PETIT 1967, LOW 1974, WOLGIN 1975.

Diagram 2.10: Optimal organisation of traditional and semi-mechanised farms with the introduction of modern cropping techniques for rice and coffee



Source: Compiled by the author.

age return to labour is thus improved by 25 %, it can be assumed that these are insufficient economic incentives to persuade the farmers to adopt the new production techniques. That the improvement in the objective function is only small, can be attributed to the fact that returns to labour of modern farming techniques are not much higher in the limiting periods II and VI than in the case of traditional production methods.

In the semi-mechanised holdings, the traditional methods are completely replaced by modern techniques for coffee and rice production. Only when the labour force is small is traditional upland rice still grown to a limited extent. Because of the reduction of the total cultivated area by 17-37 %, the share of coffee drops to 25-45 %, and that of semi-mechanised rice and maize increases (see Diagram 2.10). As in the case of the traditional holdings, the change in farm organisation leads only to a slight increase in net cash income. The 20 % rise in net cash income and the higher return to family-labour, caused by a slight decrease in the total labour input, are certainly higher in the semi-mechanised holdings than in the traditional holdings, but it remains doubtful whether these incentives are enough to encourage the farmers to adopt the new methods.

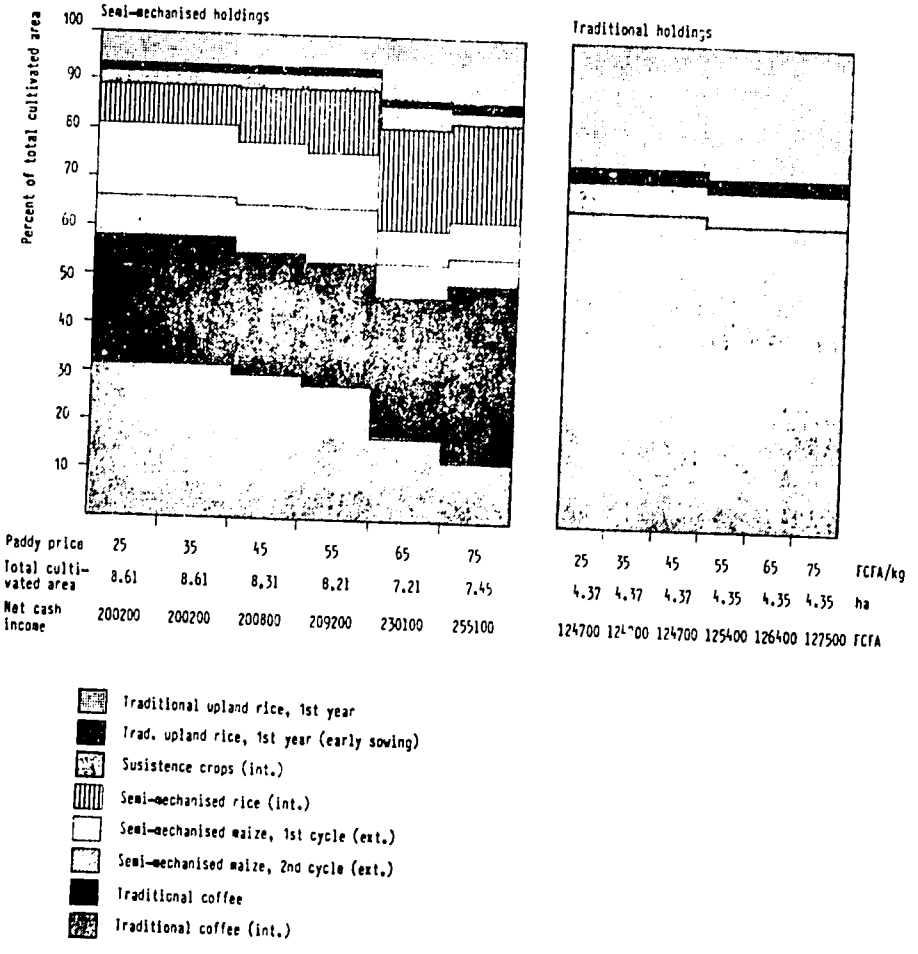
There is only an insignificant improvement in farm profits when early-maturing rice varieties are introduced into semi-mechanised rice cropping (rise in net cash income of 3 %). The cultivation of varieties with a longer vegetation period is thus replaced on about a quarter of the semi-mechanised arable land. On account of the lower yields of the early-maturing varieties, the result is a decline in rice production and an increase in coffee and maize production, since traditional upland rice cultivation is reduced and semi-mechanised maize cropping in the second cycle and coffee production are expanded and intensified because of the labour released in periods V and VI.

If only modern upland rice production is introduced as an alternative in the model, this activity appears in the solution to an extent of 70 % and 45 % of the hand-cultivated rice area in traditional and semi-mechanised holdings respectively, although it is not conducive to any significant rise in net cash income (3 % and 1 %). Even if new varieties are available, with an average yield of 25 dt/ha with the hand method and 30 dt/ha by semi-mechanised cropping, the 6-10 % improvement in the objective function remains relatively small. Moreover, such improved rice varieties have scarcely any impact on the optimal farm organisation, if modern coffee cropping is also included. Only in the traditional holdings modern coffeee production is slightly reduced and replaced by intensive traditional cultivation methods. The total rice area remains unchanged, and the surplus production resulting from the increase in rice yields is sold. Thus rice accounts for 17 % of the cash return, and the net cash income rises by 22 %. In the cooperative holdings, on the other hand, the net cash income would rise by 44 % and the optimal farm organisation remains the same as in the case of actual average rice yields. With these technical advances in rice production, the marginal value of the semi-mechanised land would double (from 23,000 to 46,000 FCFA/ha) in holdings with a labour force of 4.5 ME.

2.3423 The effect of price changes of inputs and products on the allocation of farm resources

Diagram 2.11 illustrates that, with regard to the change of paddy prices, the organisation of traditional holdings is relatively stable. With a coffee price of 150 FCFA/kg, the price of paddy must be at least 55 FCFA/kg for upland rice to be grown to a limited extent as a cash crop. Up to a paddy price of 75 FCFA/kg, the organisation of the holdings remains unchanged, and since rice is mainly grown as a sub-

Diagram 2.11: The effect of paddy price changes on the optimal organisation of traditional and semi-mechanised holdings



Source: Compiled by the author.

sistence crop, price changes for paddy scarcely have any effect on the net cash incomes of the holdings[1]. There is also no significant change if improved seeds and mineral fertiliser are used. The amount of rice sold per holding (with 3.2 ME) rises from 108 to 156 kg with a paddy price of 55 FCFA/kg, and reaches 358 kg with a price of 65 FCFA/kg. If modern coffee production is included, paddy is only sold at a price of 75 FCFA/kg (113 kg). These examples show that upland rice as a cash crop is not very important in traditional farming systems, and that in view of the current coffee prices, price policy measures relating to rice scarcely seem appropriate to raise rice production.

The optimal organisation of semi-mechanised holdings is much more affected by changes in the price of paddy (Diagram 2.11). At a paddy price as low as 45 FCFA/kg, rice becomes more important as a cash crop. With semi-mechanised farming, maize is still competitive on account of the higher return to labour, so that the rotation constraint on rice only becomes effective at a price of 65 FCFA/kg paddy. A further increase of rice production is obtained by expanding traditional cropping. The amount and intensity of coffee production decreases relative to the increasing importance of rice.

In 1974, the price relations in Ivory Coast were distorted, as the farm-gate prices fixed by the Government were increased for paddy from 28 to 65 FCFA/kg and for coffee from 120 to 150 FCFA/kg. In the same year, price increases of material inputs and machine hire ranged between 25 % and 80 %. As Table 2.36 illustrates, these price changes have hardly any effect on the organisation of the traditional holdings. The area devoted to rice is simply increased by 7 %, rice is sold on a small scale and the coffee area is is only slightly reduced. The net cash income improves by about a third, and amounts to 126,400 FCFA per holding.

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1) Naturally the profitability of rice production increases, and the farm income and farm family income rise accordingly.

Table 2.36: Optimal organisation of traditional and semi-mechanised farms in West Ivory Coast under the price relations of 1972/73 and 1974/75

	Traditional holdings (3.2 ME)		Semi-mechanised holdings (4.5 ME)	
	1972/73	1974/75	1972/73	1974/75
Total cultivated area (ha)	4.34	4.36	8.86	7.17
- trad. upland rice (ha)	1.21	1.30	0.82	0.94
- other subsistence crops (ha)	0.27	0.28	0.26	0.34
- coffee (ha)	2.86	2.78	4.28	3.39
- semi-mechanised upland rice (ha)	-	-	0.50	1.50
- semi-mechanised maize, 1st cycle (ha)	-	-	1.50	0.50
- semi-mechanised maize, 2nd cycle (ha)	-	-	1.50	0.50
Labour input (ME-days)	546	555	828	803
- family labour (ME-days)	486	492	716	691
- hired labour (ME-days)	60	63	112	112
Sale of rice (kg)	-	108	-	2,237
Sale of maize (kg)	-	-	7,470	2,090
Sale of coffee (kg)	1,003	971	891	793
Net cash income (FCFA)	94,560	126,440	194,960	233,160

Source: Compiled by the author.

On the other hand, price changes bring about a considerable modification in the optimal organisation in semi-mechanised holdings. Rice as a cash crop has no importance under the price relations of 1972/73, where in the optimal solution three-quarters of the semi-mechanised land is cropped with maize (intensive cultivation in both cropping cycles). Thus maize is the most important cash crop and provides 60 % of the cash income, and coffee only 40 %. With the improvement in the price relation for paddy, the semi-mechanised rice area is expanded to the limit imposed by the rotation constraint and maize cultivation is reduced and maize is grown with a low level of inputs in the first cycle. Moreover, the coffee area is reduced and coffee is produced with a higher labour-intensity (40 % of the coffee area with intensive cultivation compared with 25 % in 1972/73)[1]. Rice, that accounts for 47 % of cash income, becomes the most important cash crop, the proportion attributable to coffee remains unchanged at 40 %, and maize, that contributes only 13 % of the total cash income, becomes insignificant as a cash crop. Because of the higher prices for purchased inputs and machine hire, the rise in net cash income of 20 % is less than in the traditional holdings. If the modern production techniques are included, the same tendencies can be seen.

At the present farm-gate prices for paddy, maize and coffee, the organisation of the holdings remains largely stable, also when the prices of purchased inputs and machine hire are changed. If modern production techniques are applied, a gradual increase in the price of fertiliser from 25 to

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1) For coffee as a perennial crop, it can be assumed that not only an increase, but also a decrease of its area extends over quite a long time, since farmers are not generally prepared to give up any of their land cultivated with perennial crops at short notice. The result would be that a larger area would be cropped with a lower labour intensity, bringing about a slight drop in net cash income.

75 FCFA/kg, and in mechanisation costs from 8,000 to 18,000 FCFA/ha for rice and 4,000 to 9,000 FCFA/ha for maize, does not lead to any substantial change in farm organisation in either the traditional or the semi-mechanised holdings. The variations in net cash income that are caused by price fluctuations are relatively small, and come to about 10-15 % in the traditional holdings compared with 20-25 % in the semi-mechanised holdings. Similarly the marginal values of labour change only slightly (10-15 %), whereas the marginal value of the semi-mechanised land is reduced to one-quarter by the rise in input prices.

2.4 Semi-mechanised Upland Rice Production Under the Unfavourable Climatic Conditions of the Central Region of Ivory Coast

2.41 Natural conditions

The central region of Ivory Coast is a transitional zone between the deciduous rainforest and the Sudan savanna. The climate is characterised by a bimodal rainfall distribution, with the first rainy season lasting from April to the beginning of July, followed by a second rainy season from the end of August to October. Between these two rainy seasons there is a more or less distinct short dry period in July and August, with an average monthly rainfall of about 100 mm. The long dry season lasts from November to March. The total average annual rainfall in Beoumi[1)] is 1200 mm. A relative maximum (150 mm) occurs in June and an absolute maximum (240 mm) occurs in September. The negative effects of the short dry season on agriculture are reduced by the low potential evapotranspiration in July and August, in which the

1) There are only slight climatic differences to those in Bouaké (see Appendix IV).

ETP Turc (Eldin) is only about 90 mm per month[1]. The average annual temperature ist 25.5°C. The hours of sunshine come to about 1950 per annum, and are very low in July/August. Soil erosion occurs to a moderate extent: the R-value on the WISCHMEIER-scale is about 600 (ROOSE 1977, p. 133).

The landscape is gently undulating, with the steepest slopes rarely exceeding 10 %. About two-thirds of the region developed from granite rocks, and the slopes are between 2 and 7 %. These mostly ferralitic soils are usually very light, with a clay content of 10-20 % and about the same proportion of gravel. The content of organic matter is on average 2.2 %, which is satisfactory. These soils provide, therefore, favourable conditions for intensive mechanised agriculture, because soil erosion is not a problem that requires expensive control measures. The second important group of soils developed from schist (about a third of the land area). In this case the slopes are steeper (7-10 %), and the content of clay (about 20 %) and of organic matter (3-3.5 %) is higher than in the soils derived from granite. But despite this higher soil fertility potential, these soils are more difficult to cultivate on account of their higher gravel content. Both soil types have a low water holding capacity, which is an important disadvantage in view of the uncertain rainfall distribution.

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1) The unfavourable rainfall conditions for upland rice production are to a certain extent compensated by this low evapotranspiration.

2.42 The development of farming systems with permanent upland cultivation

In Ivory Coast in 1971 the first villages were resettled that were being flooded by the lake of the Kossou Dam. The resettlement programme was undertaken by a semi-government organisation, the Autorité pour l'Aménagement de la Vallée du Bandama (AVB). As part of this programme, one of the main objectives in the agricultural sector was to replace traditional bush fallow systems by semi-mechanised permanent cultivation in some of the farms (AVB 1975, pp. 1 et seq.).

To achieve this, so-called "Groupements pour l'Utilisation du Materiel Agricole" (GUMA) were founded and equipped with machines and agricultural implements (45 KW tractors and mulching equipment, disc ploughs, disc harrows and seed drills). Each GUMA comprises 30-40 farmers and cultivates an area of 150-200 ha, a so-called "ensemble". The costs of the development of this land were entirely undertaken by the Government. Each ensemble is divided into 5-6 sections according to the rotation followed, and each of these sections is devoted to the production of one crop. The sequence of cropping, cultural operations and production methods are determined to a large extent by the AVB, and farmers are obliged to follow the instructions of the extension service. The following rotations are mainly adopted[1]:

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1) The original rotation had been suggested by agricultural research stations(IRAT, IRCT). In view of the price change for paddy in 1974, the proportion of rice in this rotation was increased, too. Since 1976, the double cropping of maize and cotton is no longer practised because most of the farmers were not interested in maize cultivation as market prices were low.

	Original rotation (1971-1976)	Modified rotation (from 1975)	Modified rotation (from 1976)
1st year	yam	yam	yam
2nd year	maize/cotton[1)]	rice	rice
3rd year	rice	maize/cotton	cotton
4th year	Stylosanthes gracilis	rice	rice
5th year	Stylosanthes gracilis	Stylosanthes gracilis	Stylosanthes gracilis
6th year	-	Stylosanthes gracilis	Stylosanthes gracilis

The Stylosanthes fallow is used for cattle grazing. At the outset this land was leased to herdsmen specialised in fattening of N'Dama cattle. After some time the attempt was made to establish communal cattle-keeping with the co-operatives' members owning the herd and making use of the fallow land.

According to the rotation, the annual cultivated area amounts to 100-170 ha. Land-use intensity is about 70-80 %, and is therefore lower than in the example from the western region (R = about 120-130).

This case study analyses the situation in six of these ensembles in the villages Assakra, Dieviessou, Fitabro and Yobouê N'Zuê in the vicinity of Beoumi town, about 40 km west of Bouakê in the centre of Ivory Coast (see Map 1, Appendix III). With regard to soil quality, these ensembles are divided into two groups, three with good soil conditions suitable for mechanised cultivation, while on the other three soils are of only average to poor quality[2)].

1) Maize is grown from April to July, cotton from August to November in the same year.

2) See page 122.

2.43 The organisation of the holdings

In a single-visit survey, information on farm structure was collected from four holdings in each of the six ensembles (July 1975)[1]. The selection of the farms was left to the agricultural extension workers and was not at random[2]. The results are therefore not representative and are only intended to give an idea of farm organisation.

2.431 Resource availability

2.4311 Labour

Although none of the holdings employs permanent hired labour, the relation of the labour force to family size is only small (r = 0.412*). The demographic features of the holdings are summarised in Table 2.37.

The family size of the sample holdings is on average 6.9 persons which is somewhat larger than the average for the region. The labour force is 3.2 ME and may also exceed the regional average slightly. The labour force per cultivated hectare is 0.63 ME.

Footnote 2 from page 121:

2) Information given to the author by Dr. CARUCCI, FAO-consultant with AVB, Bouaké, October 1975. The soil quality also varies considerably within the individual ensembles, but there is no detailed information available. The classification was the result of a pedological survey before clearance.

1) See Appendix V for the method. For financial reasons it was unfortunately not possible to carry out a similar, intensive and comprehensive survey over a longer period of time or to include traditional holdings as in the previous case study.

2) It was not possible to estimate the traditionally cultivated area in one holding, which was therefore excluded from the analysis.

Table 2.37: Demographic features and labour force in semi-mechanised holdings in the central region of Ivory Coast

Feature	Regional average[a)]	AVB holdings (n=23) $\bar{x}$	CV(%)
Number of persons per household	6.5	6.9	34
Number of wives per farmer	-	1.4	56
Age of farmer (years)	-	42.0	28
Labour force (ME)	3.2[b)]	3.2	32

a) Results of the agricultural census 1974 for the region "Bouakê Centre".

b) Number of persons 15 to 59 years old.

Source: RCI/MINISTERE DE L'AGRICULTURE 1976, Tab. 1.61 and 1.71.

2.4312 Land

The land used for agricultural production comprises the area of the holdings within the ensemble and the fields cultivated by traditional methods. According to the traditional law of the Baoulê, a right to land use of only limited duration can be claimed, and for this reason the fallow fields in the traditional farming system may not be included in the land area of the holdings. Perennial crops are not grown[1)]. The average farm size is 5.2 ha, of which approximately 90 % is cultivated by tractor, as Table 2.38 illustrates.

1) Only small areas of coffee and cocoa are grown in the region. In the past farmers cultivated some areas of land which is now flooded, but as yet no new plantations have been established. One farmer owned a coffee plantation of 7 ha in the south of the country that he had let on lease. Since this was exceptional, it was not included in the analysis.

Table 2.38: Farm size of semi-mechanised holdings in the central region of Ivory Coast (n=23)

	Mechanised land		Traditional land		Total land	
	$\bar{x}$(ha)	CV(%)	$\bar{x}$(ha)	CV(%)	$\bar{x}$(ha)	CV(%)
Total cultivated area	4.53	11	0.63	59	5.16	12
Theoretical farm size[a]	-	-	-	-	6.62	26

a) Estimated according to an average fallow period of 4 years.

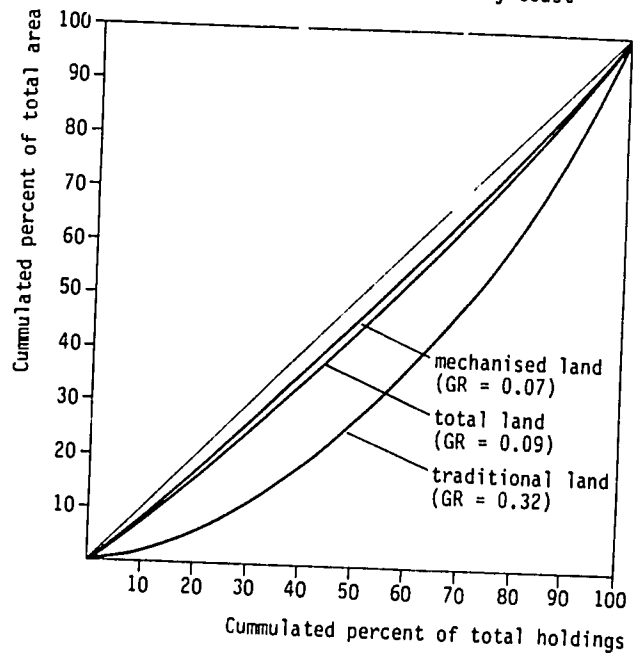
Source: Compiled by the author.

The difference between the actual land area and the theoretical farm size is only slight on account of the small proportion of land that is traditionally cultivated.

The semi-mechanised holdings are thus much larger than the average for the region; the agricultural census of 1974 revealed an average farm size of only 1.6 ha per holding (RCI/MINISTERE DE L'AGRICULTURE 1976, Tab. 2.11).

The very slight variation in farm size (see Diagram 2.12) can be attributed to the fact that an area of 4 to 6 ha in the ensembles was allotted to each farmer irrespective of the family size or the labour force of the individual farmer. Since the traditionally cultivated land is too small to influence the variation in the farm size appreciably, the area of land per ME clearly decreases as the labour force of the holdings increases ($r = -0.860^{***}$).

Diagram 2.12: Relationship between the number of holdings and the total cultivated area in semi-mechanised farming systems in the central region of Ivory Coast



Source: Compiled by the author.

2.4313 Capital

Capital goods in the holdings are limited to simple hand implements and containers for transport, and they do not create a bottleneck for agricultural production.

With the exception of poultry, stock-keeping in the holdings is forbidden by the project management, in order to avoid crop damage. About three-quarters of the holdings keep poultry, mostly hens, almost entirely for subsistence. The average stock is 9.0 birds per holding.

2.432 Land use

2.4321 Methods of crop production

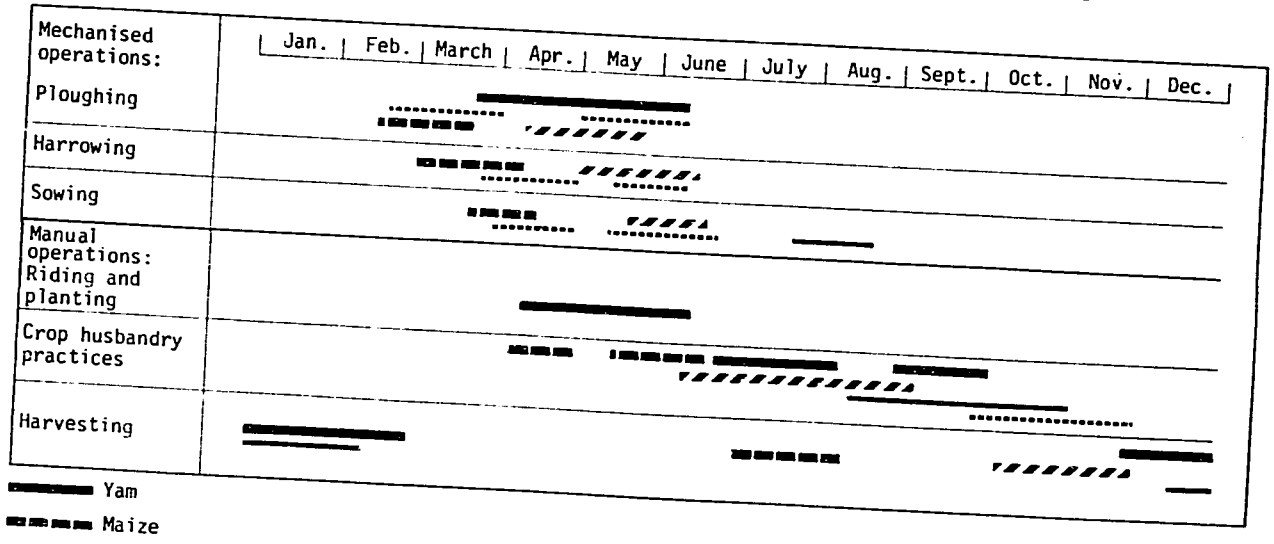
Farmers are obliged to grow particular crops on the mechanically cultivated land. Land preparation and the sowing of maize, rice and cotton are carried out with tractors; for yam the land is simply ploughed. All other operations, like ridging and planting of yam, weeding, pest control and harvesting, are done manually by the farmers. Diagram 2.13 illustrates the pattern of field work in the holdings.

Yam is the first crop in the rotation. After tractor ploughing, ridges are made on the field with a hand hoe. Mostly late-maturing varieties of the species Discorea cayenensis are grown. For planting, sections of tuber are used (1500-2000 kg/ha). After planting, the plots are continuously weeded, and harvested from December into February. Mineral fertiliser application is not practised.

Until 1975, maize was grown during the first rainy season. The variety used, a composite (CJB) with a vegetation period of 110 days, was sown at the end of March or the beginning of April and harvested during July. The soil was ploughed and harrowed once or twice. A single-seed drill was used for sowing (30 kg/ha). Thinning, weeding and harvesting were done by hand, and no mineral fertiliser was applied.

After maize, disc harrowing once or twice is usually sufficient to prepare the seedbed for cotton. Pest control is performed using knapsack sprayers, and the number of sprayingsranges between three and five. The input of mineral fertiliser is 200 kg NPK 14-14-14 per ha. Since 1976, cotton has been cultivated without being preceded by maize in the same year in order to eliminate one of the main reasons for the low yield level, namely late sowing (sometimes not until the end of August) caused by delayed maize harvesting.

Diagram 2.13: The pattern of field work in semi-mechanised upland farming in the central region of Ivory Coast



Yam
Maize
Upland rice
Cotton
Stylosanthes gracilis

Source: VIRICELLE no year, pp. 14 et seq., AVB 1974.

Seedbed preparation for upland rice consists of ploughing and harrowing the land. Sowing is at the end of May or the beginning of June towards the end of the first rainy season. The seed rate is 50 kg/ha and the varieties grown are Morobêrêkan and Iguapé Cateto (see Appendix II). Mineral fertiliser application is the same as in the case of cotton, but sometimes a further dose of 100 kg ammonium sulphate is given when shooting takes place. Rice is harvested in October/November, and paddy is threshed with mobile power take-off operated threshing machines.

The Stylosanthes fallow should be established during May. Since the soil has to be ploughed and harrowed as in the case of maize and rice, and machine time is sometimes limited, establishing the Stylosanthes fallow extends from May to August. Mulching is the only husbandry practice, and it is carried out once a year. The fallow areas are fenced in and grazed rotationally with N'Dama cattle.

The traditional form of land use is hoe cultivation in a bush fallow system. Yam is mostly grown as the first crop after land clearance and is planted from February to May. The land is ridged with a fairly large hoe, whereby weeds are worked into the soil. Early maturing varieties are grown first, and in May/June late-maturing yam varieties are planted. According to variety, harvesting takes place after 6 to 8 months. About three months after the first harvest, early maturing varieties produce a further yield of small tubers that are mostly used as seeds. As a rule, mixed cropping is practised, and the density of the stands of other crops is low. Maize, cassava, okra (Hibiscus esculentus), tomatoes, egg plants (Solanum sp.) and spices (Capsicum sp.) are frequently grown (RCI/MINISTERE DU PLAN 1966, Vol. 2, pp. 84 et seq.). In the second year, a part of the land is mostly cropped twice: maize, groundnuts, ouré-ouré (Cucumis amarus) during the first rainy season, followed by upland rice or more rarely by cotton. The last

crop is cassava, which stays in the soil as food reserve that is harvested according to need, and is overgrown in time by the fallow vegetation. The duration of the fallow after these two to three years of cropping ranges between three and about eight years, depending on population density.

2.4322 Crop areas

The total cultivated area per holding is 4.7 ha, of which 86 % is mechanised (see Table 2.39). In the ensembles, the land-use intensity is 120 %, because maize and cotton are cultivated in the same year. If we include the fallow land, the R-value is 90. As can be seen from Table 2.39, rice is the most important crop and accounts for 37 % of the mechanically cultivated land; maize accounts for 24 %, yam for 22 % and cotton, that is not grown in all holdings, for 17 %. The biggest proportion of the traditionally cultivated area (44 %) is devoted to yam, while 20 % is devoted to groundnuts and 20 % to cassava. Only 5 % of the land is cropped twice a year.

Among the reasons for practising traditional farming are the need to ensure subsistence requirements and the employment of the idle family labour. Since there is no recognisable relation between the traditionally cultivated land and the size of the family ($r = 0.027$), a basic reason for traditional cultivation might well be the full employment of the family labour force, although even this relation is not very close ($r = 0.490^{*}$).

The total cultivated area per ME is 1.6 ha, and it decreases clearly with the increasing labour force of the holdings ($r = -0.761^{***}$). Compared with traditional agriculture in the region, the cultivated area per ME in the semi-mechanied holdings could be increased by almost three times[1].

1) See page 130.

Table 2.39: Crop areas in semi-mechanised holdings in the central region of Ivory Coast (n=23)

Crop	Mechanised		Traditional		Total	
	$\bar{x}$(ha)	CV(%)	$\bar{x}$(ha)	CV(%)	$\bar{x}$(ha)	CV(%)
Yam	0.68	13	0.29	.86	1.18	22
Rice	1.49	29	a)		1.53	26
Maize	0.97	17	a)		0.99	19
Cotton	0.67	69	-	-	0.67	69
Groundnuts	-	-	0.13	74	0.13	74
Cassava	-	-	0.14	123b)	0.14	123b)
Others	-	-	0.05	196b)	0.05	196b)
Total cultivated area	4.01	16	0.66	62	4.67	18

a) Only two farmers cultivated uplard rice, and one farmer maize on the traditionally cultivated area.

b) High coefficient of variation caused by a large number of zeros.

Source: Compiled by the author.

2.433 The labour economy

Data on the labour use in the period April/October in 16 of the 24 holdings is available from a survey carried out by ORSTOM in 1975[1]. With the exception of harvesting, in-

Footnote 1 from p. 129:

1) The average cultivated area per ME in the region is 0.5 ha (BDPA no year, Vol.2, p. 116; RCI/MINISTERE DE L'AGRICULTURE 1976, Tab. 1.71 and 2.11).An area of 1.6 ha/ME is high even in comparison to other mechanised projects in the region: a comparison of traditional and semi-mechanised holdings showed a total cultivated area per ME of 0.46 ha in the traditional holdings, compared with 0.96 ha in the semi-mechanised holdings (RCI/MINISTERE DE LA RECHERCHE SCIENTIFIQUE/GERDAT 1977, Vol.2, Tab.10).

1) Unless otherwise stated, all data are derived from ORSTOM 1976.

formation about the most important cultural operations in this survey is provided by traditional and semi-mechanised farming.

During the survey period[1], the average labour input per holding was 15.5 ME-days per week, which would correspond to a total labour input of about 800 ME-days per year. The actual figure might range between about 600 to 700 ME-days, if we bear in mind that the labour input is lower in the dry season. 79 % of the total labour input was provided by family members, the rest mainly by non-family labour within neighbours' cooperation groups[2]. For these reasons, the actual figure is about 150-180 ME-days per employed person, or 900-1100 working hours per year[3]. The input of family labour is thus much higher than in the western region.

If we examine the behaviour of the farmers in respect of the labour input, we can differentiate between three groups of holdings:

- holdings with above-average labour force, in which both the labour input per person and non-family labour as a proportion of the total labour input are relatively low;
- holdings with a low labour force and a relatively high proportion of hired labour (25 %) and high labour input per unit of family labour; and
- holdings with an average labour force and very high input per unit of family labour, with only about 15 % non-family labour.

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1) The periods vary between 16 and 30 weeks for the individual holdings.

2) According to the author's own investigations in 1975, about two-thirds of the farmers and half of their wives were members of so-called "N'Bli" (neighbours' cooperation). Since this assistance is mutual,family labour as a proportion of the total labour input is in fact considerably higher.

3) The average working time in the region is 6 hours per day. Surveys in the early mechanised projects in the region (1968/69) mentioned average figures of 1,152 hours per annum (192 days) for men and 893 hours per annum for women (BONNEFOND 1971, p. 129).

On average, about 86 % of the total labour input is devoted to the semi-mechanised part, and 14 % to the traditionally cultivated area. As these proportions correspond also to the proportions of the area devoted to each cultivation method, the labour intensity on both semi-mechanised and traditionally cultivated areas must be the same.

With regard to the pattern of work in the holdings, there are two labour peaks: ridging for and planting of yam in May/June and another peak in July/August when yam and rice weeding and maize harvesting must be carried out.

It was possible to estimate the labour input per hectare for four operations. Ridging for yam cultivation after tractor ploughing requires on average 87 ME-days/ha. In this case the growth of Imperata cylindrica plays an important role, because if weed growth is dense, the labour input rises to about 150 ME-days/ha. The average labour input of 21 ME-days/ha for weeding of maize was relatively low, since maize is cultivated directly after yam. In contrast, weeding for rice and cotton demands a considerably higher labour input of about 75 ME-days/ha. There are on average 20-25 days between sowing and the beginning of weed control. The longer this interval is, the higher the labour requirement for weeding (maize r = 0.460, rice r = 0.670**). In the case of cotton, however, this relation is reversed (r = -0.714**), which can be explained by the fact that weeding has to be started very early on plots especially with intense weed growth.

The relationships between the labour input per hectare and the cultivated area are relatively weak for all operations, which leads to the conclusion that there are no significant economies of scale. On the other hand, the labour input per hectare rises with the increasing labour force of the holdings (rice r = 0.817***, maize r = 0.782**), i.e. with more available family labour, production becomes more labour-intensive.

2.44 Development of yields

A period of 5-6 years (1971-1976) is certainly too short to draw conclusions about the change of soil fertility in this farming system, or to demonstrate trends in the development of yields. This applies particularly in the case under study, where the irregular rainfall distribution gives rise to pronounced variations of yield. But the available information allows us to make some tentative statements regarding the possibilities of permanent upland cultivation within smallscale farming systems in this region.

2.441 Crop yields and yield variation over time

If the average yields of the different crops in all ensembles is considered, it becomes obvious that the initially planned yields are realised only in the case of yam (see Table 2.40). The yields of the other crops are 15 %, 20 % and almost 50 % below the target figures for maize, rice, and cotton respectively. The coefficient of variation is the smallest for yam (25 %), which is the most important subsistence crop in the region, not least because of its relatively stable yields. The coefficients of variation for the other crops are about 45 %, which is very high, and except for cotton (10 % higher), they correspond largely to coefficients of variation that have been observed in agricultural research stations (see Le BUANEC 1972, pp. 1207 et seq.).

If crop yields in ensembles with good soil quality are compared to those in ensembles having poor soils, differences of about 20 % in the case of rice and cotton and 46 % for maize are observed. The difference in yield of yam is only slight. The variation of yields is usually higher on good soils than where the soil quality is moderate, since soils with a high water holding capacity serve as a buffer in

Table 2.40: Average yields[a] and coefficients of variation over time in six AVB-ensembles 1971-1976 (yields in dt/ha and coefficients of variation as a %)

Crop	Planned yield[b]	Average yields and coefficients of variation over time in all ensembles		3 ensembles with good soil quality		3 ensembles with moderate soil quality		Difference between 3 and 4	
		$\bar{x}$	CV	$\bar{x}$	CV	$\bar{x}$	CV	$\bar{x}$	CV
	1	2		3		4		5	
Yam	120	125.6	24.9	129.2	20.9	122.0	29.3	n.s.	n.s.
Maize	22	19.0	46.8	22.8	40.8	15.6	47.0	n.s.	n.s.
Cotton	12	6.4	44.5	7.0	38.0	5.9	52.4	n.s.	**
Upland rice	20	15.7	46.3	17.1	47.2	14.1	43.6	n.s.	n.s.

a) Yields of yam and maize were measured by placing two 100 m² quadrants at random on the plot of each farmer. Rice yields indicated here are the quantities of paddy weighed after mechanical threshing, and hence might be slightly underestimated. Cotton yields represent the quantities sold by farmers.

b) AVB 1975, p. 19.

Source: Compiled by the author from unpublished documents of AVB.

short dry spells and thus reduce the effect of drought on yields. Most of the differences are, however, not statistically significant, a fact which is partly due to the great variation of yields.

Another reason for the low level of yields, apart from soil quality, is poor crop husbandry (ORSTOM 1976, pp. 36 et seq.). In particular, weeding is started too late and pest control is not carried out properly in the case of cotton. A further difficulty is the fact that the cooperatives often do not succeed in carrying out timely mechanised field operations, on account of weather conditions (land preparation for maize and cotton, sowing of maize and rice), delayed maize harvesting (sowing cotton) and frequent technical breakdowns that are caused by lack of experience of tractor drivers, poor maintenance and difficulties in the supply of spare parts.

If we compare the average yields in the first three years of the project with those in the following years (1974 to 1976), a declining trend of maize and cotton yields is apparent (see Table 2.41). However, these differences can be atributed basically to the unfavourable climatic conditions in recent years (which would also explain the higher coefficients of variation) and must not be interpreted as an indication of a decline in soil fertility[1].

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1) Certainly, we cannot exclude that a decline in soil fertility has had some effects on crop yields, but if the variation of yields caused by climate is high, a period of six years is too short to quantify this influence.

Table 2.41: Development of yields of yam, maize, cotton and upland rice in six AVB ensembles from 1971-1976

Crop	Average yields and coefficients of variation 1971-1973 $\bar{x}$	CV(%)	1974-1976 $\bar{x}$	CV(%)	Difference
Yam	122.1	25	128.6	25	n.s.
Maize	23.0	33	15.4	57	*
Cotton	7.8	22	5.3	60	*
Rice	16.7	50	14.0	51	n.s.

Source: Compiled by the author based on unpublished documents of AVB.

2.442 The variation of yields between holdings

If it is assumed that important yield-determining factors like climate, crop varieties, time of sowing, land preparation, fertiliser application and to some extent soil quality vary only slightly within an ensemble, the variation of yields between the holdings is to be attributed to the performance of the individual farmer. It is not, therefore, surprising that cotton has the highest coefficient of variation (see Table 2.42), because in addition to weeding pest control acts as another factor leading to yield variation between the holdings.

As in the case of yield variation over time, the variation of crop yields between the holdings increases with deteriorating soil quality. This is particularly obvious for maize and cotton, but also for yam and rice as the maximum values indicate.

As a rule, the variation of yields between the holdings is higher in climatically unfavourable years. The correlation coefficients between crop yields and coefficients of variation are r = -0.829*** for cotton, r = -0.554* for maize

Table 2.42: Coefficients of variation of yields between the holdings in six AVB ensembles, average 1971-1976 (%)

Crop	All ensembles	Ensembles with good soil quality		Ensembles with moderate soil quality	
	average	average	maximum	average	maximum
Yam	28.5	27.8	34.6	29.3	46.1
Maize	43.9	38.3	58.4	48.8	77.6
Cotton	47.6	38.8	53.4	58.2	86.8
Rice	34.5	33.2	48.0	36.2	67.6

Source: Calculated by the author based on unpublished documents of AVB.

and r = -0.555** for rice. This means that the higher the yields or the better the climatic and edaphic conditions, the smaller the variation of yields between the holdings. This does not apply to the same extent to yam (r = -0.122).

2.45 The profitability of upland rice production under unfavourable climatic conditions

For purposes of economic analysis, two indicators are relevant here to evaluate the profitability of a crop: the gross margin per hectare as an indicator for the efficiency of land use and the gross margin per ME-day as an indicator for the efficiency of labour use.

Since the variation of crop yields is very important on account of the uncertain distribution of rainfall, averages are only of a limited value. The available data is not sufficient for the application of sophisticated statistical methods[1]. In the following, therefore, in addition to the

1) A method of evaluating the profitability of crop production methods under the condition of yield uncertainty caused by climate is given in Appendix VII.

use of average figures in the economic analysis, the values ($\bar{x} \pm s$)[1] are also used in order to give an idea of the impact of yield uncertainty on the profitability of the different crops.

From Table 2.43 it can be seen that yam is superior to all other crops with regard to returns per unit of area. With a farm-gate price of 15 FCFA/kg, even a yield of 26 dt/ha would be sufficient to cover the total variable costs. In the case of maize and cotton, net returns from both crops must be added, since they are grown in the same year. Even then the gross margin per hectare is lower than that for upland rice. Since the yield of both crops is positively correlated ($r = 0.502^*$), i.e. high cotton yields can be expected in years of high maize yields and vice versa, the cultivation of both crops does not lead to risk reduction for the farmers.

As Diagram 2.14 illustrates, in spite of the high labour requirements, yam and upland rice are clearly superior to maize and cotton in respect of returns to labour. Compared with upland rice, yam is less profitable in years with favourable climatic conditions, but otherwise produces a higher gross margin per ME-day. In this case, the decisive factor for the economic evaluation is the farmer's reaction to risks in production[2].

If there is risk aversion, yam is preferable to upland rice[3]. In a comparison of maize and cotton, however, it must be

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1) If an approximately normal distribution of yields is assumed, the values $\bar{x} \pm s$ each explain about 16 % of the cases.

2) On the problem of decision making under uncertainty, see ARROW 1971, DILLON/ANDERSON 1971, HANF 1969, MOSCARDI 1976, Von NEUMANN/MORGENSTERN 1947, WOLGIN 1975.

3) In this context the problem of securing subsistence needs should be noted. In African smallcale holdings, an important economic objective is an adequate supply for domestic needs, even in climatically unfavourable years. A very common fact is that the crops constituting the staple food of the population show a comparatively low variation of yield over time in relation to other crops (see also Le BUANEC 1975b, p. 3).

Table 2.43: Profitability of yam, maize, cotton and upland rice in semi-mechanised farming in the central region of Ivory Coast (prices 1974/75)

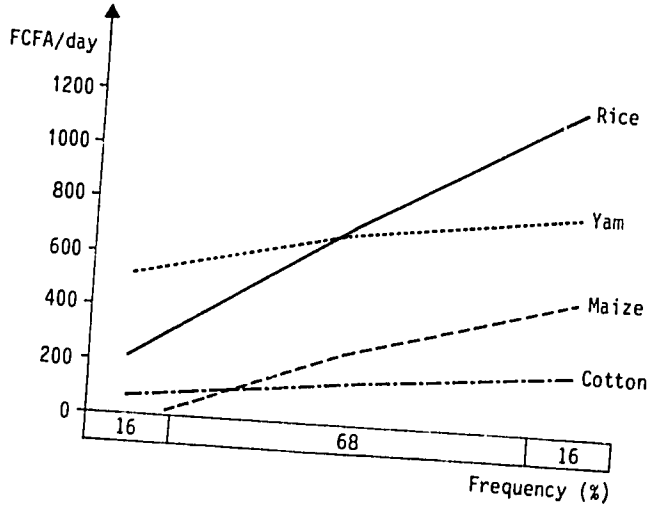
	Yam			Maize			Cotton			Upland rice		
	$\bar{x} - s$	$\bar{x}$	$\bar{x} + s$	$\bar{x} - s$	$\bar{x}$	$\bar{x} + s$	$\bar{x} - s$	$\bar{x}$	$\bar{x} + s$	$\bar{x} - s$	$\bar{x}$	$\bar{x} + s$
Yield (dt/ha)	94.0	125.0	156.0	9.5	19.0	28.5	4.5	6.5	8.5	8.8	16.0	23.2
Coefficient of variation (%)		25			50			30			45	
Gross returns (FCFA/ha)	141,000	187,500	234,000	17,100	34,200	51,300	31,500	45,500	59,500	61,600	112,000	162,400
Variable costs (FCFA/ha)	38,700	38,700	38,700	20,900	20,900	20,900	22,900	22,900	22,900	38,600	40,800	43,000
- Seeds	30,000[a]	30,000[a]	30,000[a]	2,400	2,400	2,400	-[b]	-[b]	-[b]	5,200	5,200	5,200
- Fertiliser	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]						
- Machine hire	8,100	8,100	8,100	17,900	17,900	17,900	12,300	12,300	12,300	12,300	12,300	12,300
- Others	600	600	600	600	600	600	9,800	9,800	9,800	17,900	17,900	17,900
							800	800	800	3,200[d]	5,400[d]	7,600[d]
Gross margin (FCFA/ha)	102,300	148,800	195,300	- 3,800	13,300	30,400	8,600	22,600	36,600	19,900	70,300	120,700
Labour requirement (ME-days/ha)[e]	195	210	235	42	50	58	125	140	155	90	95	100
Gross margin per ME-day (FCFA)	525	709	831	-	266	524	69	162	236	221	740	1,207

a) Planting material and weight losses.
b) Seeds and insecticides are supplied free to the farmer, costs are considered in the farm-gate price.
c) No application of mineral fertiliser.
d) Costs of mechanical threshing included.
e) Estimated from AVB 1975, ORSTOM 1976 and BONNEFOND 1971.

Source: Compiled by the author.

borne in mind that one of the main reasons for the low level of cotton yields is the fact that it usually cannot be sown at the optimum date because of delayed maize harvesting. Experience shows that the yields are on average about 200 kg/ha higher when cotton is not preceded by a crop in the same year, and thus can be sown during July (CIDT 1974, p. 46). Consequently, the profitability of cotton would rise, but it would still be considerably lower than for yam and rice.

Diagram 2.14: The variation of gross margins per ME-day of yam, maize, cotton and rice in semi-mechanised cultivation in the central region of Ivory Coast



Source: Compiled by the author.

The variation of the gross margins caused by the variation of crop yields is higher than the variation in yields. The coefficient of variation of the gross margins per ha is 31 % for yam, 62 % for cotton, 72 % for rice and 129 % for maize. The variation of gross margins per unit area is the greater over time:

- the greater the variation of crop yields;
- the weaker the relationship between yields and total variable costs, and
- the higher the total variable costs are as a proportion of the gross returns, i.e. the less favourable the input-output price relation.

In the case of yield uncertainty due to climate combined with a relatively inelastic demand, price fluctuations for agricultural products can generally be observed, in particular for products that cannot easily be transported or stored. This applies to yam and to a lesser extent to maize in the central region of Ivory Coast, because farm-gate prices for rice and cotton are fixed by the Government. Price fluctuations reduce risk and thus the variation of gross margins. The economic evaluation of crop production on the basis of average figures produces better results, if relative price changes are not much higher than the yield fluctuations. UPTON and CASEY (1974, pp. 147 et seq.) point out, however, that the use of mathematical expected values is not without its problems, and can lead to incorrect conclusions:

"- where two variables (e.g. yields and price) are correlated,

"- where decisions are made sequentially and the possibilities of future outcomes are dependent upon decisions made earlier in the sequences, and

"- where fixed constraints prevent the producer from taking advantage of better than average outcomes."

This range of problems cannot be dealt with here in any more detail, because of the lack of information on these factors.

3. The Evaluation of Rainfed Rice Production from the Macro-economic Point of View

In the light of the analysis of the profitability of rainfed rice production at the farm level, conclusions of only limited value can be drawn about the feasibility of rainfed rice production at the macro-economic level.

Taking the Ivory Coast as an example, the economic aspects of rainfed rice production at the national level are discussed here. In this context, two fundamental questions are of vital importance:

1. Is it macro-economically feasible for Ivory Coast to produce rainfed rice or are there alternatives of greater benefit with regard to the optimal allocation of scarce resources?
2. By which method should rice be produced if self-sufficiency is a stated political target?

To deal with the first question would require a comparison with other production alternatives competing for the use of production factors at the national level. This is, however, beyond the scope of this study. The analysis concentrates, therefore, on the second question, which is, above all relevant form the point of view of political decision makers. Reducing dependence on imports of basic foodstuffs, that are moreover subject to sharp price fluctuations on the world market, is an important political target in the long run [1].

As in other West African countries, complete self-sufficiency in rice is a goal in Ivory Coast too, and the question is simply which form of rice production is the most economically feasible from the macro-economic point of view to reach this objective.

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1) Dealing with the first question would reveal how big the loss of the value added would be if this aim were pursued, assuming that the best utilisation of scarce resources is not achieved by rice production.

3.1 Methodology

Generally speaking, the macro-economic feasibility of development activities that have been planned or actually realized is evaluated by using cost-benefit analyses. These analyses are usually based on a project which is the smallest operational unit that is separately planned, implemented and administered (RUTHENBERG 1977b, p. 13), whereby the development in conjunction with a project is compared with the development without a project. Due to lack of sufficient data, this comparison was not possible, and therefore another approach has to be used which is presented in the following.

The economic evaluation of rice production is based on a cost-benefit analysis per unit of area (ha)[1], whereby, in contrast to the analysis at farm-level, the time-factor is taken into account, and all costs and benefits are valued at economic prices reflecting the situation of product and factor markets at the national level. The criterion for evaluation is the value added that is achieved by a productive activity, i.e. its contribution to the national income.

For the appraisal of development projects, there is actually a number of methods with various systems of valuation that have been devised for cost-benefit analyses, on which no further details need be given here[2]. In this analysis only the direct effects are discussed and all indirect effects (forward and backward linkages, technical spillovers, etc.)

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1) As in the case of the total cost accounting at the farm level, there is here too the basic problem of how those costs are to be considered that do not change relative to the area. The validity of the results is therefore limited, since costs cannot be clearly allotted to the individual activities.

2) The main approaches are dealt with by GITTINGER 1972, LITTLE/MIRRLEES 1969 and 1974, MISHAN 1971, ROEMER/STERN 1977, RUTHENBERG 1977b, SQUIRE/Van der TAK 1975 and UNIDO 1972.

are ignored. Moreover, the impact on socio-economic targets as regards employment, income distribution, balance of payments, etc., are dealt with qualitatively.

The internal rate of return is used as a profitability criterion. In the initial calculation, all costs and benefits are valued by the domestic market prices in 1974/75. This assumes that the market prices reflect the scarcity of goods and services in the economy. In the case of the labour, it is assumed that wages for hired workers in agriculture correspond to the opportunity costs of unskilled labour (220 FCFA/ME-day). In reality, however, the marginal return to labour[1] could be considerably higher than wages. For this reason, an alterrative calculation is carried out with higher opportunity costs for labour[2].

In addition to this analysis at domestic market prices, further calculations are made with the partial use of accounting prices on the basis of world market prices, since rice[3] and a large part of inputs are internationally traded goods. Where no information on world market prices is available, accounting prices are estimated on the basis of domestic prices[4]. The opportunity costs of labour are assumed to be 275 FCFA/ME-day[5].

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1) As the case study of West Ivory Coast shows, the average return to labour in the traditional farming systems amounts to about 400-700 FCFA/ME-day. Since the marginal return to labour is lower than the average return, the opportunity costs are assumed to be 400 FCFA/ME-day.

2) Cost-benefit analyses on the basis of domestic market prices provide information about the economic feasibility of development activities under the market conditions which are influenced by political decision makers (custom duties, taxes, subsidies, price fixing, etc.).

3) Paddy is an intermediate product and is not traded internationally. A world market price for paddy is deduced in Appendix IX.

4) See Appendix IX. This is only a rough estimation of the figures taking into account taxes, custom duties, subsidies, etc.; for the precise method see SCOTT et al. 1977.

5) See page 145.

The analyses cover a period of 20 years, during which prices are kept constant. Apart from cultivation by traditional methods, it is assumed that in this period yields per hectare of rainfed rice increase by 20-30 % and of wet rice by 40-60 % on account of advances in plant breeding.

3.2 The Profitability of Rainfed Rice Production at the Macro-economic Level

3.21 Results of the cost-benefit analysis

If domestic market prices are used, both investments and running costs are higher than those at the farm level from the macro-economic point of view, because not all investments are realized or paid for by the farmers, and the costs of extension services, maintenance of the infrastructure, etc., do not have to be borne by the individual farms.

Table 3.1 illustrates the investments, costs and returns of various rainfed rice production methods. Investments and costs valued at domestic prices are higher for the mechanised techniques than those derived on the basis of world market prices, since in Ivory Coast domestic prices for investment goods and inputs are higher. This does not apply, however, to hand cultivation methods, since the domestic wages for unskilled labour are below its opportunity costs valued at world market prices. The difference in the total costs per hectare between the two approaches of evaluation is only slight, except for fully mechanised production,

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Footnote 5 from p. 144:

5) If coffee or cocoa production were regarded as the best alternatives, the labour opportunity costs would be much higher. The use of a high accounting price for labour is however limited, because of the export situation of these products on the world market and the deficit in the domestic production of foodstuffs.

Table 3.1: Investments, costs and benefits in rainfed rice production in Ivory Coast on the basis of domestic prices (D) and world market prices (W) in 1974/75 (FCFA/ha)

	Central Region				Western Region									
	Ox-team cultivation		Semi-mechanised cultivation		Traditional cultivation		Manual cultivation with fertiliser		Ox-team cultivation		Semi-mechanised cultivation		Fully-mechanised cultivation	
	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)
Investments (FCFA/ha)	59,300	45,200	206,400	178,500	13,200	16,400	13,200	16,400	68,900	53,200	221,900	191,300	281,100	242,400
- Land development	16,500	13,700	130,000	107,900	13,200	16,400	13,200	16,400	25,800	21,400	144,000	119,500	144,000	119,500
- Infrastructure (roads)	2,100	1,700	6,000	5,000					2,400	2,000	7,500	6,200	9,000	7,500
- Machinery and buildings[a]	38,600	28,100	67,900	63,500					38,600	28,100	67,900	63,500	122,100	110,400
- Overheads	2,100	1,700	2,500	2,100					2,100	1,700	2,500	2,100	6,000	5,000
Costs (FCFA/ha)	80,600	75,600	76,700	70,800	39,100	45,300	72,500	73,200	80,700	76,600	80,700	76,000	79,300	64,400
- Material inputs	26,600	20,200	23,600	17,700	6,100	4,200	24,900	18,700	26,600	20,200	23,600	17,700	32,100	24,700
- Machinery and buildings[b]	7,100	4,900	14,300	9,900					6,200	4,200	14,300	9,900	33,800	24,900
- Unskilled labour	27,500	34,300	26,400	32,900	33,000	41,100	37,400	46,600	29,900	37,300	30,800	38,400	8,800	11,000
- Extension service, administration[c]	18,000	15,000	10,200	8,500			10,200	8,500	16,400	13,600	9,300	7,700	1,600	1,300
- Infrastructure[d]	1,400	1,200	2,200	1,800					1,600	1,300	2,800	2,300	3,000	2,500
Benefits (FCFA/ha)														
- At the beginning of development[e]	97,500	67,500	117,000	81,000	104,000	72,000	130,000	90,000	130,000	90,000	130,000	90,000	130,000	90,000
- At full development[f]	130,000	90,000	149,500	103,500	104,000	72,000	130,000	90,000	162,500	112,500	162,500	112,500	162,500	112,500

a) Including draught oxen
b) Including variable costs of oxen
c) 50% of the initial costs from year 11 and 25% from year 16
d) Costs occur in the period of 3 to 4 years
e) Years 1 to 5
f) Years 6 to 20

Source: Compiled by the author.

since in this case the amount of unskilled labour is relatively low (11 % and 17 % of the total costs). With other mechanised techniques, this proportion is 30-50 %, and 80-90 % in traditional farming.

Apart from traditional upland rice cultivation, the difference in the total costs between the individual production methods is also relatively small.

On the other hand, the differences in capital requirements for investments are considerable. In the case of manual production systems, investments are almost exclusively for land clearance. By comparison, investments in systems using animal power are five times as high, in semi-mechanised production seven times and in fully mechanised cultivation more than twenty times as high. Where mechanical land clearance is practised, a substantial part of the investments are for land development.

Because there is a difference of over 40 % in paddy price between domestic and world markets, there are very clear differences in the macro-economic benefits. With one exception[1], however, they are always higher than total costs, even if in the calculation at domestic prices opportunity costs for unskilled labour are used that are above the level of wages (as illustrated in Table 3.2).

Assuming higher opportunity costs for labour, the total costs per hectare rise by 30 % in the mechanised systems, by 40 % in manual labour systems with mineral fertiliser application and by 70 % in traditional farming. The investments rise by 80 % in manual labour systems, by 20-25 % in the case of animal traction and by 10 % in semi- and fully mechanised production.

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1) Because of the low yields, ox-team cultivation in the central region leads to losses in the first few years.

Table 3.2: Investments, costs and benefits in rainfed rice production in Ivory Coast on the basis of domestic market prices assuming opportunity costs of labour of 400 FCFA/ME-day

	Central Region				Western Region		
	Ox-team cultivation	Semi-mechanised cultivation	tradi-tional cultivation	Hand cultivation with mineral fertiliser	Ox-team cultivation	Semi-mechanised cultivation	Fully mechanised cultivation
Investments (FCFA/ha)	70,100	227,700	24,000	24,000	85,800	243,600	303,300
- of which land development	27,300	151,300	24,000	24,000	42,700	166,200	166,200
Total costs (FCFA/ha)	103,100	98,300	66,100	103,100	105,200	105,900	86,500
- of which unskilled labour	50,000	48,000	60,000	68,000	54,400	56,000	16,000
Benefits (FCFA/ha)							
- at the beginning of development	97,500	117,000	104,000	130,000	130,000	130,000	130,000
- at full development	130,000	149,500	104,000	130,000	162,500	162,500	162,500

Source: Compiled by the author.

In a cost-benefit analysis, however, it is not possible to consider rainfed rice as an isolated activity, since for crop sanitary reasons it cannot be grown, like wet rice, as a monocrop. Accordingly the whole rotation has to be included in the analysis. The result thus depends on the profitability of other crops also, and is not derived from rice alone[1].

As could be expected, rainfed rice production is more profitable on the basis of domestic prices than if accounting prices were used (see Table 3.3), because of the price differences for paddy.

A comparison of production methods on the basis of domestic market prices shows that traditional and improved manual rainfed rice cultivation represent very good alternatives from the macro-economic point of view[2]. Of the mechanised methods, ox-team cultivation produces the best result, although it is very sensitive to fluctuations in rice yields. Even the semi-mechanised cultivation methods still have an internal rate of return that could be assumed to be higher than the opportunity costs of capital in Ivory Coast (cf. LINN 1977).

The differences between the production methods become smaller if world market prices are used in the analysis. Semi-mechanised cultivation in the central region becomes more profitable because of the favourable accounting prices of yam and cotton. All production techniques are highly sensi-

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1) For this reason, ox-team cultivation in the central region and fully mechanised production in the Western Region are ignored, since the result is influenced principally by other crops or farm enterprises.

2) Since practically no capital investments are required in the hand cultivation systems, it is doubtful whether criteria of financial analysis should be applied. This approach has nevertheless been chosen since comparisons would not otherwise be possible.

Table 3.3: Internal rate of return of rainfed rice production in Ivory Coast on the basis of domestic market prices (D) and world market prices (W) 1974/75 (%)

	Central Region		Western Region									
	Semi-mechanised cultivation a)		Traditional cultivation b)		Hand cultivation with mineral fertiliser application non-intensive b)		intensive c)		Ox-team cultivation d)		Semi-mechanised cultivation e)	
	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)
Internal rate of return f)	18.0	17.1	-	-	-	-	-	-	53.5	14.1	22.4	10.0
Internal rate of return with a change of												
- investments by + 10%	15.6	13.9							47.3	11.0	19.3	7.7
- running costs by + 10%	11.9	8.8	-	-	-	66.8	-	-	33.7	3.9	17.3	4.4
- costs of unskilled labour by + 10%	13.2	13.8	-	-	-	-	-	-	44.2	5.3	20.2	7.7
- rice yields by - 10%	14.1	11.8	-	-	-	55.1	-	80.1	33.6	3.8	16.1	3.2
- yields of the other crops by - 10%	13.6	11.1	-	-	-	-	-	-	44.0	9.6	20.8	8.1
- rice yields by + 10%	22.4	22.3	-	-	-	-	-	-	90.1	26.2	29.9	16.7
- yields of the other crops by + 10%	22.9	23.7	-	-	-	-	-	-	64.9	19.0	24.1	11.9

a) rotation yam - rice - maize/cotton - rice; 120 ha per tractor.
b) 3-years land use (rice - groundnuts/cassava), 5 years-fallow.
c) 3-years land use (rice - rice - cassava), 5 years-fallow.
d) rotation rice - maize/cotton - rice/*Stylosanthes* - *Stylosanthes*, 6 ha per ox-team.
e) rotation rice - rice - maize/maize, 120 ha per tractor.
f) An internal rate of return cannot be calculated, if the benefits exceed the costs in the initial phase (-).

Source: Compiled by the author.

tive to changes in running costs and in yields and prices of rice. An increase of 10 % in the running costs noticeably reduces the profitability of the mechanised cultivation methods, and assuming an increase of 20 %, a positive internal rate of return can no longer be achieved.

If opportunity costs for unskilled labour of 400 FCFA/ME-day are used in the analysis at domestic market prices, hand cultivation methods remain economically superior to mechanisation (see Table 3.4), but they are very sensitive to a change in costs and rice yields. In the central region, because of the labour intensive crops (yam, cotton) in the rotation, a positive result can only be achieved with semi-mechanised cultivation if higher yields can be attained. Because of the increase in the opportunity costs of labour, the internal rate of return of rainfed rice production using animal power drops drastically from 53 % to 4 %, and it thus corresponds to that of semi-mechanised cultivation.

In summary, it can be concluded that even with high opportunity costs of unskilled labour the systems of hand cultivation are macro-economically superior to mechanised rainfed rice production[1]. Only if rice yields of about 30 dt/ha could be achieved in mechanised cultivation, would these techniques be competitive. If, on the other hand, a yield level of over 20 dt/ha cannot be attained from mechanised cropping in the long term, there is no longer any positive internal rate of return if rice occupies over 50 % of the area in the rotation. If the world market price of rice decreases to below 250 US $ per tonne, rainfed rice production is no longer profitable from the macro-economic point of view, regardless of the production method.

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1) The destruction of forests by shifting cultivation has been ignored in the analysis. If opportunity costs for the destruction of forests are below 50,000 FCFA/ha, the hand cultivation methods are still economically superior to mechanised production.

Table 3.4: Internal rate of return in rainfed rice production in Ivory Coast on the basis of domestic market prices and opportunity costs of labour of 400 FCFA/ME-day (%)

	Central Region	Western Region				
	Semi-mechanised cultivation a)	Traditional cultivation a)	Hand cultivation with mineral fertiliser application non-intensive a)	intensive a)	Ox-team cultivation a)	Semi-mechanised cultivation a)
Internal rate of return b)	*	-	23.1	-	4.1	4.5
Internal rate of return with a change of						
- investments by + 10%	*	19.1	*	-	3.6	3.7
- running costs by + 10%	*	27.1	*	-	*	*
- costs of unskilled labour by + 10%	*	6.9	*	-	*	1.3
- rice yields by - 10%	*	-	*	6[illegible].6	*	*
- yields of the other crops by - 10%	3.1	-	-	-	*	2.5
- rice yields by + 10%	2.2	-	63.3	-	14.2	11.8
- yields of the other crops by + 10%					8.1	6.4

a) for cropping techniques see Table 3.3
b) An internal rate of return cannot be calculated, if benefits exceed costs in the initial phase (-) or if the sum of the undiscounted differences between benefits and costs becomes negative (*).

Source: Compiled by the author.

3.22 Evaluation of rainfed rice production with regard to socio-economic targets

In addition to the profitability of development activities, there are a series of other macro-economic criteria whose relative importance depends on the objectives of the political decision makers[1]. Basic criteria that are often employed in the evaluation are the impact of development projects on the balance of payments, regional and personal income distribution, effects on the employment situation, on the income use (capital formation) and on the State budget (fiscality).

If a cost-benefit analysis is carried out with accounting prices on the basis of world market prices, the effects on the balance of payments are considered endogenously, i.e. if the internal rate of return is greater than zero, the effect of a project on the balance of payments is positive. This applies to all production methods analysed, except when in mechanised rice cultivation a yield level of 25 dt/ha cannot be achieved in the long term.

There are no differences between the production methods with regard to the balance of regional development, but there are differences in respect of income distribution. If we compare the capital requirements for investments in mechanised and in hand cultivation systems, and if we consider the costs of extension services, that are particularly high in the initial phase, it becomes obvious that it would not be possible for small farmers to shift to mechanised farming if the State did not subsidise at least part of the capital requirements. Since not all farmers can participate in mechanised projects, income distribution problems appear, where the family farm income in the mechanised

1) Frequently a greater weight is put on profitability (internal rate of return, net present worth) than on other criteria of evaluation.

holdings is higher than in traditional agriculture[1]. At the same time, a burden is put on the national budget if direct income and land taxes are not levied, since the indirect taxes on purchased inputs, services and products are usually lower than subsidies for land development and sometimes for machinery and implements. Where material inputs are either not subsidised at all, or only to a very small extent, as for example in Ivory Coast, there are clear advantages regarding the fiscality in introducing bio-technical advances compared with innovations connected with machine technology. Moreover, a larger number of farmers can be reached.

The effects on employment can scarcely be assessed from the labour requirements of the individual production methods because upland rice is always included in a rotation with other crops and cannot be considered as an isolated activity. Labour intensity automatically declines as the degree of mechanisation increases, but the repercussions on employment are dependent on the structure of the farm organisation[2]. The employment effects of mechanisation are positive, as can be observed in the central region, particularly if the cultivated area can be enlarged in smallscale holdings by reducing labour peaks. Consequently, the effects of mechanisation on employment are very much influenced by the natural conditions of the region.

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1) In the case study of the western region, this is not so, but it does apply, e.g., to the central region of Ivory Coast (BONNEFOND 1971, MINISTERE DE LA RECHERCHE SCIENTIFIQUE/GERDAT 1977, Vol. 2).

2) However, fully mechanised cultivation leads in all cases to a reduction in employment.

3.3 A Comparative Analysis of Irrigated and Rainfed Rice Production from the Macro-economic Point of View

A surprising phenomenon in the rainforest zone of West Africa is the fact that valley bottoms are scarcely cultivated, even where high population densities are to be found (DOZON 1974, KARR et al. 1972, LAGEMANN 1977). Nevertheless, in almost all the countries of this region the expansion of wet rice cultivation is a priority in agricultural development policy (WARDA 1974a). This is mainly due to the following reasons:

- Suitable technology from Asia is already available (new varieties with high yield potential, chemical inputs, hand and mechanised production techniques, etc.), and this technology can be adopted in Africa without any further expensive research efforts.
- Compared with rainfed rice, wet rice production is subject to far lower fluctuations of yield. By developing irrigated rice cultivation, production can be stabilised on a national level, and the supply of rice to the population can be ensured in the long term.
- In contrast to permanent upland farming, irrigation farming involves far fewer problems in respect of maintaining soil fertility, particularly in the humid tropics.

By means of an additional analysis of the various forms of irrigated rice production, the following examines to what extent the development of wet rice cultivation in Ivory Coast represents an appropriate alternative to rainfed rice cultivation at the national level.

3.31 Ecological problems

It is not the author's intention to carry out an economic analysis of the changes in rural eco-systems as a result of the development of the various forms of rice production[1], but simply to discuss some relevant problems.

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1) See page 156

Upland rice production in shifting cultivation systems requires a great deal of land, and can only be maintained where there is a relatively low population density (GREENLAND 1975, p. 5; UHLIG 1975, pp. 375 et seq.). Population growth and increasing production of cash crops lead to the expansion of the cultivated area and accordingly a shortening of the fallow period. The impact of this kind of development on the ecology of a region is well-known. The forest, to a certain degree necessary for the maintenance of the ecological equilibrium, is reduced and the production potential of the region declines if the necessary measures to preserve soil fertility are not taken (AUBREVILLE 1949, pp. 309 et seq.). Farming systems "tend to drift into a low-output steady state. Extended areas of the tropics show that this mechanism is a most powerful one, the more powerful the warmer and more humid the climate" (RUTHENBERG 1976b, p. 50)[1].

Studies in, for example, Ivory Coast (SODEFOR 1975) reveal that during the period 1956 to 1966 about 280,000 ha of "forêt dense" were annually converted into a "forêt dégradée"[2]. From 1966 to 1974 this figure rose to 440,000 ha. Other factors are certainly involved in this development, but the expansion of upland rice production has a consider-

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Footnote 1 from p. 155:

1) Any attempt to do so would certainly go beyond the limits of this study. On the economics of eco-systems see BARLOWE 1958, CIRIACY-WANTRUP 1968, KRUTILLA/FISCHER 1975, SMITH 1972 and WHITE 1976.
In farming systems in which cultivation methods are practised which lead to soil deterioration and erosion, an exhaustible natural stock resource is removed, and it seems doubtful in a case like this whether decisions should be based primarily on economic considerations.

1) See also LAGEMANN 1977.

2) The term "forêt dense" is applied to a forest that:
a) has a stand of trees of more than 10 m in height on at least 10 % of its area, and
b) the trees thus defined are homogeneous over an area of at least 100 ha.
If b) does not apply, the term "forêt dégradée" is used.

able influence especially in the traditional cropping areas (JORDAN 1964, MOHR 1969). MOUTON (1959, p. 31) has examined this phenomenon in the western region of Ivory Coast and observes: "La forêt disparaît lentement faute de régénération convenable, les pluies favorables a l'agriculture diminuent, la saison sèche s'accentue en intensité et en durée... ".

There are basically three ways in which this type of development can be avoided: the transition to permanent upland cultivation, to irrigation farming or to the increased cultivation of perennial crops. The combination of land use for agriculture and forestry would be another possibility, but till now no appropriate farming systems of this type are available. With regard to the land-man ratio, irrigation farming is superior to rainfed cultivation. But, as the case study in the western region illustrates, the land requirements per unit of labour clearly drop if part of the farm area is used for permanent arable cultivation[1].

As cropping intensity in upland farming increases, the problems involved in maintaining the yield potential of the soil also increase. The more humid and warmer the climate and the poorer the soil quality, the greater the problems involved (see LAGEMANN 1977, GREENLAND/HERRERA no year). Particularly when permanent mechanised cropping is practised, frequently not all conditions are met that would prevent a decrease in soil fertility and erosion (LANG 1976, p. 231), and in the long term this means that the success of mechanised farming systems is endangered. The reasons for this may be partly technical difficulties (GREENLAND/HERRERA no year, p. 22), but socio-economic factors also play a decisive role, as JANZEN (1973, p. 1212) explains: "It is widely believed in temperate zone countries that tropical countries

1) In the semi-mechanised holdings, the land-man-ratio is on average 2.3 ha/ME and significantly lower than in traditional holdings (3.8 ha/ME).

disregard the rules of sustained-yield agro-eco-systems out of ignorance. This condescending evaluation is sometimes correct for certain aspects of the decision-making process. However, there are many more situations in which a key manager is deliberately maximising short-term returns at the expense of long-term returns." This behaviour is not uncommon in smallscale farms.

In contrast with Africa, irrigated rice cultivation in many parts of Asia has made a contribution towards preventing or at least mitigating negative effects of this kind on the eco-system (CASTILLO 1975, WHYTE 1976, WILHELMY 1975). In those regions where the yield potential was reduced by soil-exhausting cultivation to such an extent that rainfed farming could no longer adequately support the population, intensive irrigation farming has developed and so-called "Kulturlandschaften" (cultural landscapes) have been created (UHLIG 1975). In Asia irrigated rice has been cultivated for centuries, sometimes as a monocrop, and grown several times a year without any noticeable decline in soil fertility, or without soil erosion being an important problem (ANDREAE 1971, p. 207). In comparison to the intensively cultivated valley bottoms, non-intensive land use or even bush or forest vegetation is found on the slopes (RUTHENBERG 1976a, p. 171).

3.32 Cost-benefit analysis of wet rice production

As Table 3.5 illustrates, investments in irrigated rice production are much higher than in rainfed cultivation. Dams, land development and construction of irrigation networks account for the major part of these investments. In traditional swamp rice cultivation, where no water control is practised, the labour input for land clearance and preparation of the plots is 350-400 ME-days/ha, and no further investment is required. If small dams are built, so that the

Table 3.5: Investments, costs and benefits of wet rice production in Ivory Coast on the basis of domestic market prices (D) and world market prices (W) 1974/75 (FCFA/ha per production period)

	Traditional swamp rice cultivation a)		Swamp rice cultivation with partial water control b)		Irrigated rice cultivation with complete water control: Hand cultivation method c)		Irrigated rice cultivation with complete water control: Single-axle tractor and land development by hand d)		Irrigated rice cultivation with complete water control: Single-axle tractor and land development mechanised e)	
	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)
Investments (FCFA/ha)	84,200	104,600	243,700	202,300	632,500	526,000	671,000	561,300	1,036,000	864,200
- Dam and main canals	-	-	-	-	360,000	298,800	360,000	298,800	360,000	298,800
- Land development and irrigation network	84,200	104,600	230,200	191,100	255,000	211,700	256,000	211,700	620,000	514,600
- machinery and buildings	-	-	7,000	5,800	11,000	10,100	48,000	44,200	48,000	44,200
- overheads	-	-	6,500	5,400	6,500	5,400	8,000	6,600	8,000	6,600
Costs (FCFA/ha)	59,100	71,400	149,300	151,800	152,800	154,900	150,800	143,400	150,800	143,400
- material inputs	4,100	2,900	35,900	27,900	35,900	27,900	35,900	27,900	35,900	27,900
- machinery and buildings	-	-	700	600	1,100	800	14,700	10,100	14,700	10,100
- unskilled labour f)	52,800	65,800	58,300	72,600	59,400	74,000	39,600	49,300	36,600	49,300
- extension, administration	-	-	48,900	46,000	48,900	46,000	52,100	49,000	52,100	49,000
- maintenance of irrigation network and infrastructure	2,200	2,700	5,500	4,600	7,500	6,200	8,500	7,100	8,500	7,100
Benefits (FCFA/ha)										
- at the beginning of development	130,000	90,000	195,000	135,000	195,000	135,000	195,000	135,000	195,000	135,000
- at full development	130,000	90,000	260,000	180,000	292,500	202,500	325,000	225,000	325,000	225,000

a) One harvest per year, yields remain constant.
b) After 5 years with 1.5 harvests per year, yields rise after 5 years from 3.0 to 3.5 and after 10 years to 4.0 t/ha.
c) Number of harvests rises from 1.0 to 2.0 in 5 years, yields rise in 5 years from 3.0 to 4.0, in 5 more years to 4.5 t/ha.
d) Hand cultivation in the first 5 years, number of harvests rises from 1.0 to 2.0 per year, yields from 3.0 to 4.0 t/ha; from year 6 cropping with single-axle tractors (20 ha/tractor), yields rise in 5 years to 4.5, after 5 more years to 5.0 dt/ha.
e) Use of single-axle tractors from year 1, after 2 years 2.0 harvests per year, yields rise continuously from 3.0 to 5.0 t/ha in 15 years.
f) Averages. The labour input is higher at the beginning of development and decreases during the first 10 years.

Source: Compiled by the author based on SODERIZ, Rapport annuel 1974 and 1975, SODERIZ 1974.

water flow can be controlled to a certain extent, the investments come to about 250,000 FCFA/ha, i.e. about the same amount as the total capital investment in semi-mechanised and fully mechanised upland rice cultivation. If the aim is to have water available all the year round as well as a complete control of it, i.e. if water storage is necessary, the investments rise to 0.6-0.7 million FCFA/ha, if land development is carried out largely by hand, and to 0.9-1.1 million FCFA/ha, if it is carried out mechanically. These figures are usually higher in the humid savanna than in the rainforest zone, since a greater storage capacity is necessary on account of the higher potential evapotranspiration.

As in the case of rainfed rice production, the total costs of about 150,000 FCFA/ha vary only slightly between the individual methods, with the exception of traditional swamp rice cultivation. Unskilled labour accounts for the largest part of the total costs (25-90 % according to the degree of mechanisation). The costs of extension work are about 50,000 FCFA/ha, and two to five times as high as for rainfed rice cultivation, because irrigation farming is new to most of the farmers. Consequently, very intensive extension work is necessary, at least at the beginning of development.

Yields of traditional swamp rice are about 20 dt/ha, and are assumed to be constant over the whole observation period. In the case of all other irrigated rice production methods, a yield level of 30 dt/ha is assumed at the beginning of irrigation; this level then rises in the course of development to 40 dt/ha in swamp rice cropping with partial water control, to 45 dt/ha in irrigated rice cultivation by hand and to 50 dt/ha when single-axle tractors are used for land preparation[1]. In traditional farming, there is only one

1) The increase in yields is due to improved technical knowledge and skills on the part of the farmers and to advances in plant breeding.

harvest per year; with partial control of irrigation water there is an average of 1.5 harvests per year and with complete water control a land use intensity of 200 % is achieved[1].

When the running costs of all production methods are valued at domestic market prices, they are lower than total benefits. But on the basis of world market prices costs exceed benefits in the initial phase, with the exception of traditional swamp rice production. By increasing both cropping intensity and yields, positive net benefits are achieved after about 5 years.

If the opportunity costs of labour are assumed to be 400 FCFA/ME-day, investments and running costs of traditional swamp rice production increase by approximately 80 %, and by 20-30 % for the other irrigated rice cultivation methods (see Table 3.6). The costs of unskilled labour as a proportion of the total costs are thus virtually unchanged in traditional wet rice cultivation, but rise from about 40 % to 50 % in the case of manual methods with water control, and from 20-30 % to 40 % when single-axle tractors are used. Thus the total costs in the initial phase of the hand cultivation methods with water control are slightly higher than the benefits.

The running costs of irrigated rice production are about twice as high as in rainfed rice cultivation, the main reason being the higher input of labour and other yield-increasing production factors. In the initial phase, benefits are 30-60 % higher than in rainfed cultivation, and 80-100 % higher when irrigation is fully developed.

As in the case of rainfed rice, traditional methods in wet rice production are superior to the more intensive types of

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1) It is assumed that, in contrast to upland rice production, wet rice is cultivated as a monocrop.

Table 3.6: Investments, costs and benefits of wet rice production in Ivory Coast on the basis of domestic market prices 1974/75 and opportunity costs of labour of 400 FCFA/ME-day

	Traditional swamp rice cultivation	Swamp rice cultivation with partial water control	Irrigation farming with complete water control		
			Manual methods	Single-axle tractors and land-development	
				by hand	mechanised
Investements (FCFA/ha)	152,600	328,000	796,100	834,000	1,196,700
- for land development and construction of irrigation network (excluding dams)	152,500	324,500	359,00	359,000	721,700
Costs (FCFA/ha)	104,100	201,000	204,500	186,700	186,700
- for unskilled labour	96,000	106,000	108,000	72,000	72,000
Benefits (FCFA/ha)					
- at the beginning of development	130,000	195,000	195,000	195,000	195,000
- at full development	130,000	260,000	292,500	325,000	325,000

Source: Compiled by the author.

cultivation from the macro-economic point of view[1] (see Table 3.7). On the basis of domestic market prices, net benefits diminish as cropping is intensified. On the other hand, if world market prices are taken as the basis of calculation, there are only slight differences between the production methods with control of irrigation water. Because of the differences of 45 % in paddy price, the internal rate of return decreases from about 20-30 % to 10-15 %. This also applies if higher opportunity costs of labour are assumed in the analysis with domestic market prices. In this case too, traditional swamp rice cultivation remains the most economically feasible method, whereas the differences between the other cropping methods are only slight.

On the basis of domestic market prices in 1974/75, irrigated rice proves to be macro-economically superior to rainfed rice cultivation with similar production techniques. But on the basis of world market prices, the difference between the two systems becomes much less, and the advantage of wet rice cultivation is no longer obvious.

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1) Irrigated rice cultivation is highly profitable at the farm level, because the majority of investments is provided by the Government, and the farmers do not have to pay for irrigation water and extension services. In Ivory Coast, the costs of material inputs (seeds, mineral fertiliser and insecticides) come to 650 kg paddy per hectare (42,250 FCFA/ha) according to the SODERIZ regulations. Since there are no other variable costs apart from those of hand implements and possibly wages for hired labour, the gross margins per hectare are far higher than those in rainfed rice production, even when there is only one harvest a year, provided yields of more than 30 dt/ha are obtained. If we assume a labour requirement of 250-300 ME-days/ha with the hand cultivation methods, this also applies to the return to labour if the yield level is above 35 dt/ha. Under these conditions the profitability of the intensified methods is higher than that of traditional swamp rice production.

Table 3.7: Internal rate of return in wet rice production in Ivory Coast on the basis of domestic prices (D)[a] and world market prices (W) 1974/75 (%)

	Western Region										Central Region			
	Traditional swamp rice cultivation		Swamp rice cultivation with partial water control		Irrigated rice cultivation with complete water control: Hand cultivation		Irrigated rice cultivation with complete water control: Single-axle tractor and land development by hand		Irrigated rice cultivation with complete water control: Single-axle tractor and land development mechanised		Irrigated rice cultivation with complete water control: Small Dams		Irrigated rice cultivation with complete water control: Large Dams	
	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)	(D)	(W)
Internal rate of return b)	- (30.4)	31.0	42.8 (17.5)	15.3	31.0 (17.3)	15.7	30.9 (18.5)	16.7	24.3 (16.2)	13.6	30.7 (17.5)	15.6	21.5 (12.2)	10.7
Internal rate of return with a change of														
- investments by +10 %			39.4 (16.3)	14.2	28.7 (15.9)	14.2	28.5 (17.1)	15.3	22.3 (14.9)	12.1	28.3 (14.9)	12.1	19.7 (11.1)	9.4
- running costs by +10 %	- (23.1)	20.8	35.0 (13.9)	10.3	27.8 (15.1)	12.5	27.7 (16.3)	13.6	22.0 (14.4)	11.2	27.6 (15.2)	12.4	19.5 (10.6)	8.3
- costs of unskilled labour by +10 %	- (23.5)	21.4	39.4 (16.0)	13.1	29.6 (16.3)	14.3	- (17.7)	15.5	23.5 (15.6)	12.8	29.3 (16.5)	14.2	20.7 (11.5)	9.6
- rice yields by -10 %	- (17.4)	12.8	31.7 (11.5)	6.3	25.4 (12.8)	9.0	25.3 (14.2)	10.3	19.8 (12.3)	8.0	25.1 (12.9)	8.9	17.6 (8.7)	5.3
- rice yields by +10 %	- (47.5)	58.4	56.5 (23.8)	24.8	36.8 (21.7)	22.2	36.6 (22.7)	22.9	28.8 (20.0)	19.0	36.4 (21.9)	22.0	25.4 (15.6)	15.6

a) Figures in brackets with opportunity costs for unskilled labour of 400 FCFA/ME-day.
b) An internal rate of return cannot be calculated, if benefits exceed costs in the initial phase (-).

Source: Compiled by the author.

The sensitivity analysis shows that, in amounts of investment, the profitability of wet rice cultivation is only slightly affected by a change of initial investment costs, and the fluctuations are even smaller than in the case of rainfed rice production. This also applies to the change in the labour input and the costs of unskilled labour. On the other hand, there is a very high sensitivity to changes in rice yields and paddy prices.

The relative advantage of one form of cultivation is affected decisively by the relation between the price of rice and the opportunity costs of labour. The lower the paddy price, or the higher the opportunity costs of labour, the higher is the profitability of rainfed rice production compared to wet rice[1]. Various factors, particularly advances in plant breeding, could lead to a reduction of the differences in the profitability between the two types of cultivation in the long term. At present, high-yielding varieties with average yields of 40-50 dt/ha and harvest are predominantly grown in wet rice cultivation in smallscale holdings. If average yields of 30-35 dt/ha could be achieved in non-irrigated rice cropping by using improved varieties, rainfed rice production would be the more economic alternative, if the yield level of irrigated rice remained unchanged.

3.33 Evaluation of wet rice production with regard to indirect effects

Two significant indirect effects result from the development of irrigation farming: the increasing spread of diseases like bilharzia and malaria, as indirect costs, and the reduction of the risk of flooding and the stabilization of production

1) This only applies, however, if the opportunity costs of land are low. Once land becomes scarce, the competitiveness of wet rice will rise ceteris paribus.

as indirect benefits. These effects are, however, difficult to quantify, and their impact on project selection cannot be generalised, but has to be examined in each individual case.

As in rainfed rice production, all methods of irrigated rice cultivation have positive effects on the balance of payments of the country.

With regard to income distribution, it can be assumed, that disparities due to irrigation farming are even greater than in mechanised rainfed rice production, since Government subsidies per unit of area are much higher, and additionally higher incomes can also be achieved with intensive cultivation[1]. An advantage, on the other hand, is the removal of regional imbalances. In Ivory Coast there are considerable differences in the stage of development between the savanna zone of the north and the southern forest region. These differences can be reduced by developing irrigation farming in the savanna zone. Wet rice cultivation gives farmers the chance to attain incomes that roughly equal those from coffee and cocoa production in the south of the country. As in the case of perennial crops, irrigation farming provides an opportunity for small-holders to invest savings or family labour in the construction of irrigation works, and thus to contribute to macro-economic capital formation through the development of their own holdings.

But it must be assumed that in the inital phase of development a high proportion of the necessary investments, as well

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1) This is also confirmed by the fact that irrigated areas, especially in the vicinity of towns, are often owned by people who are not farmers (officials, business men, etc.), and this land is cultivated almost exclusively by hired labour. In some cases shareholder systems have developed, although this is not permitted by the SODERIZ regulations. Something could be done about these developments if, for example, land taxes, a water price, etc., were levied in order to tax away the additional benefits of irrigated land (see DOPPLER 1977).

as the running costs of extension, that are very high at this stage, have to be borne by the Government. The capital investment per hectare is much higher than in the case of rainfed rice cultivation, i.e. the burden on the budget is greater. But if the necessary subsidies are related to a holding and not to a unit of area, the differences between irrigated and non-irrigated rice cropping are less, since the area required to fully employ one unit of labour is smaller.

The effects on employment are positive in two respects. Irrigation farming is highly labour-intensive: the labour requirement for manual cropping methods is 230-290 ME-days/ha. If it is possible to control and store irrigation water, the field work can be spread relatively evenly over the year. In rainfed rice cultivation, this is possible only to a very limited extent, since the time of planting can be varied slightly.

4. Considerations on an Appropriate Strategy for Increasing Rice Production in West Africa

In many parts of the world, and particularly in Asia, irrigated rice cultivation constitutes the basis of life of the population, and forms the foundation for social development. If the target of a country is to guarantee the supply of rice in the long term from domestic production, then wet rice is certainly to be preferred - in Africa too, even though the example of Asia cannot be simply transferred to the African setting.

As the results of this analysis have so far shown, irrigated rice cultivation has a number of advantages compared with rainfed rice production from the macro-economic point of view. Irrigated rice is advantageous in respect of both the profitable utilisation of scarce resources or of economic growth, and also in relation to other targets of the national economy. Nevertheless, when considering whether rice production should be increased by promoting either rainfed or wet rice cropping, it is not possible to decide in general and exclusively in favour of irrigated types of farming.

If we want to know the general conditions under which preference is to be given to one type of cropping, the problem is relatively simple as far as the natural conditions are concerned. Wet rice is always to be preferred where upland rice produces only relatively low yields with a high yield uncertainty because of an unfavourable rainfall distribution. But there is no alternative to wet rice in regions where rice cannot be cultivated without irrigation.

Upland rice is becoming more and more important as an alternative in locations with favourable natural production conditions, and where land is available wet rice cultivation is scarcely found in the humid regions of West Africa. Even in regions with high population densities, valley bottoms are only occasionally cultivated (KARR et al. 1972, LAGEMANN

1977, pp. 117 et seq.). Even where it is highly profitable to produce, a number of problems militate against the rapid expansion in wet rice cultivation at the farm level, particularly in those regions where upland rice constitutes the basis of life of the population:

- The soils in valley bottoms in West Africa are frequently shallow and only moderately fertile, with the result that yields decline after just a few years unless fertiliser is applied (FAO 1971, p. 18).
- People avoid the humid valley bottoms for health reasons (bilharzia, malaria, etc.) (USAID 1968, p. 12).
- For many tribes, rice cropping in valley bottoms is typical female work that is refused by men (MOHR 1969, p. 91).
- Land clearance and laying out the rice fields require a high labour input and are physically very demanding activities.
- Work on irrigated land (land preparation and transplanting) is mostly considered to be much more strenuous and unpleasant than the work of upland farming.
- Varieties of rice recommended for irrigated cultivation often differ in taste from the varieties previously grown, and they are rejected for this reason.
- Cash income can be obtained with less effort from cultivating perennial crops like coffee, cocoa, oil palms or hevea.

In many parts of West Africa irrigaiton farming is, therefore, a totally new method of land use whose expansion demands, moreover, a high level of capital investment in land development and the construction of irrigation works. If it is assumed that traditionally operating farmers cannot raise the capital required for investment, and cannot bear the costs of extension that are high in the initial phase, subsidies have to be provided by the Government, which involve a much higher consequential burden on the budget than rainfed rice production. Since budget funds are limited, only a small number of farmers can be reached via irrigation projects. Moreover, these farmers sometimes enjoy considerably increasing incomes through irrigation farming and, unless additional incomes are skimed off in the form of taxes or water charges, this can lead to an undesirable distribution of in-

come. As cropping is intensified, particularly through mechanisation, the above applies also to upland rice production, although to a much smaller extent.

In this context another factor should be mentioned, namely that the establishment of larger irrigation projects sometimes involves the settlement or resettlement of a large number of people, especially in West Africa where population densities are usually low, and this presents additional problems and demands considerable investment in the infrastructure.

For the reasons stated, rice production can only be increased slowly by expansion in irrigated rice cultivation. If the target is a short-term increase in production, it can be achieved more easily by promoting rainfed rice cropping. As the economic analysis shows, a profitable alternative from the macro-economic point of view is the intensification of traditional farming by introducing technical innovations, e.g. improved seed and mineral fertiliser. In those regions where upland rice is traditionally produced in smallholdings, it is, however, almost exclusively grown for subsistence, and is scarcely of any importance as a cash crop. Thus price policy measures are - at least in the short term - not an effective method for increasing rice production.

Moreover, the expansion of the cultivated area in bush fallow systems creates an increasing distortion to the ecosystem, because the forest is destroyed. These negative effects on the environment can be remedied if shifting cultivation is replaced by forms of permanent upland farming. In the long term, the main problems of permanent arable cultivation are the maintenance of soil fertility and the protection of soils against erosion. In practice the measures necessary to maintain the yield potential are frequently not taken or not adhered to by the farmers, with the concomitant danger that the existing production potential of a region is rapidly exhausted. In contrast these problems are much

less serious and can be solved more easily in irrigation farming.

If land becomes scarce in the course of development, the opportunity costs of land have to be taken into account. This means that rainfed rice cropping on non-hydromorphic soils incurs rising opportunity costs for land, whereas there is scarcely any alternative use for the wet valley bottoms apart from the cultivation of rice, i.e. the opportunity costs are virtually nil.

As yet this situation is found only rarely and confined to particular regions in West Africa. Labour and capital are usually the limiting production factors. But in the case of mechanised rainfed farming, land can also be a constraint, because only some areas are suitable for mechanised cropping, according to the texture and depth of the soil or the topography. Therefore, the potential availability of land for mechanised farming in a region may be sometimes small. Consequently, the opportunity costs of land are rapidly increasing as the mechanically cultivated area is extended.

If we bear in mind the target of self-sufficiency, upland farming in the humid regions will remain an important form of land use in addition to perennial crops in the foreseeable future, or will possibly even gain in importance. Because of the given climatic conditions in West Africa, upland rice is a suitable crop for arable farming irrespective of the cropping technique followed. It has to be examined whether upland rice is just as profitable as other arable crops from the macro-economic point of view as it is at the farm level. The stronger competition for the scarce resources will arise from perennial rather than from arable crops, although the competitiveness of the former does decline as the length and intensity of the dry season increases. If we take into account the sharp fluctuations in price of these crops on the world market which is also true for rice, it is virtually impossible to draw confident long-term conclu-

sions about the relative economic advantage of producing any one crop.

For the reasons given, it is not advisable in West Africa, at least in those countries where part of the area lies within the zones of tropical rainforest and Guinea Savanna to increase rice production exclusively by means of developing wet rice cultivation, as was sometimes the case in the past. As an alternative, more weight should be given in future to the development of rainfed rice production.

5. Summary

In many West African countries, rice is an important staple food, and in recent years it has gained considerably in importance because in most countries production has lagged behind the constantly growing demand. A priority target of the agricultural development policy of these countries is therefore the reduction of rice imports by increasing domestic production. In the past the efforts to increase rice production involved almost exclusively the development of irrigated rice cultivation, even in those regions with favourable natural conditions for rainfed rice production.

The present study investigates to what extent the development of rainfed rice cropping with differing levels of mechanisation represents a suitable and economically feasible alternative for increasing rice production in West Africa.

At the farm level, mechanised production methods prove to be economically superior to traditional upland rice cultivation. The reason for this is not so much the return to land as that to labour, which usually constitutes the limiting production factor in smallscale farms. This also applies when, with mechanised land clearance, the investments in land development have to be borne by the farmers. This, however, is usually not the case, or at least a substantial part of the investment costs is subsidised by the Government. The use of animal power is economically inferior to semi-mechanisation when the input of manual labour is much higher, which is frequently the case in the initial phase when ox-teams are introduced.

Compared with other arable crops, upland rice is very profitable irrespective of the level of mechanisation. Under the price relations prevailing in Ivory Coast, this applies even to those regions with less favourable climatic conditions for rainfed rice production. In evaluating the profitability of rainfed rice, a crucial role is played by the

attitude of the farmers towards risk, because yield uncertainty due to climate is much higher in the case of rice than of other crops like yam, cotton or groundnuts.

Under favourable climatic conditions, in other words with increasing annual rainfall and a decreasing number of dry months, the cultivation of perennial crops like coffee, cocoa, oil palms, etc., becomes more and more profitable. This applies particularly with regard to cash income, which is an important economic target in smallscale farms, where most of the agricultural production is consumed in the household. A comparison of traditional and semi-mechanised holdings in West Ivory Coast reveals that upland rice produces more than half the gross returns in both farming systems, but is of only secondary importance as a cash crop compared with coffee. This observation is confirmed by the results of linear programming models for the traditional farms. On the other hand, the expansion of upland rice cultivation and a reduction of the coffee area in the semi-mechanised farms would lead to an increase in net cash income and improve the economic situation of the holdings. Because of the differences in farm size, semi-mechanised farms have on average a higher farm income, farm family income and net cash income. But if these figures are related to the labour force or the cultivated area of the holdings, only small differences exist between the two farming systems as regards returns to land and labour.

Fully mechanised rainfed rice production is scarcely found in West Africa. Since upland rice has to be included in a rotation for crop sanitary reasons, the main problem with this form of cropping is to find other production alternatives that can be integrated into a highly mechanised farming system and carried on profitably. The profitability of rice production is affected decisively by the productivity of the machines and the level of yields achieved.

In contrast to the observations at the farm level, a cost-benefit analysis shows that hand cultivation is economically superior to mechanised cropping from a macro-economic point of view. However, the possibility of increasing rice production within traditional shifting cultivation is limited. Moreover, any extension of the cultivated area in these farming systems leads to the destruction of forest and, therefore, to an increasing disturbance of the eco-system.

If wet rice production is considered as an alternative at the national level, irrigated rice proves to be economically superior to rainfed rice with the same level of mechanisation, as a cost-benefit analysis on the basis of unmodified domestic market prices shows. This still applies when the opportunity costs of unskilled labour are relatively high, approximately double the wages of agricultural labour. A cost-benefit analysis on the basis of world market prices, on the other hand, reveals only slight differences between the two types of rice production as far as returns to the input of scarce resources are concerned, a fact that is to be attributed basically to the distinct difference in the price of paddy.

The advantage of wet rice applies not only with regard to its profitability, but also is apparent in respect of other socio-economic objectives at the national level like employment, the elimination of regional income disparities or the encouragement of capital formation.

In many parts of West Africa, irrigation farming constitutes a completely new type of land use, the expansion of which, moreover, requires a high level of investment in land development and the construction of irrigation works. If we assume that some of the capital investments and the running costs of extension have to be subsidised by the Government, so that farmers are enabled and encouraged to practise irrigated rice production, a considerably higher burden is

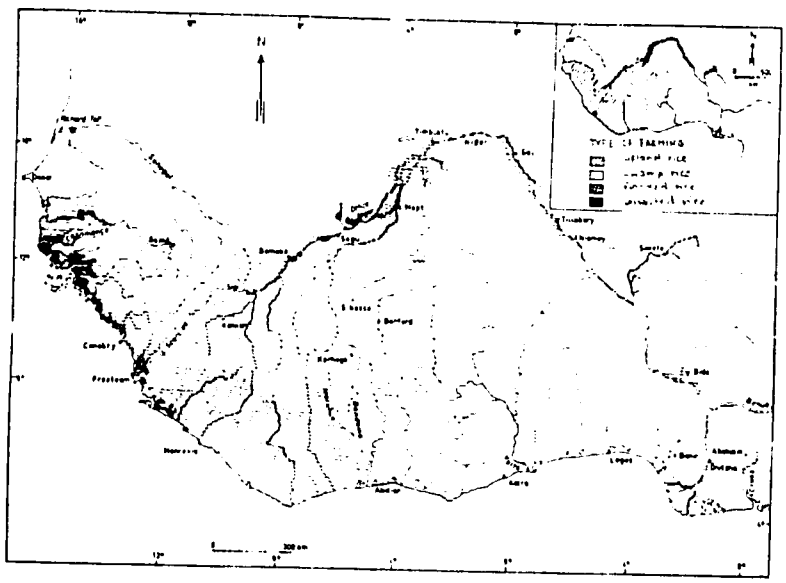
placed on the State budget than by rainfed rice cultivation. Therefore an intensification of rainfed rice cropping is more appropriate if the target is the rapid increase of production, since the capital requirement per tonne of rice produced is lower in rainfed rice than in wet rice cultivation.

For these reasons, it is therefore not advisable to increase rice production in West Africa exclusively by developing irrigated rice cultivation, as often happened in the past. As an alternative to this strategy, greater emphasis should be placed in future on the development of rainfed rice cultivation.

A P P E N D I C E S

Appendix I

Rice Cultivation in West Africa by Region and Type of Farming



Permanent rice cultivation (nearly as a monocrop)
Rice predominant
Rice as an important crop
Rice of secondary importance

Source: MOHR 1969, p. 141.

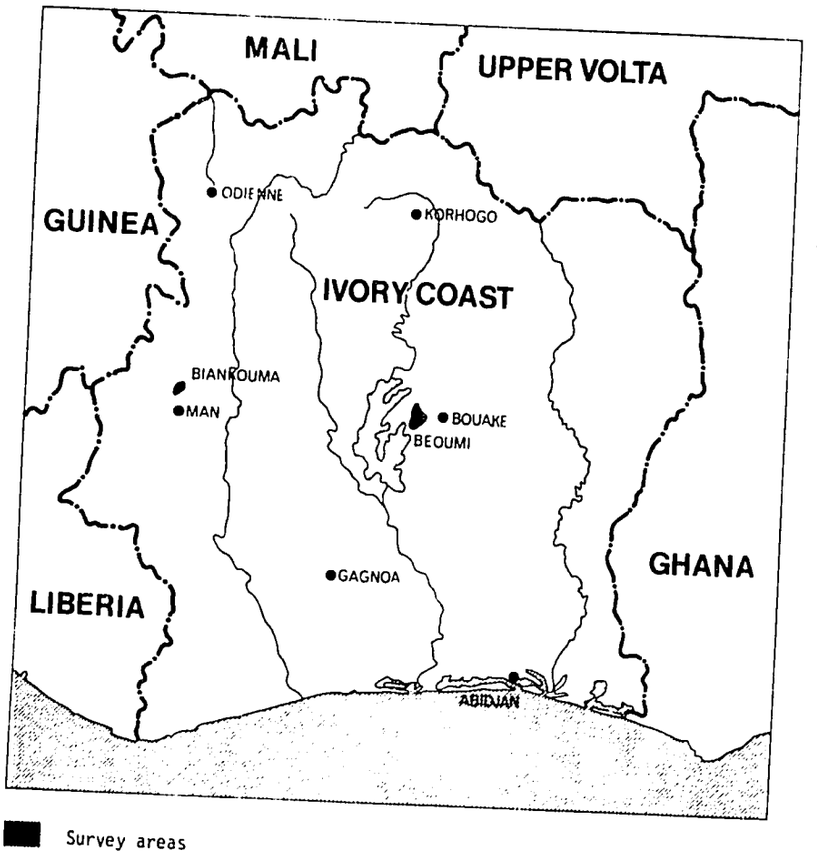
Appendix II: Important Rice Varieties Grown in Rainfed Cultivation in West Africa

Name	Origin	Type	Vegetation period (days)	Sensitivity to photo-period	Plant height (cm)	Tillering capacity	Susceptibility to grain losses	100-grain weight (g)	Response to mineral fertiliser	Susceptibility to loging	Draught tolerance	Resistance to Piricularia oryzae	Yield potential (dt/ha)
Anethoda	Sierra Leone	indica	130–140	low	99–123	high		2.12	moderate	moderate	high	moderate	30
Morobérékan	Ivory Coast	indica	145	no	150	low	very low	2.8–3.0	moderate	moderate	high	very high	40
ROK 3	Sierra Leone		140–145	low	103–139			2.73	moderate	low	high	very high	29
Paté Blanc	Ivory Coast	indica	130–135	no	130–140	moderate	moderate		moderate	moderate	high	high	35
LAC 23	Liberia		130–145						moderate				35
OS 6	Zaire		120–130		130		moderate		moderate				40
63–83	Senegal	indica	115–120	low	130	low	moderate	3.34	moderate	moderate	high	high	35
Durado Precoce	Brasilia	indica	105	no	140	low	moderate	3.32	moderate	high	high	moderate	40
Iguapé Cateto	Brasilia	indica	135	no	150	moderate	moderate	3.30	moderate	high	moderate	high	50
I Kong Pao	Taiwan	indica	110–140	no	85	very high	moderate	2.40	very good	very low	very low	low	55
IR 422	Philippines	indica	125	no	115	very high	moderate	2.44	good	very low	high	low	45
IRAT 8	Ivory Coast	indica	130	no	140	low	very low	2.80	moderate	moderate		very high	45
IRAT 9	Ivory Coast	indica	125	no	85	high	low	2.40	good	very low		very high	60
IRAT 10	Ivory Coast	indica	110	no	100	moderate	moderate	2.90	good	very low		high	55
IRAT 13	Ivory Coast	indica	125–130		115	moderate	moderate	4.40	good	low		high	50
SE 302 G	Senegal	indica	90–100	low	85	high	high	2.50	very good	very low	moderate		50
SE 319 G	Senegal	indica	95	moderate	85	high	high	2.40	good	very low	high	very high	40
ROK 1	Sierra Leone	indica	128–135	low	79–106	high		2.57	good	very low	high	high	32
ROK 2	Sierra Leone	indica	128–135	low	83–108			2.89	moderate	moderate	high	high	39

Source: Compiled by the author from WARDA 1975b and 1975c, RCI/MINISTERE DE LA RECHERCHE SCIENTIFIQUE/IRAT, Fiches de variétés de riz, 1974

Appendix III: Maps of Ivory Coast

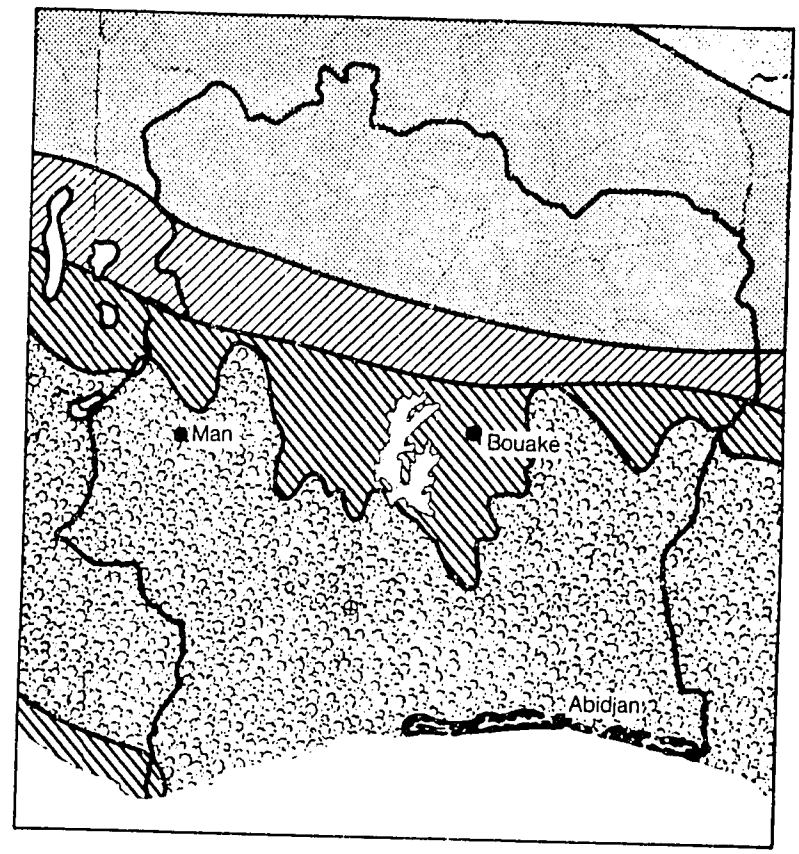
Map 1: Survey areas in Ivory Coast



Survey areas

Source: Compiled by the author.

Map 2: Vegetation zones in Ivory Coast



Mangrove vegetation

Tropical rainforest

Forest-savanna mosaic

Montane vegetation

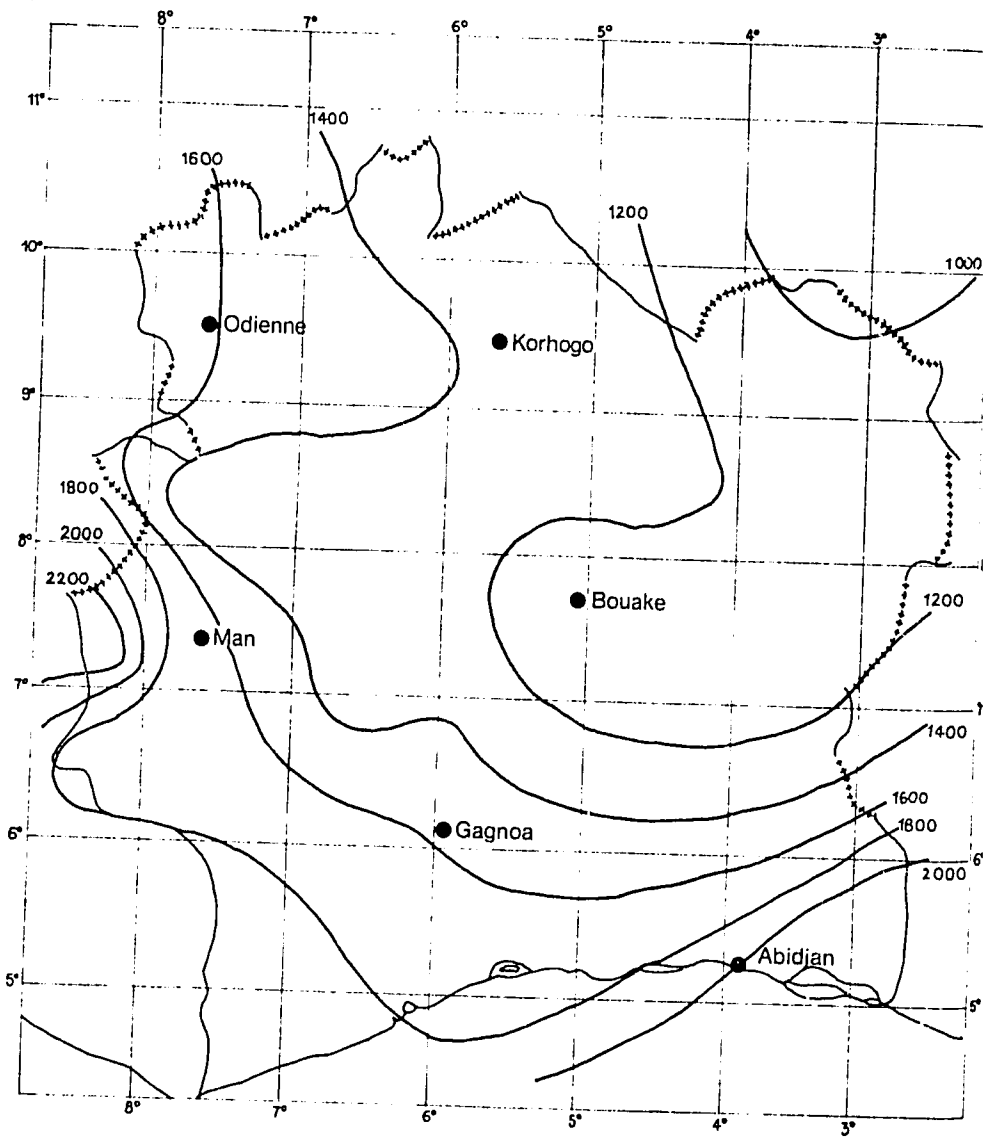
Moist savanna

Wooded savanna

Savanna

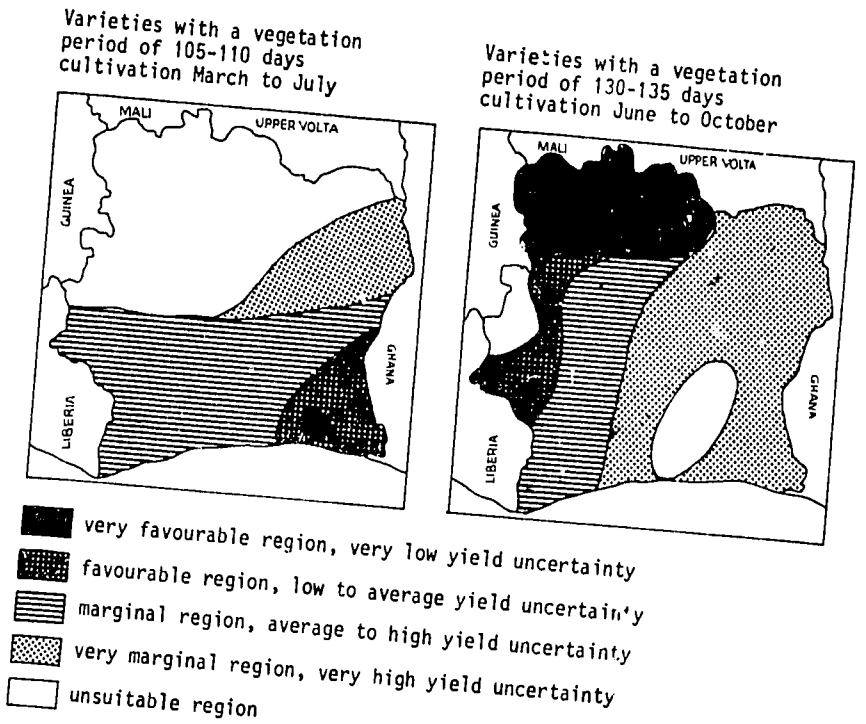
Source: COCHEME 1971.

Map 3: Isohyetes in Ivory Coast



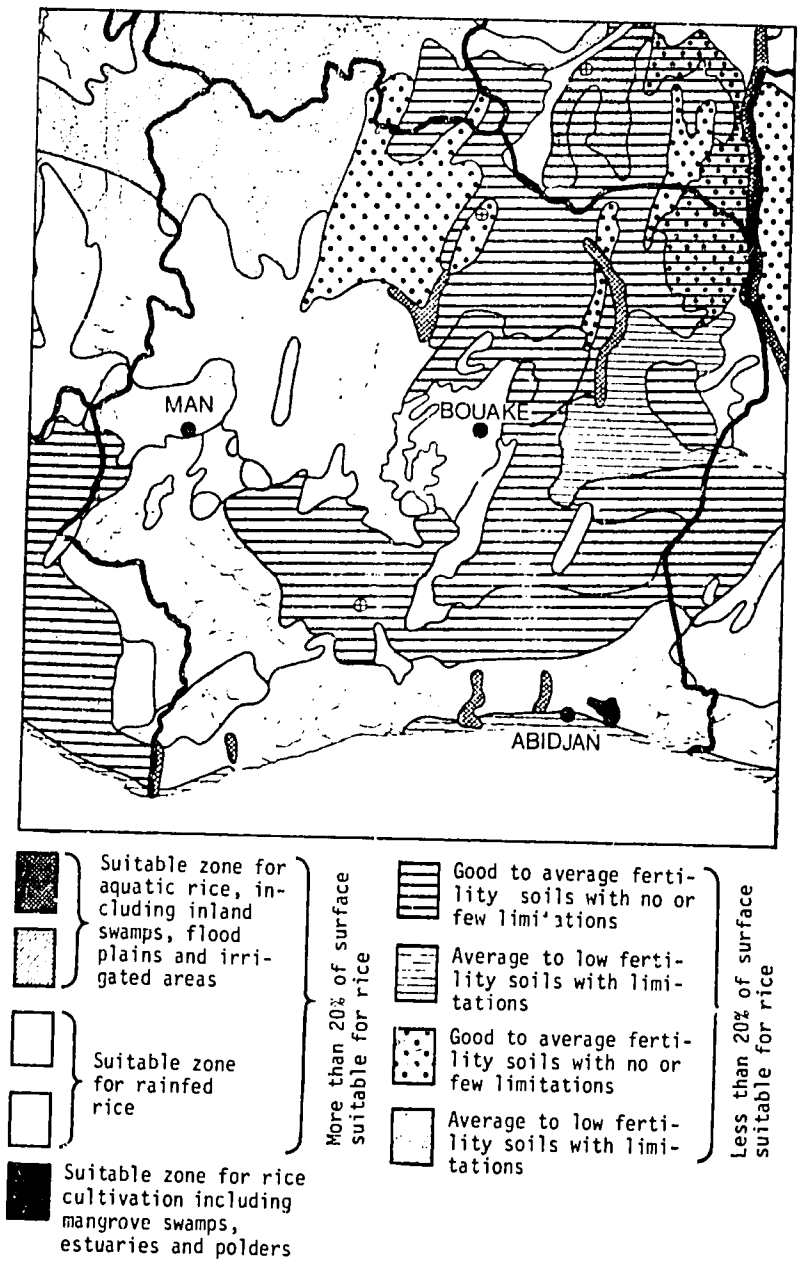
Source: RCI/MINISTERE DE L'AGRICULTURE, Développement rural de la zone de Plolequin Zoukougbeu 1974, p. A-31.

Map 4: Suitability of regions for upland rice cultivation with regard to climate



Source: GIGOU 1973, p. 874 et seq.

Map 5: Soil suitability for rice cultivation in Ivory Coast



Source: COCHEME 1971.

APPENDIX IV: Experiments With Permanent Upland Cultivation Conducted by IRAT in Ivory Coast

1. Permanent upland cultivation under humid conditions

This experiment has been carried out at the agricultural research station in Man in the west of Ivory Coast since 1959, to investigate whether it is possible to practise continuous cropping without fodder crops in the rotation. Originally there was a rotation of rice and cotton that was followed by a preliminary crop (maize, soya) in the same year. Since 1970, the following rotation has applied:

1st year:	rice	(May-October)
2nd year:	maize	(April-July) / soya (August-December)
3rd year:	rice	(May-October)
4th year:	maize	(April-July) / cotton (August-December)

Land preparation (ploughing, harrowing) and sowing are carried out by tractor, but all other operations by hand. The level of mineral fertiliser application is relatively low: 40-60 kg each of N, P_2O_5 and K_2O per hectare. All harvest residues except rice straw are ploughed back into the soil, and no other form of organic fertiliser is used.

The experiment is being carried out without replication on plots of 0.2 to 0.4 ha. Since the site is practically level, such small areas do not require any special measures to control erosion.

The annual rainfall is on average 1730 mm and falls in one rainy season from March to October, with a maximum in August/September (see Table IV/1). The temperature varies only slightly and is on average 24.8°C over the year. The annual hours of sunshine come to 1876, which is relatively low, especially in July/August, and thus reduces rice yields.

Table IV/1: Climatic data from the Agricultural Research Station Man/Ivory Coast (averages 1953 - 1973)

Month	Rainfall (mm)	Evaporation (Piche)* (mm)	Sunshine (h)	Temperature (°C) Max.	Min.	Average	Relative humidity (%)
January	15.7	103.2	218.7	32.1	16.4	24.3	68
February	56.3	103.4	200.1	33.1	19.0	25.9	68
March	114.0	89.1	194.1	32.4	20.5	26.3	73
April	155.5	66.9	165.3	31.4	20.9	26.0	78
May	160.6	61.0	169.7	30.7	21.0	25.8	80
June	207.2	43.0	117.4	28.6	20.7	24.7	83
July	201.2	37.2	86.6	27.4	20.1	23.7	86
August	256.8	34.6	76.5	27.1	20.2	23.6	87
September	318.7	36.8	120.5	28.6	20.3	24.3	85
October	166.5	44.3	173.7	29.6	20.1	24.7	83
November	55.9	50.8	174.4	30.2	19.4	24.7	82
December	20.0	73.3	178.7	30.7	16.5	23.9	76
Year	1730.4	743.7	1875.7	30.2	19.7	24.8	79

*) incomplete

Source: RCI/MINISTERE DE LA RECHERCHE SCIENTIFIQUE/IRAT, Division d'Agronomie, Rapport analytique, Fascicule I, 1974, pp. 7 et seq.

2. Permanent upland cultivation under semi-humid conditions

In 1960 an area with a gentle slope of about 10 ha was cultivated at the agricultural research station Bouaké. The average slope is 1.5 to 2 %, but is as high as 6 % in the middle of the site. The soil belongs to the group of ferralitic soils and consists of sandy loam. The clay content is low and varies between 10 % and 20 % in the lower and upper sections of the slope respectively. The content of organic matter also drops from 2.5 % to 1.3 %. The pH value is 6.3. To prevent erosion, smaller plots were laid out and separated

by strips of grass about 2 m wide approximately following the contour lines.

The rotations were not uniform at the beginning of the experiment. Since 1966 the following rotations have been practised:

	1966 - 1970			since 1971		
1st year	Yam	Yam	Rice	Yam	Yam	Yam
2nd year	Maize/ cotton	Groundnuts/ cotton	Maize/ cotton	Maize/ cotton	Groundnuts/ cotton	Maize/ cotton
3rd year	Rice	Stylo-santhes	Stylo-santhes	Rice	Rice	Rice
4th year	Stylo-santhes	Stylo-santhes		Maize/ soya	Maize/ soya	
5th year				Rice		

Except for rice straw, all the harvest residues are ploughed back into the soil, and since 1971 there has been no organic fertiliser in the form of green manure. The input of mineral fertiliser is roughly equal to the amounts of nutrients removed by the crops, and consists of 25-80 kg/ha N, 20-60 kg/ha P_2O_5 and 0-60 kg/ha K_2O. Tractors are employed to prepare the land, for sowing and spraying herbicides, but all other operations are done by hand. The size of the plots varies between 0.1 and 0.7 ha; the experiment is being carried out without replication.

The climate of the region is characterised by a bimodal rainfall distribution. The first rainy season lasts from March to June (400-500 mm), followed by a short dry season in July/August, during which about 200 mm of rain fall. The second rainy season from the end of August to October is certainly shorter, but has a more even rainfall distribution than the first season. The long dry season lasts from November to the beginning of March. The total rainfall amounts to 1200 mm per year, and therefore exceeds the evaporation (piche) of on average 1050 mm. There are 2064

hours of sunshine per year, which is almost 200 hours more than at Man. The average annual temperature is 25.8°C, with a maximum of 27.6°C in February/March and a minimum of 23.9°C in August. The relative humidity is 75 % on average, and even during the dry period it rarely drops as a monthly average below 50 %. The climatic data are given in detail in Table IV/2.

Table IV/2: Climatic data from the Agricultural Research Station Bouaké/Ivory Coast (averages 1953 - 1973)

Month	Rainfall (mm)	Evaporation (Piche) (mm)	Sunshine (h)	Temperature (°C) Max.	Min.	Average	Relative humidity (%)
January	13.0	158.0	241.8	32.9	20.4	26.6	59
February	45.5	150.6	222.4	33.9	21.5	27.6	61
March	90.4	132.0	217.7	33.3	21.8	27.5	68
April	137.6	93.7	196.9	32.3	21.8	27.0	74
May	144.1	77.0	207.2	31.3	21.7	26.3	78
June	148.9	55.1	137.2	29.3	20.9	25.1	82
July	97.4	52.9	98.0	27.7	20.4	24.0	84
August	106.2	49.1	77.4	27.6	20.4	23.9	84
September	212.5	46.6	112.0	28.7	20.6	24.6	84
October	137.8	54.7	167.6	29.8	20.7	25.2	82
November	37.5	68.0	189.9	31.0	20.8	25.8	80
December	21.2	108.4	105.4	31.5	20.3	25.8	69
Year	1192.1	1046.2	2063.5	30.8	20.4	25.8	75

Source: RCI/MINISTERE DE LA RECHERCHE SCIENTIFIQUE/IRAT, Division d'Agronomie, Rapport Analytique 1974, Fascicule 1, pp. 7 et seq.

APPENDIX V: Method of Data Collection

A farm survey was carried out in the villages Mangouin, Yrongouin, Tēh, Komadepleu and Dingouin from February 1974 to April 1975. All the villages are situated in the southern part of the Sous-prēfecture Biankouma in the Dēpartement de l'Ouest of Ivory Coast (see Map 1, Appendix III). The object of the survey was to compare traditional holdings with holdings operated by farmers who were members of an agricultural machinery cooperative and in which semi-mechanised cropping was practised in additon to traditional cultivation.

1. Selection of holdings

The 122 members of the agricultural machinery cooperative (CUMA) Mangouin constituted the total number of semi-mechanised holdirgs; no data were available in respect of the traditional holdings. To select the sample, therefore, a list was compiled of the names of all the independent farmers with the help of the heads of family groups (chefs de lignage) in the various villages, and in this way about 90 % of all holdings have probably been included. From the total population of the two types of holdings, a stratified sample of 30 holdings was chosen at random, with the number of holdings per village corresponding to the proportion of the mechanically cultivated land area. One farmer refused to cooperate and was replaced by another one.

2. Data collection

Data were collected by means of interviews. Since only just a few farmers spoke French, questions were asked in Dioula, that was spoken by all farmers.

At the beginning of the survey, data on the resource base of the holdings and the areas of the different crops were collected. To estimate the labour force, the total number of persons was recorded who were permanently living with the farmer and who worked on his fields. The farmers were also asked about their animal stock and the number of tools and machines. The areas of the different crops and crop mixtures were measured by walking along the fields using a compass and in the presence of the farmers. The pattern of land use and the length of the cropping and fallow periods were established for each plot. A cadastral register on the mechanically cultivated areas was available.

Data on the labour input and all cash receipts and expenses connected with farming were collected by interviewing the farmers once a week. As regards the labour input, classified according to sex and age, a distinction was made between the farmer, other members of the family, assistance from neighbours and hired labour.

To measure the yields of rice and maize, plots of 25m² were selected at random, and these plots were harvested separately, and the harvest was further processed by the farmers. The product was weighed after sun-drying.

3. Data analysis

After consistency checks, most of the data were punched on computer cards and statistically analysed with the help of the SPSS[1]. The arithmetic mean, the variance and frequency distributions were normally calculated. Differences between variables were tested for significance by the t-test, F-test and, where these could not be applied, by the chi-square-test or the WILCOXON-test[2].

1) Statistical Package for the Social Sciences, Version 1975.
2) See SIEGEL 1956, pp. 42 et seq. and pp. 75 et seq.

3.1 Labour

To estimate the labour force of the holdings and the labour input, the following conversion factors were used, bearing in mind the availability of labour, physical productivity and the length of the working day:

Tabele V/1: Conversion factors to estimate labour units

Labour group	Age (years)	ME	ME-days[a)]
Children	<10	-	0.15
Children	10 - 14	0.35	0.35
Young males	15 - 19	0.70	1.00
Young females	15 - 19	0.70	0.70
Adult males	20 - 50	1.00	1.00
Adult females	20 - 50	0.70	0.70
Adults (both sexes)	>50	0.35	0.35

a) The conversion factors were not differentiated according to activities. Only in the case of guarding the fields were the working days of all labour groups except children under 10 years of age weighted with the factor 1.0.

Source: Compiled by the author.

To estimate the labour input, half-day units were taken as a basis for data collection, since a finer differentiation or the measurement of labour in terms of hours proved to be impracticable[1)]. The working day includes the time spent for getting to and from work, working-time as well as breaks. The length of the working day varies according to the season and the nature of the field operations between 4.5 (land clearance and preparation) and 8.0 hours (weed control, harvesting), the average being about 6-6.5 hours.

1) To record the labour input in hours with any degree of acuracy, it would have been necessary to measure exactly the time spent, and this was not possible because of the high costs that would have been incurred.

3.2 Land

The plots of each crop were individually numbered and marked, so that the cultivated area of the holdings could be estimated. If the shape of the plots revealed large deviations between the beginning and end point, the plot was measured again. The area was estimated by using a planimeter. In the case of mixed cropping the plots were recorded according to the most important crop, that could usually be clearly distinguished. Inclusion of the fallow land would have been too demanding, and since land is cleared almost exclusively for traditional upland rice cultivation, a theoretical farm size can be estimated according to the following formula:

Theoretical farm size = traditional upland rice area x (average fallow period + 1) + area cultivated with perennial crops + semi-mechanised cultivated area

This farm size is only theoretical, since, according to traditional laws, rights of land use of only limited duration can be acquired.

To determine the actual total cultivated area, a plot or a section of a plot was included twice in the calculation if two crops were grown in the same year, or if a dense stand had developed in the case of cassava, plantains or perennial crops.

3.3 Yields

Yields of rice and maize were calculated from the results of the sample measurements. When using this method the yields are usually overestimated, with the deviations from the actual yields being greater in the case of the traditionally cultivated land than in semi-mechanised cropping

(see Van SANTEN 1972c, p. 2). Nevertheless, the yields that were measured were not corrected, because no total surveys were carried out, and therefore it is not possible to know the degree of error of estimation.

Calculation of the per capita consumption of rice on the basis of the estimated yields as a control measure results in a rice consumption of 140-150 kg per person.

	Traditional holdings	Semi-mechanised holdings
Rice production (kg)	2,332	4,058
Losses 10 % (kg)	233	406
Seed requirements traditional farming (kg)	107	49
Marketable production (kg)	1,992	3,603
Sales (kg)	396	831
Available for consumption (kg)	1,596	2,772
Per person (kg paddy)	231.3	245.7
Equivalent rice (60 %)	138.8	154.0

This relatively high figures of rice consumption suggest that yields are slightly overestimated, since the actual figures should range between 110 and 130 kg (BDPA no year, Vol. 3).

3.4 Gross returns and total costs

To estimate the gross returns, total production of the holdings was valued at farm-gate prices. In the case of products for which the price is not fixed by the State (maize, yam, cassava, etc.), the average market price for the period in which most of the production was sold was applied. Because of the high costs it was not possible to measure any yields apart from rice and semi-mechanised maize.

In the case of coffee and cocoa, the total production and the amount sold were identical, since processing of those products for consumption is unknown. The production of all other crops was estimated on the basis of the following average figures:

Table V/2: Average yield estimates and market prices of traditionally cultivated food crops in West Ivory Coast

	Yields in kg/ha			Market price FCFA/kg
	Pure stand	Important mixed crop	Mixed crop of secondary importance	
Upland rice (paddy)	a)	a)	400	65
Groundnuts (dried shells)	1,100	800	300	12
Maize	1,400	1,100	200	18
Yam	9,500	8,500	3,000	8
Cassava	9,000	7,500	2,500	6
Plantains	9,000	7,500	4,000	8
Sweet potatoes	8,000	6,500	3,000	10
Vegetables (Okra, etc.)	7,000	5,500	2,500	35

a) Yield was measured.

Source: Compiled by the author according to BDPA (no year, Vol. 3), BLANCKENBURG/CREMER (Vol. 2, 1971), LEAKY/WILLS (1977), REHM/ESPIG (1977).

Income from collecting, stock-keeping, etc., was estimated at 10 % of the value of production from perennial crops plus the income from the sale of these products. The value of recently established perennial crops was ignored.

To arrive at the total costs of the holdings, cash expenses were recorded from interviews, and other costs were estimated. Wages paid in kind to hired labour were valued at 32 FCFA/day, and 77 FCFA/day in the case of neighbours' co-

operation, because often better meals are sometimes provided twice a day. The costs of establishing cocoa and coffee are 50,000 to 60,000 FCFA/ha and are depreciated over a period of 20 years[1].

3.5 Cash income

With regard to monetary transactions, the only cash income and expenses that were recorded were those directly connected with farming. In so doing, the repayments of credit for purchased inputs, that had to be in the form of paddy according to the SODERIZ contracts, were treated as cash income and expenses.

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1) It is extremely difficult to estimate the costs of establishment of perennial crops if the plot is used in the first few years for mixed cropping, because the costs cannot be exactly allocated to the individual crops.

Appendix VI: Basic Data for Linear Programming Models

Table VI/1: Monetary and production coefficients of the activities (1 ha)

	Traditional upland rice 1st year sowing early (1/E)	normal (1/N)	2nd year early (2/E)	normal (2/N)	Subsistence crops year 2/3 ext.	int.	Modern upland rice hand cultivation 1st year sowing early	normal	2nd year early	normal	Semi-mechanised upland rice sowing May ext.	int.	early sowing	Semi-mechanised maize 1st. cycle ext.	int.	2nd cycle ext.	int.	Traditional Coffee ext.	int.	Modern Coffee
Yield (kg)	1200	1600	800	1000			1800	2100	1700	2000	2000	2500	2100	2000	2800	1700	2300	160	350	950
Subsistence units					1.0	1.3								0.05	0.05	0.05	0.05			
Seeds (kg)	100	100	100	100			120	120	120	120	120	120	120	60	60	60	60			
Cash expenditure for																				
– tools etc.	650	650	450	450	450	450	650	650	450	450	420	420	420	420	420	420	420	450	450	750
– fertiliser, pesticides	–	–	–	–	–	–	14880	14880	14880	14880	14880	14880	14880	4500	13500	–	13500	–	–	10500
– machine hire	–	–	–	–	–	–	–	–	–	–	10000	10000	10000	5000	6500	5000	5000	1600	3500	9500
Labour requirements (man-days)																				
Period I	77.0	25.1	46.1	8.0	20.5	26.5	89.0	27.6	58.0	8.8	5.6	7.2	29.0	19.0	29.0			1.0	1.0	14.8
" II	39.7	55.9	45.0	40.1	19.5	28.4	45.0	63.0	49.5	50.0	19.6	24.8	53.0	16.0	26.2			4.4	4.9	35.5
" III	23.8	31.8	26.0	36.8	30.8	35.5	29.0	36.0	29.0	39.6	28.0	40.0	21.0	16.3	24.8			3.6	15.9	1[illegible].7
" IV	22.9	12.5	20.4	14.9	6.0	6.5	56.5	17.0	56.5	14.0	11.0	22.0	63.4	28.7	27.0	14.0	23.0	0.4	12.7	0.7
" V	26.4	41.8	20.3	41.0	4.5	5.5	3.9	43.0	3.9	43.0	31.2	34.4	6.8			18.0	26.0	7.4	6.7	12.7
" VI	3.0	32.7	2.0	26.3	2.0	3.5	2.6	36.7	2.6	36.2	35.1	39.6	6.8			1.8	4.0	17.5	27.5	53.9
" VII	6.0	8.6	5.9	5.4	4.5	6.5	–	10.8	–	10.8	9.3	12.0	–			33.2	34.0	11.3	22.9	50.5

1) Including post-harvest losses.

Source: Compiled by the author.

Table VI/2: Periods of and available days for field work in the western region of Ivory Coast

Period		Operations	Days	Available days for field work Max.[a]	ER[b] (%)	ER[b] Days	LP[c]
I	10. 2. - 9.4.	Land clearance, seed-bed preparation Sowing and guarding the early-sown rice fields Sowing of groundnuts, maize, etc. Sowing of semi-mechanised maize	58	27	33	19	24.5
II	10. 4. - 5.6.	Land preparation for rice and other subsistence crops Sowing of rice and guarding the fields Planting of other subsistence crops (maize, cassava, etc.) First weeding of early-sown crops Weeding of semi-mech. maize	57	27	30	17	23
III	6. 6. - 19.7.	First weeding of rice Second weeding of early-sown crops Planting of cassava Husbandry of coffee (intensive production) Beginning of maize harvest (1st cycle)	44	22	39	17	21.5
IV	20. 7. - 31.8.	Harvest of early sown crops Sowing semi-mech. maize (2nd cycle) Fencing of rice fields Husbandry of coffee (int. production)	43	22	40	17	21
V	1. 9. -15.10.	Second weeding or rice Weeding of late-maturing subsistence crops Beginning of rice harvesting Weeding of semi-mech. maize (2nd cycle) Husbandry of coffee (ext. and int. production)	45	25	42	19	23.5
VI	16.10. -10.12.	Rice harvesting Harvesting of late-maturing subsistence crops Husbandry of coffee, beginning of harvest	56	31	42	24	29
VII	11.12. - 9. 2.	Rice threshing Harvesting of late-maturing subsistence crops Harvesting of semi-mech.maize (2nd cycle) Coffee harvesting	61	33	26.5	16	22.5
Total			364	184		129	165

a) Maximum available working-days (author's survey)
b) Available working-days according to BDPA (no year, Vol. 3c, Tab. 211c)
c) [illegible]

APPENDIX VII: The Evaluation of the Profitability of Improved Production Methods Under Conditions of Yield Uncertainty Caused by Climate[1)]

1. Introduction

The introduction of improved production methods has brought about considerable increases in yields and profitability in upland farming in temperate climates. In rainfed farming in the tropics, particularly in the inner tropical convergence zone, modern cropping methods are frequently not efficient because of insufficient water supply. The water holding capacity of most of the soils is low, and periods of only a few days without rain at certain stages in the crops' growth can cause considerable reductions of yield.

The following illustrates an approach to evaluate the profitability of mineral fertiliser application at differenc levels of mechanisation under conditions of yield uncertainty due to climate.

On the basis of results from an experiment in Ivory Coast on the agronomy of yam, maize, rice and cotton:

- the relations between crop yields and climatic variables are analysed;
- the effect of innovations like mineral fertiliser application, use of animal power and tractors on the yields is quantified;
- and finally the profitability of improved production methods is estimated, taking into account the yield uncertainty due to climate.

1) For details see LANG/BARTSCH 1977.

2. Data basis

The data are taken from a long-term agronomy trial that has been carried out at the IRAT research station in Bouaké since 1967. The aim of the experiment is to examine the influence of mineral fertilisers and manure with different depths of ploughing (about 5 cm by hand, 10-15 cm by ox-team and 25-30 cm by tractor) on the yield development in permanent upland cultivation without fallow.

The lay-out of the experiment is as follows: the area is divided into 3 blocks in keeping with the crop rotation yam - maize/cotton - rice. Each block is divided into 4 plots corresponding to the production methods: hand cultivation with mineral fertiliser - use of animal power with mineral fertiliser - animal power with stable manure[1] - tractor ploughing with mineral fertiliser. Each plot is further subdivided into 3 smaller plots measuring 12 x 12 m, corresponding to the levels of fertiliser application.

Fertiliser doses were varied in the first few years of the experiment. Since 1970, the following quantities have been applied (N - P_2O_5 - K_2O in kg of pure nutrients per ha):

	Yam	Maize	Cotton	Rice
no fertiliser (F_0)	0-0-0	0-0-0	0-0-0	0-0-0
medium fertiliser application (F_1)	40-30-60	40-40-60	30-45-45	33-40-40
high level of fertiliser (F_2)	80-60-120	80-80-120	60-90-90	66-80-80

The same varieties of yam (Suidié, a variety of the species Dioscorea alata), cotton (Allen) and rice (OS 6) were grown from 1967 to 1974. Only in the case of maize was the variety HJ replaced by CJB (Composite Jaune de Bouaké) in 1970.

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1) This method has not been included in the analysis.

3. The method

The profitability of the various production methods under conditions of yield uncertainty is evaluated on the basis of the gross margins per hectare and per ME-day that can be expected with a certain probability from the individual crops.

In detail, the analysis comprises the following steps:

(1) Correlation analyses are carried out to determine the influence of the different variables in question on crop yields. The statistical significance of the relations thus established is examined with the help of the Student's t-test.

(2) The variables included in the mathematical model are selected with the help of relevant hypotheses and combined in multiple regression analyses, for which linear, quadratic and Cobb-Douglas functions are used. For further analysis the functions having the best fit are retained.

(3) For the independent variables used in the functions, marginal values are calculated at a given probability level[1]. To do this, frequency distribution functions of the variables are adapted for an incomplete gamma function of the type PEARSON III following MANNING (1950) and GIGOU (1973):

$$F(u) = F_o + (1 - F_o) \frac{1}{(\gamma)} \int_0^u u^{\gamma-1} \cdot e^{-u} \, du$$

1) Apart from rainfall, it was not possible to include other variables such as temperature, duration of sunshine, etc., in the analysis because of the insufficient data.

where

$F(u)$ = the probability that u will not be exceeded ($0 \leq F(u) \leq 1$)

$u = \frac{x}{s}$

x = amount of rainfall

s = the parameter of scale of the function

γ = the parameter of form of the function

F_0 = the shift of the function from the origin on the $F(u)$ axis.

The parameters (γ, s, F_0) are calculated according to GIGOU (1973, pp. 860 et seq.), whereby the function is restricted to the range $0.1 \leq F(u) \leq 0.9$, since estimations beyond this range are subject to considerable error.

(4) With the marginal values of the variables of the climatic factors thus established, and with the help of the functions retained, the corresponding marginal values of crop yields are calculated.

(5) On the basis of these values, the corresponding gross margins per hectare and per working-day are estimated and used in the evaluation of the profitability of production methods.

A further step that could follow these calculations would involve finding out the attitudes of the farmers applying these technical innovations towards risk, and thus to arrive at decision-making criteria regarding the economic advantage of particular crops and production methods[1].

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1) Decision-making under uncertainty is dealt with by e.g. ARROW 1971, HANF 1969 and Von NEUMANN/MORGENSTERN 1947.

4. Results

4.1 Yam

For the individual correlations with the yield of yam up to a fertiliser level of F_2 ($r = 0.417^{***}$), the production methods have no significant effect on the yield. This is explained by the fact that the variance of the yields between the cropping methods is small compared to the variance caused by climate.

If climatic factors are included as a variable in an explanatory model, we see that both the fertiliser level F_1 and mechanisation increase yields of yam significantly, as can be seen in the following function:

$$Y_y = 0.268\ RAS^{0.959}_{***} \cdot 1.22^{D_M}_{**} \cdot 1.50^{D_1}_{***} \cdot 1.87^{D_2}_{***}$$

Y_y = Yam yield in dt/ha

RAS = Rainfall for August and September in mm

D_M = (0,1)-variable for mechanisation

D_1 = (0,1)-variable for fertiliser level F_1

D_2 = (0,1)-variable for fertiliser level F_2

The Cobb-Douglas function is statistically very reliable, and with a coefficient of determination of 0.76 it has the best fit of all the functions.

It can be seen that mechanisation raises the yield by approximately 22 %, fertiliser level F_1 by 50 % and fertiliser level F_2 by about 87 % compared with hand cultivation without fertiliser application. Mechanisation combined with the use of mineral fertiliser increases the yield of yam by about 83 % at F_1 and by about 126 % at F_2. Cultivation using animal power in the absence of mineral fertilising has no significant effect on the yield of yam.

Tables VII/1 and VII/2 illustrate the profitability of the various production methods with yield fluctuations caused by the climate. The basis of comparison is hand cultivation without any application of fertiliser. It is clear that, under the present price conditions, mechanisation combined with the application of high fertiliser doses represents the most profitable production method for smallscale farmers. The gross margin both per hectare and per working-day is not exceeded by any other cultivation method.

It is true that with animal traction a lower gross margin per hectare is produced than with the manual method, but on the other hand the labour productivity is usually higher and only in 20 % of the years traditional cultivation is superior to ox-team cultivation. However, the differences are too small to represent an important economic incentive to adopt the use of animal power.

Mineral fertiliser application is profitable in all cases - independent of the rainfall distribution and the degree of mechanisation - and high amounts give better results than medium fertiliser doses.

4.2 Maize

If we take the relation between the various production methods and yields, only fertiliser level F_2 has a significant effect on maize yields ($r = 0.459^{***}$). The following function, in which the variance of yields due to climate is partly explained, shows that yields can also be significantly raised by applying only moderate quantities of mineral fertiliser:

Table VII/1: The effect of technical innovations and mineral fertiliser application on the profitability of yam (FCFA/ha)

Frequency (%)	Gross margin per hectare hand cultivation without mineral fertiliser (F_0)	Additional gross margin per hectare due to				
		Mineral fertiliser		Mechanisation	Mechanisation and mineral fertiliser	
		F_1	F_2	(F_0)	F_1	F_2
20	> 63,400	> 28,000	> 43,700	> 4,680	> 43,020	> 66,320
20	44,480 - 63,400	18,500 - 28,000	27,250 - 43,700	500 - 4,680	27,250 - 43,020	42,050 - 66,320
20	33,400 - 44,480	13,000 - 18,500	17,680 - 27,250	-1,920 - 500	18,120 - 27,250	27,920 - 42,050
20	20,400 - 33,400	6,500 - 13,000	6,370 - 17,680	-4,780 - -1,920	7,330 - 18,120	11,280 - 27,920
20	< 20,400	< 13,000	< 6,370	< -4,780	< 7,330	< 11,280

Source: LANG/BARTSCH 1977, p. 250.

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Table VII/2: Return to labour under various production methods of yam cultivation (FCFA/ME-day)

Frequency (%)	Rainfall (mm)	Hand cultivation			Animal power			Mechanisation		
		F_o	F_1	F_2	F_o	F_1	F_2	F_o	F_1	F_2
20	> 445	> 291	> 294	> 327	> 261	> 334	> 372	> 355	> 461	> 529
20	365 - 445	167 - 291	212 - 294	231 - 327	181 - 261	235 - 334	258 - 372	245 - 355	335 - 461	381 - 529
20	305 - 365	128 - 167	161 - 212	170 - 231	133 - 181	173 - 235	183 - 258	178 - 245	251 - 335	283 - 381
20	240 - 305	80 - 128	96 - 161	93 - 170	71 - 133	92 - 173	88 - 183	91 - 178	141 - 251	155 - 283
20	< 240	< 90	< 96	< 93	< 71	< 92	< 88	< 91	< 141	< 155

Source: LANG/BARTSCH 1977, p. 250.

$$Y_M = 16.73\ RM^{\underset{***}{0.324}} \cdot TM^{\underset{***}{2.186}} \cdot \underset{***}{3.66}^{D_1} \cdot \underset{***}{5.81}^{D_2}$$

Y_M = Maize yield in kg/ha
RM = Rainfall, 10th - 31st May in mm
TM = Average minimum temperature in May over 18°C
D_1 = (0,1)-variable for fertiliser level F_1
D_2 = (0,1)-variable for fertiliser level F_2

The Cobb-Douglas function has the best fit, where the multiple correlation coefficient is $r^2 = 0.86$. None of the functions revails a significant yield effect due to the use of animal power or tractors.

As can be seen from Table VII/3, the profitability of fertiliser application depends to a high degree on climatic conditions and shows great fluctuations. Fertiliser level F_2 under unfavourable climatic conditions is conducive to higher losses than in the case of medium fertiliser doses (the difference is in the order of 8,000-10,000 FCFA/ha), but the additional profits from high fertiliser quantities under favourable conditions are much greater and come to between 35,000 and 45,000 FCFA/ha. A confident statement about the advantage of the individual production methods cannot be made, since it is not possible to establish frequency distributions of temperature values because of the inadequate data base. The manual cropping method is superior to mechanisation at the relatively low maize price of 18 FCFA/ha (see Table VII/4). Semi-mechanisation of maize cultivation in particular involves a high degree of risk for smallholders, since in combination with fertiliser application, losses of 30,000-60,000 FCFA/ha can occur in years of unfavourable climatic conditions.

Table VII/3: The profitability of mineral fertiliser application in traditional maize cultivation (FCFA/ha)

Frequency (%)	Gross margin per hectare in traditional maize cultivation without mineral fertiliser with an average minimum temperature in May of		Additional gross margins due to mineral fertiliser with an average minimum temperature in May of			
			20°C		22°C	
	20°C	22°C	F_1	F_2	F_1	F_2
20	> 3,670	> 27,190	> -2,360	> -8,100	> 60,290	> 105,190
20	2,930 - 3,670	23,990 - 27,190	-4,230 - -2,360	-11,480 - - 8,100	51,790 - 60,290	89,800 - 105,190
20	2,270 - 2,930	20,750 - 23,990	-5,980 - -4,230	-14,640 - -11,480	43,170 - 51,790	74,200 - 89,800
20	1,380 - 2,270	16,910 - 20,750	-8,360 - -5,980	-18,950 - -14,640	32,970 - 43,170	55,780 - 74,220
20	< 1,380	< 16,910	< -8,360	< -18,950	< 32,970	< 55,780

Source: LANG/BARTSCH 1977, p. 252.

Table VII/4: Return to labour under various production methods of maize cultivation (FCFA/ME-day)

Frequency (%)	Rainfall (mm)	Hand cultivation			Animal power			Mechanisation		
		F_o	F_1	F_2	F_o	F_1	F_2	F_o	F_1	F_2
20	> 130	> 136	> 229	> 251	> 74	> 228	> 256	> -96	> 162	> 210
20	90 - 130	122 - 136	199 - 229	215 - 251	47 - 74	188 - 228	211 - 256	-139 - - 96	114 - 162	159 - 210
20	60 - 90	106 - 122	166 - 199	174 - 215	17 - 47	141 - 188	158 - 211	-183 - -139	57 - 114	97 - 159
20	35 - 60	86 - 106	120 - 166	166 - 174	-23 - 17	75 - 141	80 - 158	-239 - -183	-24 - 57	7 - 97
20	< 35	< 86	< 120	< 116	< -23	< 75	< 80	< -239	< -24	< 7

Source: LANG/BARTSCH 1977, p. 252.

4.3 Upland rice

Neither mechanisation nor mineral fertiliser application show a significant effect on the yield in the case of upland rice cultivation. If climatic factors are included in the analysis as independent variables, it becomes clear that a medium quantity of fertiliser raises the yield of rice by about 165 %. A doubling of the fertiliser dose produces a further yield increase of only 7 %, as can be seen in the following function:

$$Y_R = 0.131\ RJA^{\underset{***}{0.447}} \cdot SO^{\underset{*}{1.354}} \cdot \underset{***}{2.65}^{D_1} \cdot \underset{***}{2.72}^{D_2}$$

Y_R = Rice yield in kg paddy/ha
RJA = Rainfall 20.7.-19.8. in mm
SO = Duration of sunshine 1.-20.10. in h
D_1 = (0,1)-variable fertiliser level F_1
D_2 = (0,1)-variable fertiliser level F_2

This function is statistically reliable and explains about 85 % of the variation in yields. The Cobb-Douglas function has in this case too the best fit of all the tested functions.

A medium fertiliser level proves to be profitable irrespective of the degree of mechanisation, and is conducive to an increase in gross margins even in climatically unfavourable years. Higher amounts of mineral fertiliser, on the other hand, prove to be no more profitable.

Mechanisation is superior to the hand cultivation method from the point of view of labour productivity. The use of animal power is slightly more profitable than semi-mechanisation, since the gross margin per ME-day with semi-mechanisation under unfavourable climatic conditions drops relatively more sharply than in the case of ox-team cultivation, although under favourable conditions the gross margin does not increase to the same extent (see Table VII/5).

Table VII/5: Return to labour under various production methods of upland rice cultivation (FCFA/ME-day)

Frequency (%)[a]	Rainfall (mm)	Hand cultivation			Animal power			Mechanisation		
		F_o	F_1	F_2	F_o	F_1	F_2	F_o	F_1	F_2
20	> 210	> 410	> 732	> 628	> 562	> 960	> 808	> 504	> 978	> 807
20	145 - 210	349 - 410	632 - 732	519 - 628	466 - 562	832 - 960	666 - 808	383 - 504	835 - 978	646 - 807
20	100 - 145	294 - 329	531 - 632	414 - 519	388 - 466	699 - 832	524 - 666	263 - 383	682 - 835	481 - 646
20	50 - 100	206 - 294	365 - 531	234 - 414	223 - 388	595 - 699	261 - 524	68 - 263	402 - 682	166 - 481
20	< 50	< 206	< 365	< 234	< 223	< 595	< 261	< 68	< 402	< 166

a) The data base was insufficient to establish frequency distributions for the duration of sunshine. An average duration of sunshine of 105 hours from 1.10.-19.10. is therefore assumed.

Source: LANG/BARTSCH 1977, p. 251.

4.4 Cotton

For cotton, as in the case of the other crops, only the correlation between yield and fertiliser level F_2 ($r = 0.632^{***}$) is statistically significant, although a medium fertiliser dose (F_1) also raises cotton yields significantly, as the following function demonstrates:

$$Y_C = 4.148 \cdot RO^{0.817}_{***} \cdot 3.32^{D_1}_{***} \cdot 5.86^{D_2}_{***}$$

Y_C = Cotton yield in kg/ha
RO = Rainfall, October in mm
D_1 = (0,1)-variable fertiliser level F_1
D_2 = (0,1)-variable fertiliser level F_2

Animal power and mechanisation methods show no significant effect on cotton yields. Although a linear function with the same variable with $r^2 = 0.83$ shows a clearly higher coefficient of determination, the Cobb-Douglas function ($r^2 = 0.68$) is retained for the economic evaluation, as a linear relation would mean that the increase in yield through mineral fertiliser application is constant, i.e. independent of the water supply, a fact that cannot be expected.

A high fertiliser level proves to be the most profitable alternative in all cases, irrespective of the degree of mechanisation. Losses due to mineral fertiliser use can be expected in less than 10 % of the years at both fertiliser levels.

As can be seen from Table VII/6, there are only slight differences between the production methods with regard to returns to labour. Without fertiliser application, hand cultivation is found to be the most profitable method. With high quantities of mineral fertiliser, animal traction cultivation is slightly superior to the other methods.

Table VII/6: Return to labour under various production methods of cotton cultivation (FCFA/ME-day)

Frequency (%)	Rainfall (mm)	Hand cultivation			Animal power			Mechanisation		
		F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
20	> 240	> 146	> 301	> 431	> 120	> 344	> 505	> 118	> 328	> 427
20	180 - 240	117 - 146	232 - 301	336 - 431	73 - 120	254 - 344	390 - 505	76 - 118	238 - -28	369 - 427
20	145 - 180	97 - 117	182 - 232	266 - 336	48 - 73	183 - 254	297 - 390	46 - 76	172 - 238	281 - 369
20	110 - 145	78 - 97	131 - 182	188 - 266	18 - 48	107 - 183	191 - 297	19 - 46	101 - 172	180 - 281
20	< 95	< 68	< 102	< 144	< 0	< 64	< 128	< 3	< 61	< 121

Source: LANG/BARTSCH 1977, p. 253.

5. Summary and Conclusions

With regard to the problem of yield uncertainty, one of the crucial economic targets for traditional smallscale farmers is insuring that subsistence needs are covered. With the introduction of innovations like mineral fertilisers or mechanisation, a further target is to adopt economically feasible production methods, because innovations create expenditure that is usually repaid by the sale of surpluses.

If both targets are considered, namely ensuring subsistence and profitability of crop production, the most advantageous crops for smallholders under the given climatic conditions, and irrespective of the degree of mechanisation in the holdings, are yam, because of its relatively stable yields, and rice, because of its relatively stable gross margins due to the favourable price relations.

Similarly cotton is an interesting cash crop. It is certainly less profitable than yam or rice, but it can help to spread the labour input on account of its long sowing period, from the end of June to the middle of August, and it can contribute to the diversification of production, and therefore to a reduction of the economic risk. Maize, which preceeds cotton in the same year, is subject to very pronounced variations of yield and gross margins, and with the present low maize prices it does not appear to be a suitable crop for small farmers, especially under mechanisation, because of the losses that are frequently to be expected.

However, one cannot draw on the experimental results of agricultural research stations without certain reservations when evaluating innovations at the farm level. As a rule, yields in experiments are higher than the average for smallscale holdings in a region (DAVIDSON et al. 1967),since in research stations:

- crop husbandry (weeding, insect and pest control) is carried out much more intensively;
- cultural operations are usually done at the optimal time;
- better seeds and sometimes also more productive varieties are used.

The conclusions on the profitability of technical innovations at the farm level on the basis of research results have to be modified to cater for the effect of these factors on crop yields and for the differences between research and field conditions. A precise knowledge of the farmers' production conditions and the problems arising from the introduction of these innovations is absolutely essential. This is confirmed by the experience gained in the early phases of development projects with semi-mechanised farming in the central region of Ivory Coast (LANG 1976, Le BUANEC 1975b).

Thus the method described above for the evaluation of the profitability of innovations under conditions of yield uncertainty due to climate on the basis of research results can only give a rough idea of the feasibility of improved production methods and serve as a framework for the planning of development projects.

APPENDIX VIII: Costs of Agricultural Machinery and Implements in Ivory Coast (1974/75)

Table VIII/1: Fixed and variable costs of tractors and combine harvesters in Ivory Coast (1974/75)

	Tractors (KW)			Combine harvesters Working width (m)		Single-axle tractor
	30 - 35	45 - 50	55 - 60	3.20-3.50	4.00-4.30	8-10 KW
Purchase price (FCFA)	2,050,000	2,450,000	2,800,000	7,850,000	12,900,000	740,000
Spare parts (FCFA)	160,000	200,000	220,000	390,000	650,000	60,000
Capital investment (FCFA)	2,210,000	2,650,000	3,020,000	8,240,000	13,550,000	800,000
Life time (years)	5	5	5	6	6	4
Fixed costs per year (FCFA)	575,000	675,000	765,000	1,795,000	2,925,000	230,000
- depreciation	410,000	490,000	560,000	1,300,000	2,150,000	185,000
- shade	30,000	30,000	30,000	50,000	60,000	5,000
- insurance	25,000	25,000	25,000	35,000	35,000	-
- interest (5 %)	110,000	130,000	150,000	410,000	680,000	40,000
Variable costs per hour (FCFA)						
- fuel	351	481	585	910	1,040	130
- oil and grease	105	144	176	228	260	33
- repairs and maintenance	273	327	373	1,636	2,680	197
- driver's wage	216	216	216	310	310	-

Source: Compiled by the author.

Table VIII/2: Fixed and variable costs of agricultural implements in Ivory Coast 1974/75

	Disc plough		Disc harrows		Slasher	Drill	Maize seed-drill	Sprayer		Fertiliser-broadcaster	Trailer	
	3 discs	4 discs	18-20 discs	28-32 discs	(1,50m)	(17 rows)	(4 rows)	9 m	16 m		5,5 t	7,0 t
Purchase price (FCFA)	360,000	420,000	350,000	470,000	380,000	530,000	710,000	380,000	960,000	220,000	1,250,000	1,500,000
Spareparts (FCFA)	180,000	210,000	175,000	235,000	40,000	55,000	70,000	30,000	35,000	20,000	125,000	150,000
Total investment (FCFA)	540,000	630,000	525,000	705,000	420,000	585,000	780,000	410,000	995,000	240,000	1,375,000	1,650,000
Lifetime (years)	5	5	5	5	8	8	8	10	10	10	10	10
Fixed costs per year (FCFA)	138,600	161,700	134,800	181,000	77,300	107,700	143,600	66,800	167,900	38,200	218,800	262,500
- Depreciation	108,000	126,000	105,000	141,000	52,500	73,100	97,500	42,000	105,500	24,000	137,500	165,000
- Shade[a]	3,600	4,200	3,500	4,700	3,800	5,300	7,100	3,800	9,600	2,200	12,500	15,000
- Interest costs (5% p.a.)	27,000	31,500	26,300	35,300	21,000	29,300	39,000	21,000	52,800	12,000	68,800	82,500
Variable costs per year[b] (Repairs and maintenance) (FCFA)	108,000	126,000	105,000	141,000	47,500	53,000	71,000	19,000	48,000	11,000	62,500	75,000
Total costs per year (FCFA)	246,600	287,700	239,800	322,000	124,800	160,700	214,600	85,800	215,900	49,200	281,300	337,500

a) 1% of purchase price
b) Average capacity

Source: Compiled by the author.

APPENDIX IX: Basic Data for Estimation of Accounting Prices in Ivory Coaston the Basis of World Market Prices

Table IX/1: Conversion factors for the transformation of domestic market prices to accounting prices based on world market prices

	Factor
Investment goods	
Agricultural machinery and implements	0.92
Buildings	0.85
Land clearing, infrastructure and irrigation works	0.83
Material inputs	
Mineral fertiliser	0.79
Pesticides and herbicides	0.83
Tools and small implements	0.83
Draught-oxen	1.00
Costs of maintenance and repairs	
Infrastructure, irrigation works	0.83
Buildings	0.81
Agricultural machinery and implements	0.75
Ox-team	0.83
Variable machinery costs	0.74
Costs of agricultural extension	0.83

Source: Estimates of the author.

Table IX/2: Estimate of paddy world market prices in Ivory Coast

	1970-1980 FCFA	1974/75 FCFA
Milling out-turn per tonne of paddy[a)]		
- 450 kg rice grade I	41,630	50,630
- 150 kg rice grade II	8,630	12,380
- 50 kg broken rice	2,070	3,130
- 80 kg by-products[b)]	400	600
Value per tonne of paddy	52,730	66,740
Costs of transport and processing per tonne of paddy[c)]		
- Transport and storage	4,150	4,250
- Processing (rice mill)	7,060	4,980
Total costs per tonne of paddy	11,210	9,230
Accounting price per tonne of paddy (ex-mill)	41,520	57,510
Transport costs of domestically produced rice[c)]	5,400	4,570
./. Transport costs of imported rice[c)]	7,890	7,060
Accounting price per tonne of paddy	44,010	60,000

a) Average milling out-turn 60 %

b) Rice flour, bran etc.

c) Conversion factor from domestic to world market prices = 0.83

Source: Compiled by the author according to SODERIZ, Annual reports 1974 and 1975; SODERIZ (1974).

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