COMPETING FOR LIMITED RESOURCES:

THE CASE OF THE FIFTH REGION OF MALI

REPORT 4

DEVELOPMENT SCENARIOS

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PREFACE

This report is written in the framework of the 'Mopti project', officially designated 'Development of a land use plan for the 5th region of Mali (Region Mopti + Cercle de Niafunké)', a joint activity of the Centre for Agrobiological Research (CABO, Wageningen, the Netherlands) and a multidisciplinary team based in Mali (ESPR, Equipe chargée de l'étude sur les Systèmes de Production Rurales en 5ème Région). The project is jointly financed by the Directorate-General for International Cooperation (DGIS) of the Dutch Ministry of Foreign Affairs and the Government of Mali (in the framework of the second 5-year plan for the 5th region, financed by the World Bank).

The aim of the project is to assess the possibilities for regional agricultural development, based on a quantitative description of agricultural production activities (arable crops, livestock and fisheries), both those currently practiced and potential ones. The project should result in suggestions for technically feasible development options for sustainable agricultural land use of Mali's Fifth Region. Within the present project, use is made of a linear programming model that combines information on possible activities in the region with information on the regional resources.

The general title of the report is 'Competing for limited resources: The case of the Fifth region of Mali'. It is subdivided in four interdependent reports.

Report 1, titled 'Ressources naturelles et population' (Cissé & Gosseye, 1990) presents a general survey of the environmental and human conditions of the Region.

Report 2 with the title 'Plant, livestock and fish production' (van Duivenbooden, Gosseye & van Keulen, 1991; van Duivenbooden & Gosseye, 1990) describes quantitatively the various agricultural activities required for the optimization model.

Report 3, titled 'Formal description of the optimization model MALI5' (Veeneklaas, 1990), describes the Linear Programming model used in the study.

Finally, Report 4 is a synthesis of the three preceding ones and presents the results of the optimizations and the conclusions. It is titled 'Development scenarios' (Veeneklaas *et al.*, 1991; Veeneklaas *et al.*, 1990).

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1. INTRODUCTION

1.1 General framework of the study

Agriculture is an essential human activity as the basis for food production. In principle, it only requires few and relatively simple resources: a piece of land, some seeds of a useful plant species, or some head of a useful animal species, the sun as a source of energy, some water and a limited amount of human effort. This has sufficed for centuries to provide mankind with food, clothing, shelter and other basic necessities. However, in this century, the rapidly growing population and the accompanying concentration of large numbers of people in urban centres, has put an increasing demand on the rural population to produce food over and above their own subsistence needs. For a long time this increasing demand could be met by extending the area under cultivation, with, however, the final consequence, that increasingly marginal areas and fragile lands were used with the associated risks of degradation and permanent or semi-permanent damage to their production capacity. Expansion of the area alone, however, is at the moment insufficient to meet the ever-increasing demand for food. Hence, in many parts of the world development programs were initiated aiming at higher food production through increasing yields per unit area. Not all of these programs have been successful, either because the external inputs required to increase production were not available or were not economically feasible, or because the suggested measures for improvement were not socially acceptable, thus seriously hampering their implementation. Moreover, the one-sided emphasis on food production tended to ignore the other functions of the rural area.

Partly as a reaction to these failures, attention shifted to the concept of integrated rural development, in which attempts were made to take into account the different functions of the rural environment and give due attention to the different aspirations of various interest groups with a stake in rural development. In this approach, soon the problem was encountered of conflicting interests between various goals such as increasing food production, securing food supply for the urban population at acceptable prices, guaranteeing a reasonable farmer's income, preserving the rural environment, contributing to the balance of payment by producing for the export market, etc. A major problem in analysing such situations was the lack of information on the relative importance attached to the various goals and aspirations and the degree to which they were mutually exclusive. Often ad-hoc solutions were then proposed, which, if they did not appear to produce the desired results, were difficult to evaluate (Breman, 1990).

What did emerge in the analyses, however, was that one of the factors underlying the failure of development programs was the fact that the various goals pursued were all calling on the same limited resources, so that competition for these resources ensued and that the outcome was dependent on both the agro-technical possibilities and the socio-economic environment, in a way that often appeared to be unpredictable intuitively. Recognizing this, de Wit *et al.* (1988) proposed a method to investigate the development possibilities for a region, based on a quantitative analysis of the natural resource base, and taking into account various constraints and demands. The method appeared suitable for the exploration of technically feasible development pathways, under a wide range of technical and socio-economic scenario's and thus presented itself as a promising tool for aid in the formulation of regional development programs.

1.2 The Region

The region that is the subject of this study, is the Fifth Region of Mali (Mopti) and the Cercle de Niafunké (Figure 1.1) and is referred to as the Region. It covers about 89 000 km^2 and is dominated by the central inland delta of the river Niger, an area of 16 000 km^2 which is, under normal rainfall conditions, flooded annually. The presence of these large quantities of water in the heart of the Sahelian region, offers opportunities for development of arable farming, animal husbandry and fisheries, far exceeding those in the surrounding area under rainfed conditions. Over the centuries, therefore, the Region has been the centre of agricultural activities, in which very efficient production systems developed (Gallais, 1967). In the last few decades the Region has come under increasing pressure, through the combined effect of increasing population density and intermittent periods of drought, that have seriously disrupted the existing production systems (Gallais, 1984).

Figure 1.1. Mali and in black the Region (Fifth Region and Cercle de Niafunké).

The intrinsically high agricultural potentials of the Region have attracted the attention of development agencies, like the World Bank, and donor organisations. The development programs that have been executed in the region, however, were often partial, and the intensifying competition for the limited resources between the various agricultural activities, i.e. arable farming, animal husbandry and fisheries were often insufficiently recognized. Therefore, a need exists for the formulation of an overall land use plan, that is based on the production capacity of the natural resources and the development goals of the various actors involved in the Region.

1.3 The project

In the second 5-year development plan for the Fifth Region, financed by the World Bank, it was recognized that such a plan should be based on a thorough analysis of the existing production systems and of potentials of the Region. It was decided, therefore, to include in that plan a special project on 'Etude des systèmes de productions rurales (Study of rural production systems: ESPR)'. The aim of that project was (cf. Terms of Reference) to collect and analyse information on the various production systems of the Region, in particular:

- increasing knowledge about the various ways of exploitation of the ecosystem;
- identifying and evaluating the major constraints and the interactions between the various activities as related to the management of the ecosystem as a whole;
- analysing the adaptative responses of the various activities to the uncertain weather pattern;
- formulating optimum strategies for the various production activities.

A project team of five local experts was appointed to carry out the study, with technical assistance provided by CABO. The latter Institute, recognizing the opportunity to further develop and test the approach proposed by de Wit *et al.* (1988), carried out the project with co-financing from the Dutch Directorate General for International Cooperation (DGIS).

Two experts were appointed by CABO, one based in the Region to work in close cooperation with the local team, mainly for the collection of basic data on natural resources and quantitative data on production techniques currently practiced in the Region. The second expert, based at CABO, was primarily responsible for synthesis of the information in a form applicable within the proposed method of analysis. In addition, CABO was responsible for the generation of information on alternative and potential production techniques, not at present practiced in the Region, but technically feasible in view of the prevailing agro-ecological conditions.

1.4 The method

The approach used in the analysis of development pathways, is based on the interactive multiple goal programming method (Spronk & Veeneklaas, 1983;

Nijkamp & Spronk, 1980). This method comprises the use of an input-output model, a set of goal variables, and an interactive multiple criteria decision procedure.

In the input-output model constructed for the present study, technical coefficients are defined that describe the range of production techniques assumed to be available for the region. These include production techniques currently practiced, production techniques practiced at the moment in comparable regions with potential applicability in the region (alternative production techniques) and production techniques that would be technically feasible under the prevailing agro-ecological conditions, if higher levels of external inputs are applied (potential production techniques). Each production technique is defined by its relevant output (production) and input (means of production) coefficients that are derived from a well-defined way of producing a certain product. The agricultural activities defined for the Region include arable farming, animal husbandry and fisheries. The technical coefficients for current production techniques are derived from surveys in the Region, as far as available. For alternative and potential production techniques, the technical coefficients are derived from the results of simulation models (Erenstein, 1990; van Duivenbooden, 1990).

The goal variables incorporated in the model should in principle cover all the major interests of the Region, so as to ensure that technical options for its development are kept as open as possible. In the present project attempts were made to derive the relevant goal variables from consultations with the major parties with a stake in the development of the region, i.e. local and regional authorities, development agencies, and national authorities. The aspirations expressed by the various interest groups appeared, however, difficult to translate unequivocally in terms relevant to the model. A subjective choice may therefore well have been made.

The interactive multiple criteria decision method used, is explained in detail by de Wit *et al.* (1988) and is therefore not further treated here. It should be mentioned, however, that mainly due to time limitations, insufficient use has been made of the interactive option of the method, that is no feedback from the interest groups in the regional development process has been incorporated in the results presented here. Therefore, these results should be considered preliminary, and a further analysis is anticipated after consultations with the interested parties.

In this fourth report of the series on this research project, emphasis is on the results of the analysis with the optimization model. For proper judgment of these results, both the input data and the structure of the optimization model are of importance. The input data are summarized in Chapters 2 (Resources) and 3 (Production activities). These chapters are based on data presented in Reports 1 and 2 of this series. In Chapter 4 (Constraints and interrelations) and Chapter 5 (Goals), the structure of the model is presented. A formal description of the model is given in Report 3. In the main chapter of this report, Chapter 6, two base scenarios for agricultural development of the Region are presented, followed by a number of variants (alternatives). In Chapter 6 a number of preliminary conclusions are drawn, both at the regional level and at the level of individual agro-ecological zones, and the report is completed with some additional concluding remarks in Chapter 7.

2. RESOURCES

2.1 Soils and agro-ecological zones

The 5th Region and the Cercle de Niafunké cover an area totalling 88 696 km^2 according to our calculations. It comprises 116 map units (Figure 2.1) which are mosaics of 46 taxonomic soil/vegetation units (Report 1, Chapter 3).

According to the particle-size distribution of the soils of 43 taxonomic units we have distinguished 7 soil texture classes which are indicated in Table 2.2. To these textural classes correspond waterholding characteristics, calculated according to two empirical equations. The maximum gravimetric water content in a soil (mass ratio of water to solid phase) at field capacity (Tc at pF 2.5) and at wilting point (or minimum water content accessible to plants, Tp at pF 4.2) are calculated by:

$$Tc = (36.97 - 0.35 * X) * 10 \qquad (1)$$

$$Tp = (0.74 + 0.39 * Y) * 10 \qquad (2)$$

where,
Tc = Water content at field capacity [g H_20 kg^{-1} of soil]
X = Fraction sand by weight [%]
Tp = Water content at wilting point [g H_20 kg^{-1} of soil]
Y = Fraction clay by weight [%].

Plant available water is given by:

$$Eu = (Tc-Tp) * Ds * De \qquad (3)$$

where,
Eu = Water available to plants [cm^3 dm^{-3}]
Ds = Average specific density of soils [1.4 kg dm^{-3}]
De = Specific density of water [1 g cm^{-3}]

Each textural class is further subdivided using secondary criteria that have an effect on the production potential of these soil types. Since there are also two types of special substrate, 18 substrates are distinguished as briefly described in Table 2.3, which also contains equivalent names of the taxonomic units of PIRT (1983) which is the basic reference used (Report 1, Chapter 3).

The Region is heterogeneous with regard to the distribution of the 18 substrates. These are not scattered at random however, but are located quite conveniently in subregions of the Region which can therefore be subdivided according to criteria of homogeneity with respect to the substrates and it is thus possible to distinguish 11 subregions, referred to as agro-ecological zones (AEZ). These are presented in Figure 2.1.

Figure 2.1. The Region and its 11 agro-ecological zones. The thin lines are the limits of the 116 PIRT basic map units which are identified by the small numbers. The underlined numbers are the 72 localities of geographical reference given in Table 2.1.

Table 2.1. Listing of the 72 geographical reference localities in the Region. The numbering corresponds with the underlined numbers in Figures 2.1 and 2.2.

NO	NAME	NO	NAME
1.	Ambiri	37.	Léré
2.	Bandiagara	38.	Madougou
3.	Banikané	39.	Mondoro
4.	Bankass	40.	Mopti-ADRAO
5.	Baye	41.	Mopti-Aérodrome
6.	Boni	42.	Mopti-OMM
7.	Boré	43.	Mougna
8.	Diafarabé	44.	N'Gorkou
9.	Dialassagou	45.	N'Gouma
10.	Dialloubé	46.	Niafunké
11.	Diankabou	47.	Ningari
12.	Dinangourou	48.	Ouenkoro
13.	Diondiori	49.	Ouo
14.	Diongani	50.	Ouro-Mody
15.	Dioura	51.	Pel
16.	Djenné	52.	Sah
17.	Dogo	53.	Sangha
18.	Douentza	54.	Saraféré
19.	Dourou	55.	Ségué
20.	Fatoma	56.	Sendégué
21.	Gathi-Loumo	57.	Sofara
22.	Goundaka	58.	Sokoura
23.	Guidio-Saré	59.	Sossobé
24.	Hombori	60.	Soufouroulaye
25.	Kami	61.	Soumpi
26.	Kani Bonzon	62.	Soyé
27.	Kanigogouna	63.	Taga
28.	Kara	64.	Ténènkou
29.	Kendié	65.	Toguéré-Goumbé
30.	Konio	66.	Toroli
31.	Konna	67.	Youwarou
32.	Koporokendié-Nah	68.	Macina
33.	Korientzé	69.	Nampala
34.	Koro	70.	San
35.	Kouakourou	71.	Tombouctou
36.	Koumaïra	72.	Tonka

Table 2.4 indicates the size of these agro-ecological zones and the extent of the 18 constituent substrates. Table 2.5 shows the proportion of each substrate in each agro-ecological zone. It also shows the importance of each of the 18 substrates in relation to the whole of the Region and the size of each of the 11 agro-ecological zones within the whole Region.

The reader is assisted in locating these agro-ecological zones by Figure 2.2 which illustrates the boundaries of the 9 Cercles that include the 62 administrative districts of the Region.

Table 2.2. Pedological characteristics of the 7 main soil types (A to G) identified in the Region; texture on the basis of weight; water content at field capacity (pF 2.5) and at wilting point (pF 4.2) [g H_2O kg^{-1} soil] and content of useful water [cm^3 H_2O dm^{-3} soil].

SOIL TYPE	TEXTURE			WATER CONTENT		USABLE WATER
	Sand	Loam	Clay	pF 2.5	pF 4.2	
A	92.5	2.5	5.0	46	27	27
B	77.5	10.0	12.5	98	56	59
C	60.0	30.0	10.0	160	46	160
D	62.5	10.0	27.5	151	115	50
E	10.0	47.5	42.5	335	173	227
F	32.5	35.0	32.5	256	134	171
G	38.5	44.0	17.5	235	76	223

Table 2.3. Substrate types as used for the study of the Region as classified by CABO and equivalences with the taxonomic units of PIRT.

CABO	CARACTERISTICS	PIRT
A	Sand	D2-4
B1	Sand loam	D5-6
B2	Idem, shallow soil water table	D7
C1	Sandy loam	DA1-5,PS2-3
C2	Gravelly sandy loam	TR1,TR2,TR6
D1	Sandy clay loam	PL4,PL6,TH5
D2	Sandy clay loam, low fertility	PL1-2,PS1
E1a	Silty clay loam	PA3,TH4,TH8,TI5
E1b	Silty clay loam, regularly flooded	TI1
E2a	Silty clay (loam), low fertility	PL7,TH1
E2b	Silty clay (loam), low fertility regularly flooded	TI3
F1	Clay loam	PL9,TH3,TH6-7
F2	Clay loam	TC1-5
F3a	Clay loam, high fertility	TH2
F3b	Clay loam, high fertility regularly flooded	TI2
G	Loam, regularly flooded	TI4,TI7
X	Rocks	X3,X5
Y	Surface water	X6

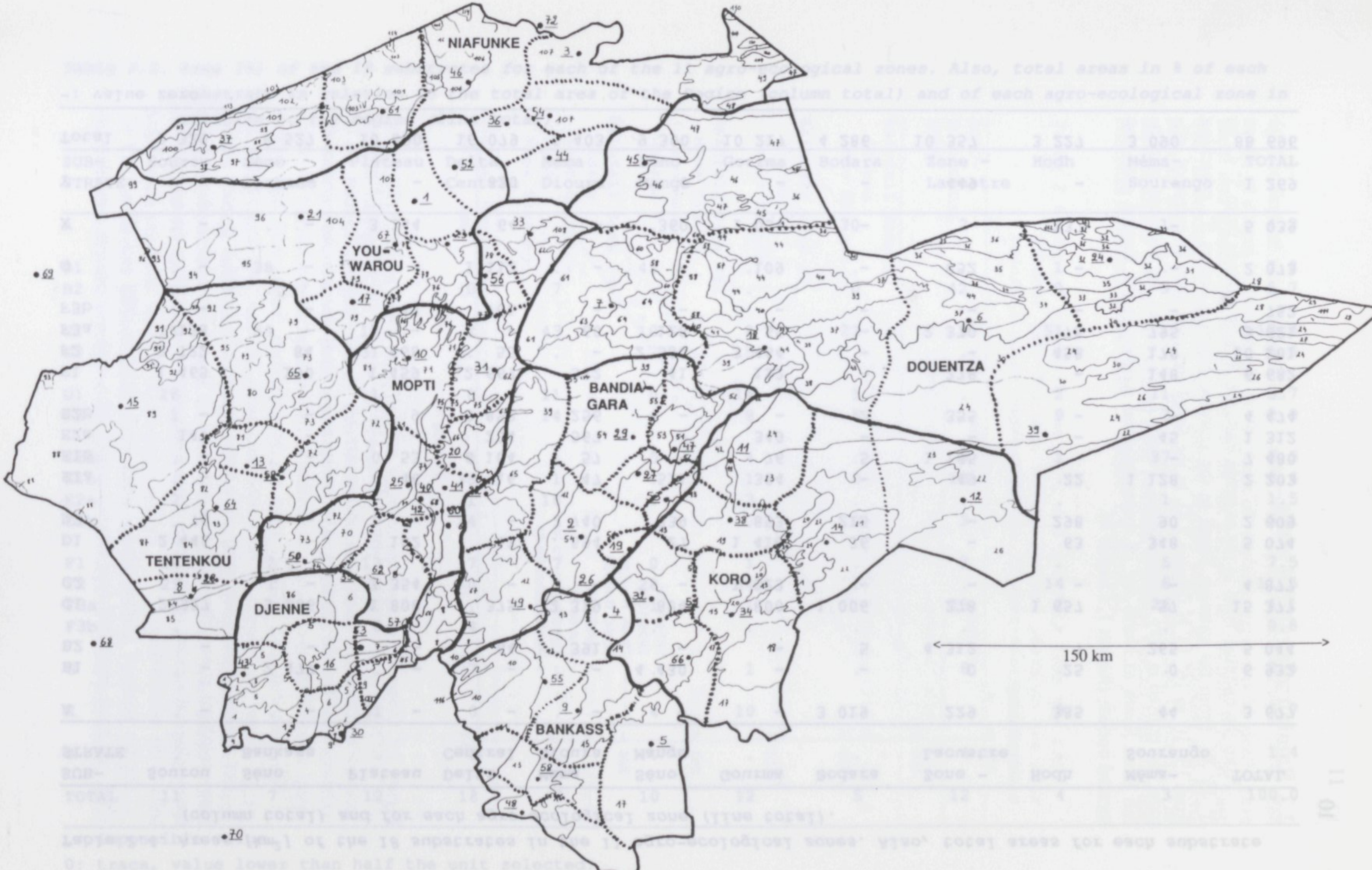

Figure 2.2. The Region (Region of Mopti and Cercle de Niafunké) comprises 9 Cercles containing 62 Districts. The underlined numbers correspond to the 72 localities of geographical reference given in Table 2.1. The limits and positions are indicative only.

Table 2.4. Areas [km^2] of the 18 substrates in the 11 agro-ecological zones. Also, total areas for each substrate (column total) and for each agro-ecological zone (line total).

SUB-STRATE	Sourou	Séno Bankass	Plateau	Delta Central	Méma Dioura	Séno Mango	Gourma	Bodara	Zone - Lacustre	Hodh	Méma-Sourango	TOTAL
A	-	-	-	-	-	-	-	3 019	229	385	44	3 677
B1	-	2 477	-	-	-	4 430	-	-	0	25	0	6 932
B2	-	-	-	64	391	-	-	5	4 312	7	265	5 044
C1	2 327	3 866	1 808	375	2 319	884	800	1 006	278	1 657	57	15 377
C2	-	-	3 354	-	-	-	1 523	-	-	-	-	4 877
D1	2 445	-	102	41	594	27	1 418	36	-	63	348	5 074
D2	76	-	-	-	740	339	853	213	-	298	90	2 609
E1a	-	-	46	16	47	511	384	-	49	22	1 128	2 203
E1b	-	-	53	6 104	57	-	76	5	1 185	-	-	7 480
E2a	147	-	-	204	567	-	349	-	-	-	45	1 312
E2b	-	-	9	3 852	256	-	-	2	355	-	-	4 474
F1	1 465	100	1 459	2 667	372	41	152	-	278	-	148	6 682
F2	2 722	84	668	55	-	2 580	3 464	-	-	458	170	10 201
F3a	138	-	-	-	60	128	55	-	2 370	75	795	3 621
F3b	-	-	47	705	-	-	-	-	-	-	-	752
G	-	-	-	1 112	-	-	109	-	852	-	-	2 073
X	-	-	3 344	64	-	360	1 034	-	-	237	-	5 039
Y	-	-	-	820	-	0	-	-	449	-	-	1 269
Total	9 320	6 527	10 890	16 079	5 403	9 300	10 217	4 286	10 357	3 227	3 090	88 696

-: value zero

Table 2.5. Area [%] of the 18 substrates for each of the 11 agro-ecological zones. Also, total areas in % of each substrate in relation to the total area of the Region (column total) and of each agro-ecological zone in relation to the Region (line total).

SUB-STRATE	Sourou	Séno Bankass	Plateau	Delta Central	Méma Dioura	Séno Mango	Gourma	Bodara	Zone - Lacustre	Hodh	Méma-Sourango	TOTAL
A	.	.	.	.	.	.	.	70	2	12	1	4.2
B1	.	38	.	.	.	48	.	.	.	1	.	7.8
B2	.	.	.	0	7	.	.	0	42	0	9	5.7
C1	25	59	17	2	43	10	8	23	3	51	1	17.3
C2	.	.	31	.	.	.	15	.	.	.	.	5.5
D1	26	.	1	0	11	0	14	1	.	2	11	5.7
D2	1	.	.	.	14	4	8	5	.	9	3	2.9
E1a	.	.	0	0	1	5	4	.	0	1	37	2.5
E1b	.	.	0	38	1	.	1	0	12	.	.	8.4
E2a	2	.	.	1	10	.	3	.	.	.	1	1.5
E2b	.	.	0	24	5	.	.	0	3	.	.	5.1
F1	16	2	13	17	7	0	1	.	3	.	5	7.5
F2	29	1	6	0	.	28	34	.	.	14	6	11.5
F3a	1	.	.	.	1	1	1	.	23	2	26	4.1
F3b	.	.	0	4	.	.	.	.	.	.	.	0.8
G	.	.	.	7	.	.	1	.	8	.	.	2.4
X	.	.	31	0	.	4	10	.	.	8	.	5.7
Y	.	.	.	5	.	.	.	.	4	.	.	1.4
TOTAL	11	7	12	18	6	10	12	5	12	4	3	100.0

.: impossible value.
0: trace, value lower than half the unit selected.

2.2 Rainfall and rainfall zones

From the extreme West to the extreme East, the Region extends from 5° 42' to 0° 45' W. From the extreme South to the extreme North it covers 3°, stretching from 13° 10' to 16° 13' N (Figure 2.1). In the Sahel and over such an extent of latitude, the rainfall is very heterogeneous. Figure 2.3 illustrates the decrease in rainfall from South to North for 18 meteorological stations in the Region plus two located outside (Report 1, Chapter 4).

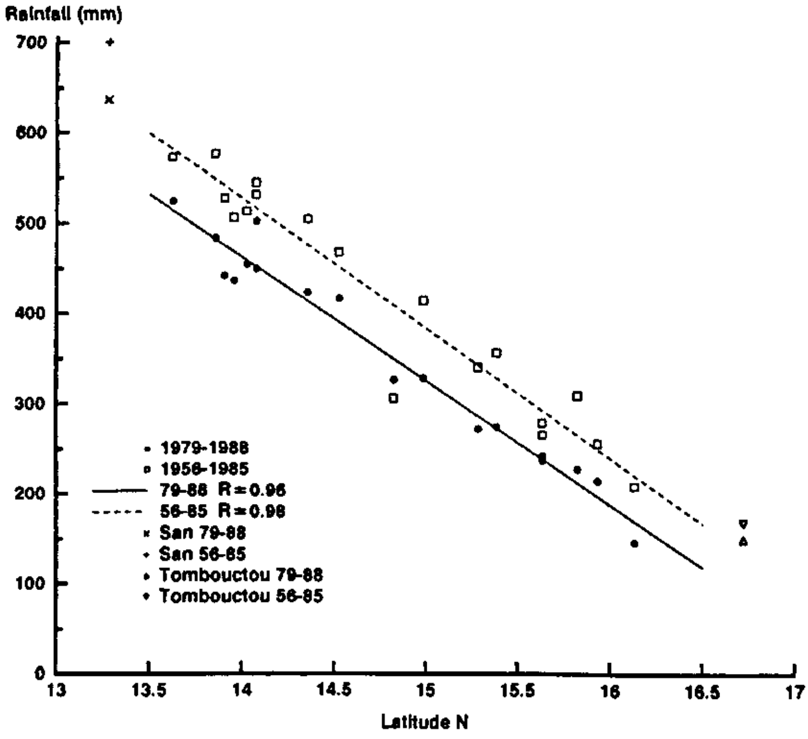

Figure 2.3. Comparison between average rainfall from 1956 to 1985 (30 years) and from 1979 to 1988 (10 years) for the 18 DNM rainfall stations (Direction Nationale de la Météo) in the Region, located on a latitudinal gradient. Also, comparison with two stations outside the Region.

For the purposes of the study, it is necessary to define rainfall in each of the agro-ecological zones identified in Section 2.1. It is also essential to identify the meteorological stations representing these zones, to be able to relate the constituent soils to the rainfall data.

On the basis of annual rainfall totals from 1959 to 1988 and from 1979 to 1988, we have identified four rainfall zones (RZ), each comprising a number of agro-ecological zones (Figure 2.1, Table 2.6). Certain compromises have been made, of course. A breakdown on the basis of rainfall criteria should ideally have taken into account the isohyets which, for the Region, run virtually West to East. The meteorological stations that represent rainfall zone I are Bankass and Koro. Rainfall zone II is represented by Djenné, Mopti-Aérodrome and Douentza. The meteorological stations at Douentza and Hombori represent rainfall zone III while Niafunké represents rainfall zone IV (Report 1, Chapter 4).

Table 2.6. Annual rainfall [mm yr^{-1}] and rainfall from May till October [mm] for dry, normal and wet years in the four rainfall zones regrouping the 11 agro-ecological zones.

AGRO-ECOLOGICAL ZONE	MAY - OCTOBRE			ANNUAL		
	normal	dry	wet	normal	dry	wet
Rainfall Zone I						
Sourou	530.5	362.5	683.0	544.5	368.1	689.0
Séno Bankass						
Rainfall Zone II						
Plateau	457.3	302.4	653.2	460.9	305.6	662.7
Delta Central						
Rainfall Zone III						
Méma Dioura	376.4	236.7	501.7	379.3	237.0	512.1
Séno Mango						
Gourma						
Rainfall Zone IV						
Bodara	255.0	153.1	356.0	256.6	153.1	356.9
Zone Lacustre						
Hodh						
Méma Sourango						

Source: Report 1, Chapter 3.

In the final results of the LP-model, rainfall can be taken into account in a variety of ways. Rainfall is one of the major determinants of primary agricultural production and, starting from there, of secondary production. One alternative would be to take into account rainfall of individual years. Given the extreme intra-annual and inter-annual variability of the rains (Figure 2.4), however, this is difficult in practice. Another alternative would be to present the results as an overall average, but Figure 2.4 clearly shows that such an approach would conceal a distinct variability. In the end an intermediate approach has been adopted. We have opted for an empirical method, since it is not the aim of the project to undertake a stochastic study of the Region's rainfall.

On the basis of annual rainfall totals for the years 1959 to 1988 (30 years) we have decided that the average of the 20% lowest values (6 years) represents what we call a dry year. The average of the 60% intermediate values (18 years) is taken as representing a normal year, and that of the 20% highest values represents a wet year.

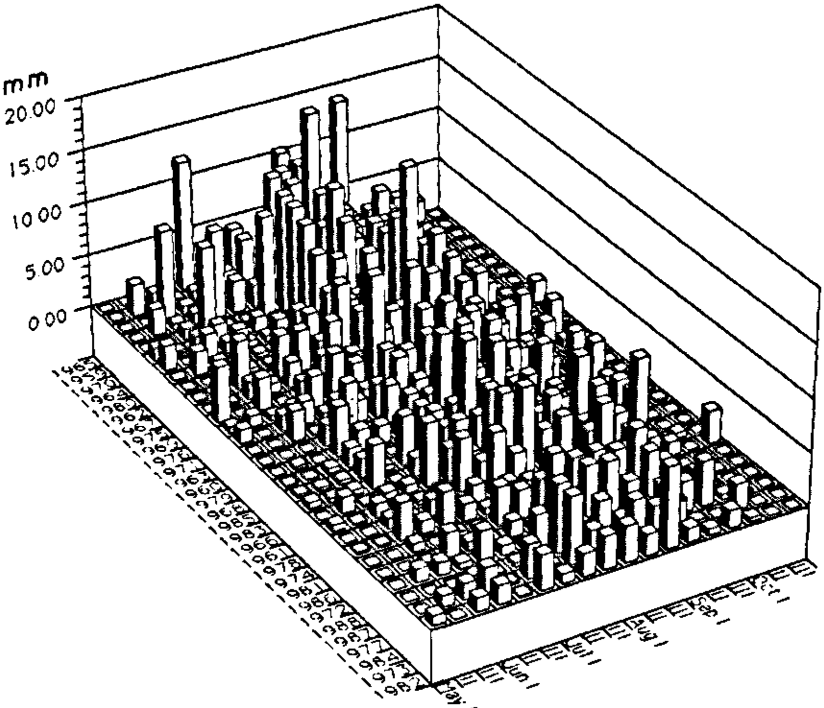

Figure 2.4. Histogram of the decadal rainfall totals from May to October between 1959 and 1988 (30 years) for Mopti-Aérodrome. The years are classified in descending order of annual total.

On the basis of annual data from the 7 representative meteorological stations, we were able to identify, for each rainfall zone, the three types of rainfall year as shown in Table 2.6. In the study the wet years have not been taken into account explicitly because they provide no information on the possible risks incurred by the farmers. The wet years are considered as an added bonus compared to normal years, while the dry years are a constraint (Report 1, Chapter 4). Figure 2.5 illustrates this general approach.

According to our information the Region has at least 81 rain-gauges spread over 67 localities (Figure 2.1 and Table 2.1). Table 2.7 has been prepared on the basis of all the available rainfall averages for the past 30 and the past 10 years. It indicates for 30 or 10 years the annual rainfall averages for each agro-ecological zone. We can also see that the averages for the last 30 years, per rainfall zone, correspond to the normal years based on observations of the seven representative meteorological stations (Table 2.6).

Table 2.7. Average rainfall [mm yr^{-1}] for 30 years (1956-1985 or 1959-1988) as well as for 10 years (1979-1988) for the 11 agro-ecological zones divided into 4 rainfall zones.

AGRO-ECOLOGICAL ZONE	30 YR-AVERAGE	10 YR-AVERAGE
Rainfall Zone I		
Sourou	532	422
Séno Bankass	536	469
Average	541	451
Rainfall Zone II		
Plateau	485	401
Delta Central	469	364
Average	471	381
Rainfall Zone III		
Méma Dioura	392	346
Séno Mango	•	331
Gourma	391	280
Average	391	306
Rainfall Zone IV		
Bodara	337	260
Zone Lacustre	279	237
Hodh	233	137
Méma Sourango	•	•
Average	298	237

•: missing value.

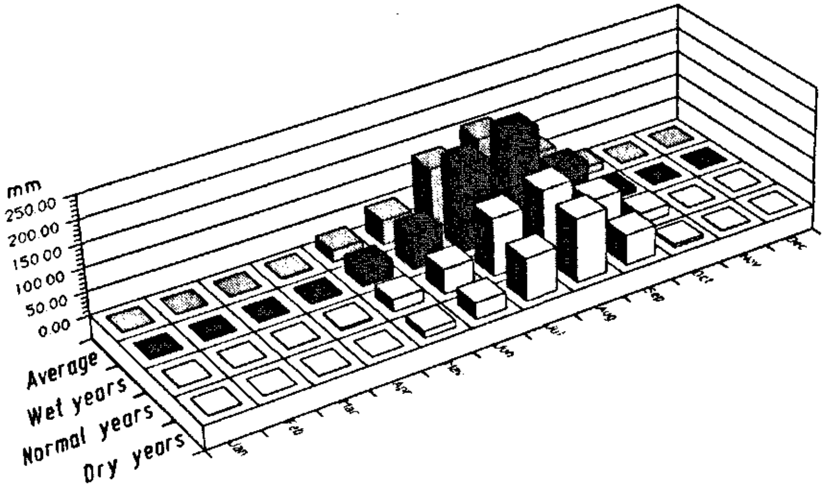

Figure 2.5. Histogram of monthly and annual rainfall totals for Mopti-Aérodrome. The numbers are the averages for 30 years from 1959 to 1988, the averages of the 6 lowest values which represent a dry year, the averages of the 18 intermediate values that represent a normal year and the averages of the 6 highest values which represent a wet year.

2.3 Flood and inundation

The Region is characterized by an inland delta fed by the rivers Niger and Bani. The delta is mainly located in the agro-ecological zones Delta Central and Zone Lacustre (Figure 2.1 & Table 2.8).

The two rivers are subject to alternating high and low water levels, as a result of intermittent influx of water originating from rains upstream. Rainfall in the Region itself makes only a minor contribution to this phenomenon. But, since rainfall in the Region reflects rainfall conditions in West Africa in general, there is a correspondence between maximum flood level of the river and average rainfall in the Region, as shown in Figure 2.6.

The alternating ebb and flow causes cyclical flooding in the delta zone, and hence the potential for agricultural production (fisheries, livestock, arable farming) in the zone is conditioned the depth and duration of submersion as well as the areas flooded. Figures 2.7 & 2.8 show the trends in maximum flood levels at Mopti from 1959 to 1988 (Report 1, Chapter 5).

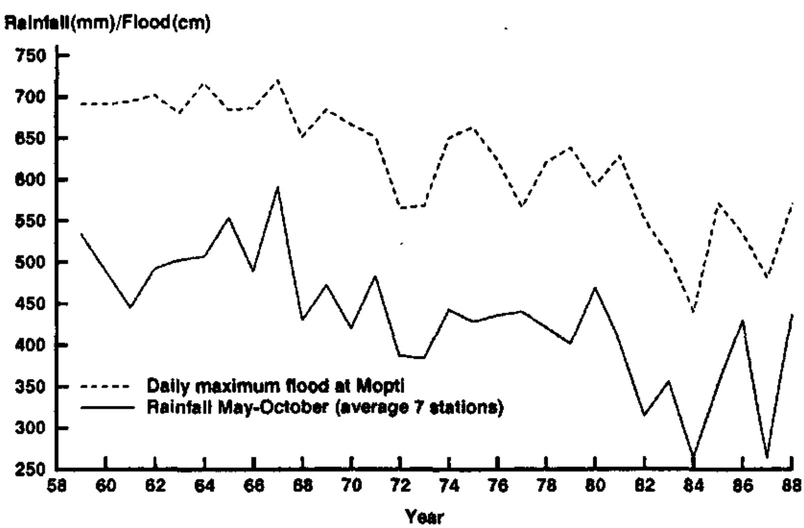

Figure 2.6. Trends in the maximum flood levels at Mopti and the average rainfall from May to October for the 7 reference rainfall stations (Bankass, Djenné, Douentza, Hombori, Koro, Mopti-Aérodrome, Niafunké), between 1959 and 1988.

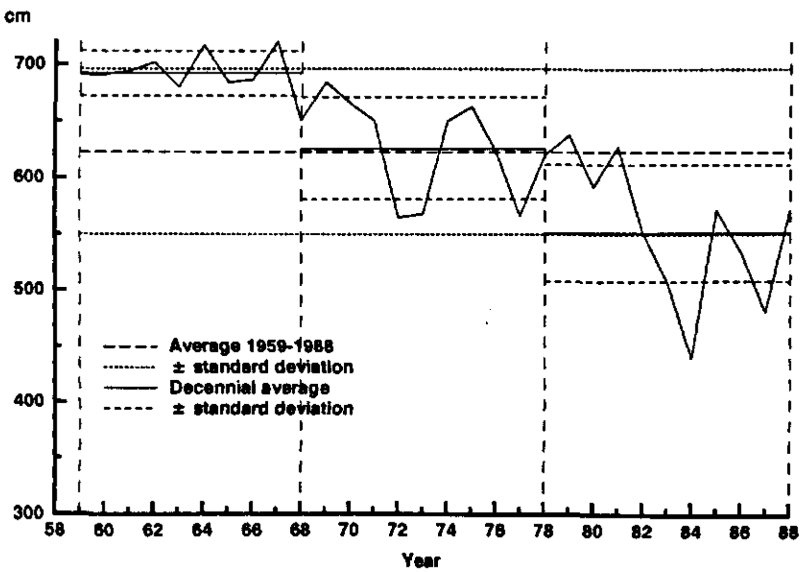

Figure 2.7. Trends in the maximum annual flood levels from 1959 to 1988 for the flood registration station at Mopti.

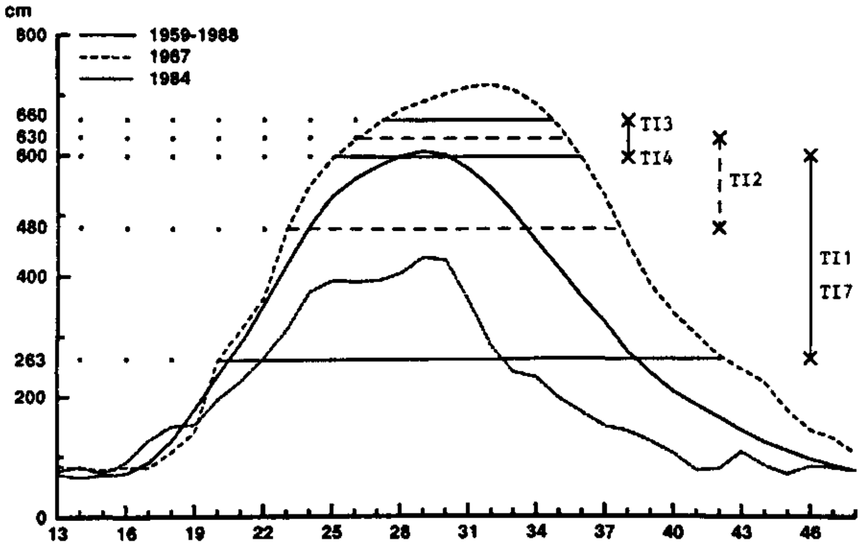

Figure 2.8. Average decadal flood over 30 years, and exceptionally high or low curve, from 1959 to 1988 for the flood registration station at Mopti. The curvy brackets (TI3 & TI4, TI2 and TI1 & TI7) give the flood levels for the various substrate types.

Table 2.8. Maximum surface areas [km²] liable to be flooded in the event of normal flooding (660 cm) and in the event of low flooding (510 cm), according to the taxonomic units of PIRT (T1 and X6) and according to the agro-ecological zones.

AGRO-EC. ZONE \CABO \PIRT	E2b TI3	G TI4	F3b TI2	E1b TI1	G TI7	Y X6	TOTAL
Year of normal flood							
Plateau	9	-	47	53	-	-	109
Delta Central	3 852	333	705	6 104	779	820	12 593
Méma Dioura	256	-	-	57	-	-	313
Gourma	-	-	-	76	109	-	185
Bodara	2	-	-	5	-	-	7
Zone Lacustre	355	-	-	1 185	852	449	2 841
Total	4 474	333	752	7 480	1 740	1 269	16 048
Year of low flood							
Plateau	-	-	9	39	-	-	48
Delta Central	-	-	141	4 474	571	820	6 006
Méma Dioura	-	-	-	-	-	-	-
Gourma	-	-	-	-	-	-	-
Bodara	-	-	-	-	-	-	-
Zone Lacustre	-	-	-	869	624	449	1 942
Total	-	-	150	5 382	1 195	1 269	7 996
Low flood as percentage of normal flood							
Plateau	-	.	19	74	.	.	44
Delta Central	-	-	20	73	73	100	48
Méma Dioura	-	.	.	-	.	.	-
Gourma	.	.	.	-	-	.	-
Bodara	-	.	.	-	.	.	-
Zone Lacustre	-	.	.	73	73	100	68
Total	-	-	20	72	69	100	50

The delta zone covers a total area (floodable and emerged land) of 28 625 km², 539 km² of which is located on the PT, 16 079 km² on the CD, 1 190 km² on MD, 217 km² on GM, 243 km² on BD and 10 357 km² on LZ.
-: nil value; .: impossible value.
Source: Report 1, Chapters 3 and 5.

The relation between the maximum flood level and the area flooded can be identified by an empirical approach. PIRT has supplied information on the land units that can be flooded (Table 2.8), while ILCA has provided data on the depths of submersion of the vegetation units that can be flooded. By comparing these two sources it is possible to determine the depth of submersion of the land units and hence the flooded areas.

Land units TI3 and TI4 which are similar in terms of submersion, ranges from 0 cm in the high areas to 60 cm in the low areas. In land unit TI2 flooding depth varies from 30 cm deep in the high areas to 180 cm in the low areas. In units TI1 and TI7, which are similar in terms of submersion, flooding depth ranges from 60 cm in the high areas to 397 cm in the low areas. This latter figure refers to the beginning of the flooding of the plains which, on the limnimetric scale of Mopti, is equivalent to a depth of 263 cm (Report 1, Chapter 5).

We assume that the perennial plant formations described by ILCA are in a state of balance with their environment, in particular with flooding. We have therefore estimated a reference flooding curve reflecting this state of balance. For this estimate flooding data from Mopti have been used as being representative for the entire delta zone. Mopti is located at the confluence of the rivers Niger and Bani. The reference is the decadal flooding level (mean and standard deviation) between 1944 and 1968, whose maximum attains 660 cm (Mopti scale), as shown in Figure 2.9.

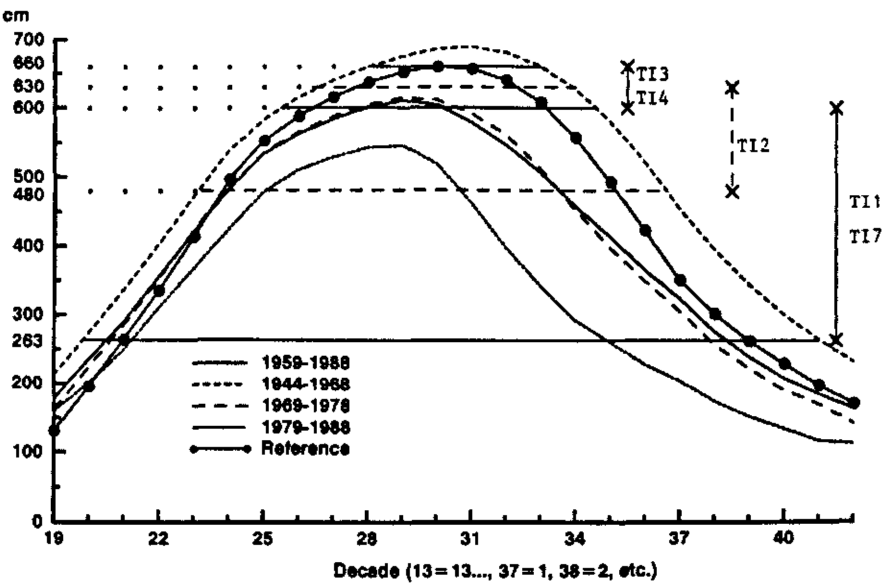

Figure 2.9. Average flood levels for various periods of time and the reference flood level. The curvy brackets (TI3 & TI4, TI2 and TI1 & TI7) give the flood levels for the various substrate types.

For this reference flood curve we assume that the areas which under normal conditions can be flooded are in fact flooded (Table 2.8, normal flood). Or in other words, under the reference flood, the delta zone would be submerged over an area of 16 048 km^2.

It is assumed that the flooding level of 660 cm (Mopti scale) corresponds to a flooding depth of 0 cm at the high areas of TI3 and TI4. Expressed in the flood level at Mopti therefore, TI3 and TI4 are submerged from 660 to 600 cm, TI2 from 630 to 480 cm and TI1 and TI7 from 600 to 263 cm. These flood levels are shown in Figures 2.8, 2.9 and 2.10.

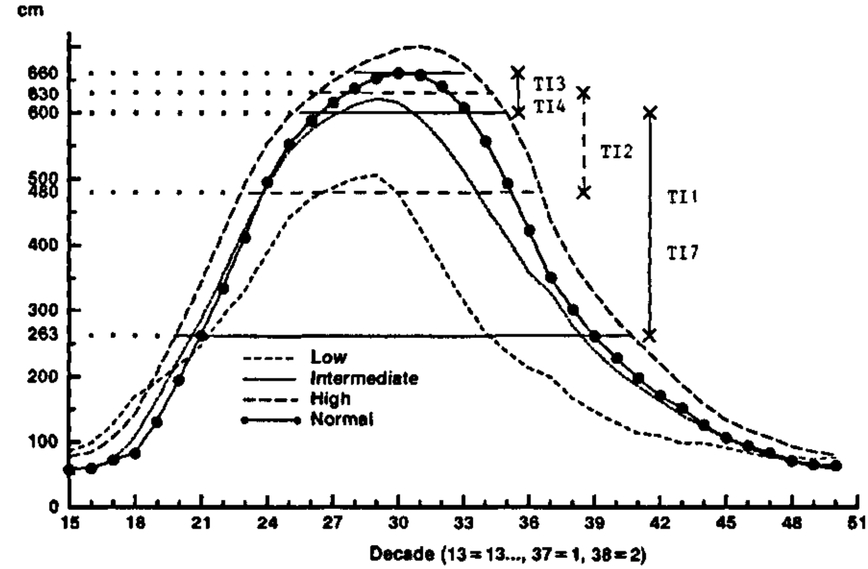

Figure 2.10. Representative flood curves for a year of low flooding, a year of intermediate flood and a year of high flooding. The reference flood level regarded as being normal is also shown. The curvy brackets (TI3 & TI4, TI2 and TI1 & TI7) give the flood levels for the various substrate types.

Under certain assumptions, it is possible to estimate the extent of the flooded areas as a function of the maximum decadal water levels at Mopti. Thus, for example, during an exceptionally high flood (1967: decadal maximum of 719 cm) the delta zone would have been flooded over an area of 20 447 km^2. During an exceptionally low flood on the other hand (1984: decadal maximum of 434 cm), it would only have been 5 822 km^2 (Report 1, Chapter 5).

As for rainfall, we are able to split the maximum flood levels for the years from 1959 to 1988 into 3 categories (Figure 2.10). A low flood level year is represented by the average of the 20% lowest floods; its decadal maximum is 510 cm. A year of intermediate flood levels is represented by the average of the 60% intermediate floods; its decadal maximum is 632 cm. A year of high flood levels is represented by the average of the 20% highest floods; its decadal maximum is 701 cm. The curve for an intermediate year (Figure 2.10) is similar to the average curve for 1959 to 1988 (Figure 2.9). In this study, however, we do not assume that intermediate values represent the norm (Report 1, Chapter 5). We consider the reference flood curve (660 cm) representative for a normal year as shown in Figure 2.11.

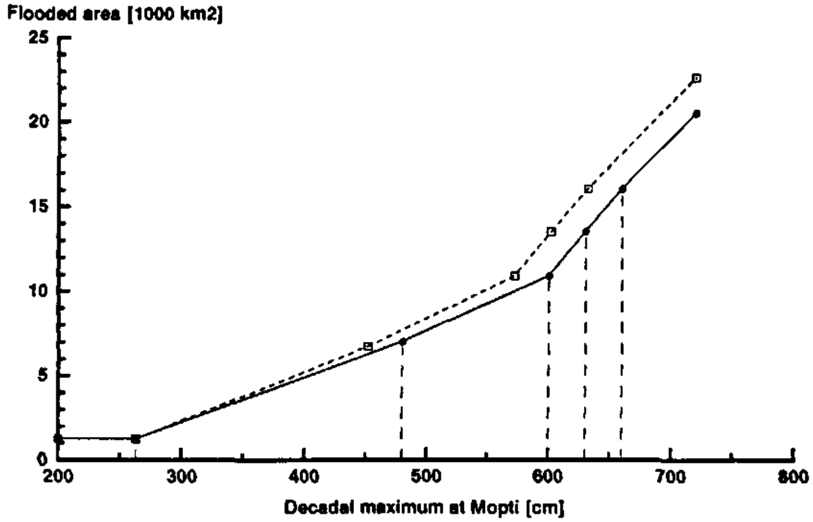

Figure 2.11. Flooded area in the delta zone as function of the decadal maximum flood level at Mopti. Solid ligne represents the relation assumed for a normal flood with a decadal maximum of 660 cm and the dotted ligne (not used) that for an intermediate flood with a decadal maximum of 632 cm.

Table 2.8 shows the areas assumed to be flooded in normal years (660 cm) and in low-flood years (510 cm). It also expresses the areas submerged under a low flood as a percentage of those normally submerged.

In a year with a normal flood an area of 16 048 km^2 in the delta zone would be flooded which is 56% of the total area of 28 625 km^2 of the two agro-ecological zones. The Delta Central and the Zone Lacustre comprise 92% of the total area of the delta zone and 96% of the area that can be flooded. For the Delta Central the maximum flooded area is estimated at 12 593 km^2 or 78% of its total of 16 079 km^2. For the Zone Lacustre the maximum flooded area is estimated at 2 841 km^2 or 27% of its total of 10 357 km^2.

In a year with a low flood an area of 7 996 km^2 in the delta zone would be submerged, or just 50% of its area that can be flooded, or only 28% of its total area. In the Delta Central no more than 6 006 km^2 is then flooded, or 27% of its total surface area; in the Zone Lacustre only 1 942 km^2 or 19%.

In a year with high flood levels (701 cm) an area of 19 105 km^2 in the delta zone would be flooded, which is 67% of its total area.

For the purposes of this study and in view of the similar pattern of flooding and rainfall (Figure 2.6) the three types of rainfall years are assumed to be associated with the three types of flood years. Thus, a year of low flood corresponds with a year of low rainfall and a year of normal flood with a year of normal rainfall.

2.4 Wood resources

The woody species form an integral part of the natural resources of the Region. The total stock of wood comprises the blocked ligneous reserve, i.e. the trees and shrubs in the fields and fallow lands, and the exploitable ligneous reserve. The latter is defined as the total quantity of woody species minus the blocked reserve. The wood productivity of an area is the annual production of all woody species, or to be more exact, the quantity of wood that can be theoretically harvested each year in that area without affecting its productive capacity. The production of leaves, fruits and other non-woody products is excluded.

The existence of a stock of wood and above all its conservation are related to both natural and anthropic processes. Soil types (Section 2.1) and rainfall pattern (Section 2.2) are major determinants for the development of natural woody formations. On the basis of information supplied by PIRL, estimates have been made of the qunatity of wood per soiltype, however, not specified per rainfall zone. But the range of values supplied by PIRL has not been used to attempt to take account of the rainfall zones. A very general value supplied by CILLS made it possible to fill in missing data. Estimates of the total stoch of wood per agro-ecological zone have been made as shown in Table 2.9, but these values are over-estimates because the effect of rainfall is not taken into account. Moreover, the method of estimation for doum-palm stands (Bocoum, 1990) is more suitable for forests that are relatively intact, hence the figures given in Table 2.9 for the Zone Lacustre are very likely grossly overestimated.

Assessment of the requirements for fire-wood and knowledge of the size of the population per agro-ecological zone, enables estimation of the quantities of wood currently harvested per year for domestic needs. The quantities of wood exported annually per agro-ecological zone and their use have also been estimated (Table 2.9).

Based on rainfall levels, rainfall zones I (Sourou & Séno Bankass) and II (Plateau & Delta Central) should have more substantial stocks of wood than rainfall zones III (Méma Dioura, Séno Mango & Gourma) and IV (Bodara, Zone Lacustre, Hodh & Méma Sourango). Table 2.9, however, shows that this is not always the case. The low population density creates more favourable conditions for woody species in rainfall zones III and IV, primarily Méma Dioura, Gourma, Bodara and the Zone Lacustre where the stock of wood are relatively extensive in view of their rainfall situation, which explains their export capacity (Bocoum, 1990).

Elsewhere, other factors must be taken into account. An agro-ecological zone may for instance have a small wooded area compared to its total surface area, but still a high wood production. This holds for the Plateau where this phenomenon is explained by the nature and density of the woody species associated with the local presence of abundant water as the result of concentration of run-off. This is also the case in the Zone Lacustre, where the shallow ground-water table and other local conditions are favourable for the establishment of forests of doum-palm.

Table 2.9 also provides an indication of the current exploitation level of the stock of wood. Without more detailed knowledge of the annual growth in wood reserves as a function of soil type and rainfall, however, it is impossible to define quantitatively sustainable exploitation activities.

Table 2.9. Wood reserve by agro-ecological zone: total and per unit of area; annual internal consumption: total and as percentage of the wood reserve per area unit; total annual exports and export purposes.

AGRO-ECOLOGICAL ZONE	WOOD RESERVE		CONSUMPTION		EX-PORT	REMARK
	total	average	total	%		
Sourou	5 875	6.30	230	0.25	-	
Séno Bankass	2 469	3.78	406	0.62	-	
Plateau	4 755	4.36	581	0.78	13	a
Delta Central	1 442	0.89	230	0.94	-46	b
Méma Dioura	3 393	6.28	53	0.11	9	c
Séno Mango	3 840	4.12	33	0.04	-	
Gourma	4 292	4.20	187	0.20	37	c
Bodara	1 341	3.12	33	0.08	-	
Zone Lacustre*	17 288	16.69	314	0.41	47	c
Hodh	1 039	3.20	11	0.04	-	
Méma Sourango	1 955	6.30	6	0.02	2	d
Total	47 689	5.37	2 086	0.32	107	

*) provisional value, see text.
a: Fuel-wood, wood for tools and construction-wood.
b: import of other agro-écological zones.
c: Fuel-wood and wood for tools.
d: Fuel-wood.
Source: Bocoum, 1990.

2.5 Population and labour supply

According to the last census in 1987, the rural population of the Region totals 1 295 582 inhabitants (Report 1, Chapter 7). In the present study they have been assumed to be all involved in agriculture (livestock, arable farming and fisheries). This number does not include the 73 979 individuals of the district of Mopti, who are not considered part of the Region as defined in the LP-model, which is delineated by geographical bouderies and is limited to agricultural activities, other economic activities being excluded (Report 1, Chapter 7).

This population must be partitioned among the various agro-ecological zones. By combining the 166 map units (Figure 2.1), the IGN maps, the populations and villages surveyed in 1976 and the 1987 census statistics, it is possible to estimate the number of inhabitants in each of the 11 agro-ecological zones. These estimates are given in Table 2.10 which also contains the area of the agro-ecological zones and their share in the total area.

The population of the Region, although regarded as being exclusively involved in agriculture, cannot be directly translated into human labour, i.e. labour supply. It is necessary to take into account age structure and certain sociological aspects so that an individual is not automatically equivalent to one labour unit or man-equivalent (Report 1, Chapter 7).

For the agro-ecological zones Sourou, Séno Bankass, Plateau, Méma Dioura, Séno Mango and Gourma, it is estimated that 25% of the population is under 7 years of age and does not contribute to the labour force, 15% is between 8 and 14 years corresponding to 0.5 labour units each, 52% is between 15 and 60 years and equivalent to 1 labour unit each and 8% is over 60 years, 4% male and 4% female, respectively estimated at 0.8 and 0.5 labour units each, respectively. For these six agro-ecological zones therefore the weighted average is 0.65 units of human labour per individual, expressed in man-day [mnd: the amount of work that can be accomplished by an adult person in one working day] or in man-year [myr: the work that can be accomplished by an adult person in one working year].

For the agro-ecological zones Delta Central, Bodara, Zone Lacustre, Hodh and Méma Sourango, the estimates are the same except that the 15 to 60 year age group is split into 25% males and 27% females who are estimated at 1 and 0.35 labour units, respectively. This distinction is due to sociological reasons. Hence for these five agro-ecological zones 1 individual is regarded equivalent to 0.46 units of human labour.

Table 2.10 gives the annual labour supply in man-years for each agro-ecological zone. It also shows the contribution of each agro-ecological zone to the total regional labour supply.

Table 2.10. Area [km^2], number of inhabitants, number of of man-years available [myr] which these inhabitants represent, and population density [inhabitants km^{-2}]. The figures are given for the 11 agro-ecological zones as absolute values and as percentages of the total.

AGRO-ECOLOGICAL ZONE	SUPERFACE	INDIVIDUALS	LABOUR	DENSITY
Absolute values				
Sourou	9 320	130 282	84 683	14.0
Séno Bankass	6 527	208 571	135 571	32.0
Plateau	10 890	296 008	192 405	27.2
Delta Central	16 079	291 008	133 864	18.1
Méma Dioura	5 403	30 066	19 543	5.6
Séno Mango	9 300	21 255	13 816	2.3
Gourma	10 217	95 326	61 962	9.3
Bodara	4 286	22 457	10 330	5.2
Zone Lacustre	10 357	185 348	85 260	17.9
Hodh	3 227	11 518	5 298	3.6
Méma Sourango	3 090	3 743	1 722	1.2
Total	88 696	1 295 582	744 454	14.6
Values as percentage of total				
Sourou	11	10	11	96
Séno Bankass	7	16	18	219
Plateau	12	23	26	186
Delta Central	18	23	18	124
Méma Dioura	6	2	3	38
Séno Mango	10	2	2	16
Gourma	12	7	8	64
Bodara	5	2	1	36
Zone Lacustre	12	14	12	123
Hodh	4	1	1	25
Méma Sourango	3	0	0	8
Total	100	100	100	100

0: trace, value lower than half the unit.
Source: Report 1, Chapter 7.

3. AGRICULTURAL ACTIVITIES

3.1 Introduction

3.1.1 Agricultural production techniques

For application of the Multiple Goal Linear Programming model (Report 3) a quantitative description of all possible agricultural production systems in the Region (Fifth Region and the Cercle of Niafunké) is required. Such a description specifies the production of a system as a function of the degree of exploitation of limited resources, both human and natural, and of the use external inputs. Three agricultural production systems are distinguished: *(i)* crop systems, *(ii)* livestock systems and *(iii)* fisheries. Crop systems (Section 3.2) comprise mainly millet, livestock systems (Section 3.3) mainly cattle, sheep and goats. Fisheries are discussed in more detail in Section 3.4. Each of these production systems can be interpreted as a mix of activities. Activities are defined as well-defined agricultural production techniques with specified and quantified inputs and outputs.

Activities may take place in principle anywhere in the Region, i.e. in any of the agro-ecological zones distinguished (Section 2.1), unless specified otherwise. All production techniques defined are assumed to be sustainable, i.e. their yield potential is not jeopardized in the long run (Subsection 3.1.2). In addition, the crop and livestock activities are defined in a **target-oriented** way, i.e. the production (output) per hectare or per animal is defined first and the requirements (inputs) to realize that production are derived subsequently. Outputs comprise e.g. grain, meat, milk or manure, whereas inputs consist of e.g. land, labour, oxen, chemical fertilizer or manure. Note that outputs of one activity can be inputs into another (e.g. manure). As a rule, technical coefficients for inputs depend only on activity, i.e. are independent of the agro-ecological zone. An exception, however, is the amount of fertilizer, which is a function of yield, and hence varies with agro-ecological zone. The technical coefficients for outputs of cropping activities, however, vary according to rainfall zone. In addition, the activities are quantified for the two distinguished weather regimes, i.e. the so-called 'normal' and 'dry' years with respect to rainfall and flood, as defined in Section 2.2. Activities are finally summarized in input-output tables.

The various production techniques comprise *(a)* existing or current, *(b)* alternative and *(c)* potential techniques. Alternative techniques refer to practices applied in similar natural environments, but not yet common in the Region; potential techniques refer to intensified production techniques not practiced in the Region at present (e.g. millet cultivation with high input of chemical fertilizer).

As labour availability can be an important constraint for the level of intensity of agricultural activities (see also Subsection 4.1.2), it is discussed in more detail in Subsection 3.1.3.

3.1.2 Sustainability

The concept of sustainability has received ample attention recently. Certainly any rural development or land use plan should consider (only or as far as possible) sustainable agricultural production systems. Sustainability can be defined as: 'the successful management of resources for agriculture to satisfy changing human needs, without degrading the environment or the natural resource base on which agriculture depends' (TAC, 1989). Evidently, degradation of the natural resource base can take many different forms. Of particular importance for the Fifth Region are the chemical exhaustion of soils, the disappearance of perennial grasses from the flood plains, the mortality of shrubs and trees on the rangelands, soil crusting and sealing and degradation of the vegetation of rangeland (i.e. changing species composition or decreasing cover leading to lower forage availability) on loamy substrates and increased wind erosion.

For operational purposes in this study, sustainability for arable crop systems has been defined as an equilibrium situation for the nutrient balances of the macro-elements (N, P and K), as illustrated in Figure 3.2 (page 37). In other words, the total amounts of nutrient elements in the soil remain constant in the long run. This criterion was selected, as in addition to uncertain, variable and low rainfall, low soil fertility (in terms of nutrient element availability) is a major constraint for crop production in West Africa (Penning de Vries & Djitèye, 1982, Piéri, 1989). If the soil can not supply sufficient plant nutrients to satisfy crop demand, the yield level is determined by the amount of the limiting element that can be taken up. This constraint can be removed by fertilizer application, provided it takes place in the right way, in the right form and at the right time. This results in increasing yields with increasing nutrient availability, until another growth factor (e.g. water, radiation) becomes limiting.

For livestock systems, sustainability refers to a stable herd of each animal species, based on sustainable forage production (in addition to the condition of chemical equilibrium, only a fraction of the total pasture biomass production can be used, Report 2, Subsection 1.3.2, Chapter 11).

For fishery production techniques sustainability refers to a maximum quota of fish that can be caught.

Water is another natural resource, whose exploitation should be sustainable. In the present study, the locations of permanent water points have been used to calculate the surface area that can be exploited by the animals during the dry season. The assumption made, is that a permanent water point supplies enough water both for human needs and for the animals that can be fed within a radius of 15 km of that water point.

3.1.3 Labour periods

Labour requirements are defined as the number of man-days required to complete an operation including the necessary travelling time. One man-day [mnd] is defined as the amount of work accomplished by a male adult during one working day. In analogy, one animal-team-day [At, "atelage"] is the work accomplished by a pair of oxen during one working day. It is assumed in this study that only oxen are used for animal traction.

Labour requirements are defined separately for six different periods of the year, to account for the occurrence of periods with peak labour demands. In such periods, labour supply may become a constraint in agricultural activities. The length of each period is given to indicate the number of days available to complete the operation(s). The periods are:

1. Land preparation and sowing time of millet (duration 20 d);
2. First weeding (duration 15 d);
3. Remainder of the growing season of millet till harvest (duration 55 d);
4. Harvest time of millet (duration 10 d);
5. Harvest time of wet season rice (duration 10 d);
6. Remainder of the year (duration 255 d).

In each period the total labour requirements (for arable farming plus animal husbandry plus fisheries) may not exceed the local supply per subregion expressed in adult equivalents. Hence, temporary migration between subregions is excluded.

Labour requirements for transport (e.g. equipment or chemical fertilizer) and for travel to and from the fields are not explicitly included in this study, except those for transport of produce and farmyard manure.

For some operations labour requirements are also a function of the level of input or output. For instance, the labour requirements for transport and application of farmyard manure are a function of the amount of manure required (input), which in turn is a function of the target yield (output). This has been taken into account in the LP-model, as described in Report 2, Subsection 1.2.2).

3.2 Crops and pastures

3.2.1 Defined production techniques

In the LP-model three crop types are considered: rainfed crops, flood retreat crops and irrigated or inundated crops. These are further classified by crop species, such as: millet, rice, sorghum, fonio, groundnut, cowpea, shallot and the so-called 'other vegetables' (comprising among others tomatoes, tobacco, cassava and cabbage). Other crops, like e.g. maize, cotton and sesame, can be grown in the Region, but their prospects are limited on a regional scale. Some additional simplifications have been introduced: In the actual situation several flood retreat crops are grown, such as sorghum, millet, cowpea and vegetables. In the LP-model, flood retreat sorghum is considered representative for all these flood retreat crops.

Each of the crops included can be grown with a specific technology, comprising different techniques, differentiated on the basis of four criteria: *(i)* fallow periods, *(ii)* oxen traction, *(iii)* application of farmyard manure and *(iv)* application of chemical fertilizer.

In addition, three intensity levels are distinguished: *(i)* extensive, *(ii)* semi-intensive and *(iii)* intensive. Extensive refers to techniques without any external nutrient inputs (chemical fertilizer), intensive to techniques with high levels of such inputs and semi-intensive to intermediate levels. In addition, intensive techniques include a high degree of innovative practices. Application of farmyard manure is considered extensive, because it is a transfer of fertility within a certain area. Fallowing can be interpreted as transferring arable fields towards the surrounding pastures and manure application as transferring fertility towards arable fields by exploitation of the surrounding pasture by animals. Vegetable growing falls outside this schematization and is considered intensive due to its high inputs of pesticides and manure.

The degree of differentiation depends on the relative importance of a crop species. For instance, for millet as the main crop of the Region, 6 techniques are distinguished, whereas for fonio (a minor crop) one technique is described only. Table 3.1 presents the crops and technologies included.

Table 3.1. Defined arable cropping activities with various technologies in the LP-model. OP-rice: Outside polder rice; P-rice: polder rice IR-rice: irrigated rice. -: no use; +: use of.

ACTIVITY CODE	CROP/ TECHNOLOGY[a]	INTENSITY	TRACTION	MANURE	FERTI-LIZER	FALLOW
i1 -i5	Millet/1	extensive	-	-	-	+
i6 -i10	Millet/2	extensive	-	+	-	-
i11-i17	Millet/3	extensive	+	-	-	+
i18-i24	Millet/4	extensive	+	+	-	-
i25-i28	Millet/5	semi-intensive	+	+	+	-
i29-i32	Millet/6	intensive	+	+	+	-
i33	Fonio	extensive	-	-	-	+
i34	Sorghum/1	extensive	-	-	-	+
i35	Sorghum/2	semi-intensive	-	-	+	-
i36	Groundnut/1	semi-intensive	+	-	+	+
i37	Groundnut/2	intensive	+	-	+	-
i38-i42	Cowpea/1	semi-intensive	+	-	+	+
i43-i45	Cowpea/2	intensive	+	+	+	-
i46	Shallot	intensive	-	+	-	-
i47	Vegetables	intensive	-	+	-	-
i49-i51	Fodder crop	intensive	+	+	+	-
i52	Bourgou	semi-intensive	+	+	+	-
i54-i56	OP-rice	extensive	+	-	-	+
i57	P-rice/1	semi-intensive	+	+	+	-
i59	P-rice/2	semi-intensive	+	+	+	-
i58	IR-rice	intensive	+	+	+	-
i48,53	vacant					

a) indicates intensification level

Source: Report 2, Chapter 1.

A crop activity is a specific combination of a soil type and a technology. The combination of a crop and a soil is made on the basis of physical characteristics of the soil (water holding capacity; Section 2.1). It is assumed in this study that arable fields are within a 6 km radius from permanent water points. The unit for definition of the technical coefficients of a crop activity is one hectare [ha]. In combination with the information from Table 3.2, one can derive that for semi-intensive millet cultivation (i25-i28, millet/5) animal traction is used, farmyard manure and fertilizer is applied, but no fallowing. This production technique can be practiced on soil types B1, B2, C1 and F1.

Table 3.2. Occurrence of crop activities on the various soil types with corresponding number of activity. OP-rice: Outside polder rice; P-rice: polder rice; IR-rice: irrigated rice.

CROP/ TECHN.[a]	SOIL TYPE											
	B1	B2	C1	C2	D1	E1a	E1b	E2a	E2b	F1	F3b	G
Millet/1	1	2	3	4	5	-	-	-	-	-	-	-
Millet/2	6	7	8	9	10	-	-	-	-	-	-	-
Millet/3	11	12	13	-	14	15	-	16	-	17	-	-
Millet/4	18	19	20	-	21	22	-	23	-	24	-	-
Millet/5	25	26	27	-	-	-	-	-	-	28	-	-
Millet/6	29	30	31	-	-	-	-	-	-	32	-	-
Fonio	-	-	33	-	-	-	-	-	-	-	-	-
Sorghum/1	-	-	-	-	-	-	-	-	-	-	-	34
Sorghum/2	-	-	-	-	-	-	-	-	-	-	-	35
Groundnut/1	-	-	36	-	-	-	-	-	-	-	-	-
Groundnut/2	-	-	37	-	-	-	-	-	-	-	-	-
Cowpea/1	-	38	39	40	41	-	-	-	-	42	-	-
Cowpea/2	-	43	44	-	-	-	-	-	-	45	-	-
Shallot	-	-	-	-	-	-	-	-	-	46	-	-
Vegetables	-	-	-	-	-	-	-	-	-	47	-	-
Fodder crop	-	49	50	-	-	-	-	-	-	51	-	-
Bourgou	-	-	-	-	-	-	-	-	-	-	52	-
OP-rice	-	-	-	-	-	-	54	-	55	-	56	-
P-rice/1	-	-	-	-	-	-	-	-	-	-	57	-
P-rice/2	-	-	-	-	-	-	-	-	-	-	58	-
IR-rice	-	-	-	-	-	-	-	-	-	-	59	-
	B1	B2	C1	C2	D1	E1a	E1b	E2a	E2b	F1	F3b	G

[a]) indicates intensification level.
-: not applicable.
Sources: Report 1, Chapter 3; Report 2, Chapters 2-10.

Natural pastures are not treated in terms of activities, as no management takes place. In the case of management, and hence additional inputs, pasture production is considered a fodder crop production technique, and is consequently treated as a crop.

3.2.2 Outputs

3.2.2.1 Crops

Outputs of crop activities comprise main products and crop residues. The former include grain (in the case of cereals and leguminous species), shallots and other vegetables, and fodder (in the case of fodder crops and bourgou cultivation). Crop residues that are available as animal feed are referred to as by-products.

Target yields of main products in normal years (Section 2.2) are based on simulation results or on data collected in the Region.

Simulation results have been used to derive target yields of the intensive and semi-intensive production techniques of millet and cowpea. The first step is the calculation of water-limited yields (i.e. yields determined by water availability only, the supply of nutrient elements assumed to be optimum) on the basis of soil characteristics (pF-curve) and observed rainfall for the period 1959-1988 of 7 meteorological stations in the Region. As no quantitative information on runoff and runon for the study area was available, and assuming that on a regional scale of hundreds of km^2 the positive and negative effects compensate each other, all rain was supposed to infiltrate. The simulation results are illustrated for millet on two soil types in Figure 3.2, which shows that in addition to rainfall, soil characteristics are important.

The assumption of optimum nutrient supply implies a high external input of nutrient elements (chemical fertilizer), as the supply from natural sources only covers a small fraction of the demand. In addition, even under optimum nutrient supply, lack of timeliness, pest and diseases, weeds, etc. lead to 'unavoidable' yield reductions, which imply waste of external inputs. Hence, in this study, the target yields in normal years for the intensified technique are set at 80% of the simulated water-limited yield. The target yields for the semi-intensive technique is set at 40% of that of the intensive technique, i.e. 32% of the simulated water-limited yield. The values of these target yields are similar to the yield levels obtained in reality when additional fertilizers are applied.

As available field data from the Region generally refer to extensive techniques (with yields varying from year to year and from place to place), they serve as a basis for defining the target yield for the extensive techniques. As yet, no simulation models exist that take into account yield determinant factors as timeliness, management, weeds, pest and diseases, etc. under conditions where alternating nutrient elements and water may be limiting. The use of animal traction in extensive techniques is estimated to raise target yields by 20%, but reducing soil fertility at a higher rate.

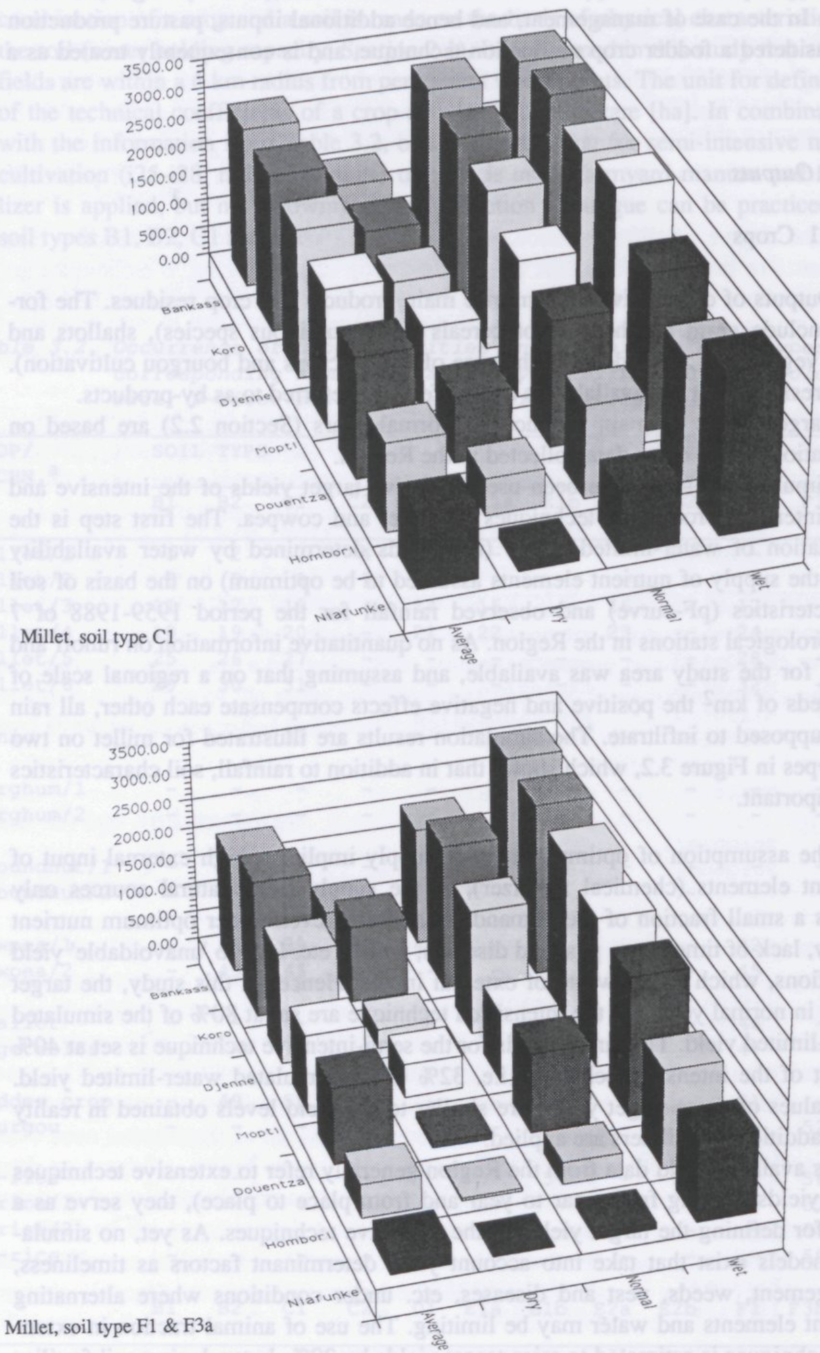

Figure 3.1. Average simulated water-limited yields of millet on two soil types as function of year type for meteorological stations in the Region.

Target yields for dry years (Section 2.2) are calculated on the basis of simulation results. The ratio of average simulated yield in dry years and in normal years has been calculated for each rainfall zone and soil type. The target yield in a dry year is then obtained by multiplying the target yield in a normal year by that rainfall zone-specific ratio.

As crop residue production depends on crop production technique, soil type and rainfall, no fixed value can be used. Hence, the simulated crop residue productions were plotted against simulated grain yield for normal and dry years over the 30-year period for each soil type in rainfall zone I. Subsequently, for each target yield of an activity (i.e. for each rainfall zone) crop residue production was derived from that curve. As in the LP-model only linear relations can be included, a linear regression line has been calculated relating crop residue production to target yield (Stover = a * target yield + c). Hence, in the LP-model total crop residue production has both a yield-dependent and an area-dependent component. However, these regression lines can not be applied for the extensive and semi-intensive techniques, as the harvest indices (ratio of yield and total above-ground biomass production) are generally lower. As pertinent information was not available, the regression lines have been adapted on the basis of common sense such that the intercept with the yield axis (c) has been reduced and the slope of the line (a) somewhat increased.

Straw can be used for building purposes, fuel or fodder, however, only the latter has been taken into account in this study. It is therefore necessary to specify the quantity available for animal consumption, expressed in terms of fraction of total production and its quality in terms of N-content. The fraction of total production available, is given for the various crops in Table 3.4. It is determined by its physical properties and chemical composition (not all parts are consumable), harvest and post-harvest losses, and accessibility.

Target yields of the various activities and the corresponding crop residue production values are listed in Table 3.3. For instance, for the semi-intensive millet activities (millet/5) target yields in dry matter range from 340 to 1 000 kg ha^{-1}, and stover yields from 1 380 to 4 630 kg ha^{-1}, depending on rainfall and soil type.

To determine, among others, Total Gross Revenue of the Region (Section 5.2), a producer price has been attached to the following products [FCFA kg^{-1} DM]: millet and sorghum: 55 (for technical reasons, in the model the price of sorghum is set at 56 FCFA kg^{-1}); rice and fonio: 70; groundnut and cowpea: 75. For shallot, the producer price for bulbs and leaves combined is set at 59 and for the other vegetables at 96 FCFA kg^{-1} fresh weight. No price is attached to crop residues (by-products).

Table 3.3. Range of target yields and crop residue production values (kg DM ha^{-1}) of the various crop activities as a function of rainfall zone in a normal year.

CROP/TECHN.[a]	SOIL TYPE	RAINFALL ZONE	YIELD	RESIDUE
Millet/1	B1,B2,C1,C2,D1	I-IV	190- 500	1 030-2 750
Millet/2	B1,B2,C1,C2,D1	I-IV	190- 500	1 030-2 750
Millet/3	B1,B2,C1,D1, E1a,E2a,F1	I-IV	230- 600	910-3 180
Millet/4	B1,B2,C1,D1, E1a,E2a,F1	I-IV	230- 600	910-3 180
Millet/5	B1,B2,C1,F1	I-IV	340-1 000	1 380-4 630
Millet/6	B1,B2,C1,F1	I-IV	840-2 390	2 700-6 230
Fonio	C1	I	250- 380	580- 880
Sorghum/1	G	NR1	600	4 650
Sorghum/2	G	NR1	1 000	5 450
Groundnut/1	C1	I	750	920
Groundnut/2	C1	I	1 380	1 230
Cowpea/1	B2,C1,C2,D1,F1	I-IV	130- 750	370-1 770
Cowpea/2	B2,C1,F1	I-IV	300-1 540	950-2 640
Shallot	NR2	NR3	35 000*	-
Other vegetables	NR2	NR3	16 000*	700
Fodder crop	B2,C1,F1	I-IV	1 430- 4 600	-
Bourgou	E1b,E2b,F3b	II-IV	15 000	-
OP-rice	E1b,E2b,F3b	II-IV	600	2 400
P-rice/1	F3b	II	1 300	5 200
P-rice/2	F3b	II	2 800	8 400
IR-rice	F3b	NR3	9 000	11 000

a) indicates intensification level.
Source: Report 2, Chapters 2-10.
NR1: not relevant, as it is based on flood of the river Niger.
NR2: soil type not relevant as soil properties are affected by manure application.
NR3: not relevant, as it is based on irrigation water.
* : Fresh weight.

Tableau 3.4. Availability of stover, straw or hay for animal consumption as fraction of their total production for the various crops.

FORAGE	CONSUMABLE	ACCESSIBLE	AVAILABLE	SOURCE[a]
Millet	0.75	0.90	0.68	chapter 2
Rice	0.90	0.70	0.63	chapter 3
Sorghum	0.45	0.50	0.23	chapter 4
Fonio	1.00	0.90	0.90	chapter 5
Cowpea	0.90	0.30	0.27	chapter 6
Groundnut	0.85	0.30	0.26	chapter 7
Shallot	0	0	0	chapter 8
Other vegetables	1.00	0.80	0.80	chapter 8
Bourgou	1.00	0.80	0.80	chapter 9
Fodder crops	0.90	0.90	0.81	chapter 10

a) in Report 2.

In addition to the quantity of available forage, the quality in terms of nutritive value for the animals has been taken into account. The approach followed is based on one parameter: the N-content in dry matter [g kg^{-1}] (Report 2, Chapter 12). Four quality classes are distinguished:

1. Low	N < 7.5	(average 3)
2. Moderate	N 7.5-10.0	(average 8)
3. Good	N 10.0-17.5	(average 12)
4. Excellent	N > 17.5	(average 20)

3.2.2.2 Pastures

Values for pasture production are based on the Manuel for land evaluation of Sahelian rangelands (Breman & de Ridder, 1991), taking into account soil type, annual precipitation, sustainability and management practices, such as burning (Report 2, Chapter 11). Two major classes are distinguished: flooded pastures in the delta of the river Niger (Delta Central, Zone Lacustre) and rainfed pastures. Production of the herb layer and of browse are treated separately. For the latter, in addition to availability, palatability has been taken into account. Biomass production in dry years is lower, but its quality in terms of N-content is higher.

3.2.3 Inputs

Inputs of crops, discussed in the following paragraphs, comprise nutrient elements, labour, cash and oxen. On natural pastures, by definition, none of these inputs are utilized.

3.2.3.1 Nutrient requirements

As a consequence of the requirement for sustainability, macro nutrient elements (N, P and K) removed from the field or subject to unavoidable losses should be replaced. They may originate from natural sources during fallowing or from manure or chemical fertilizer, or a combination of the three. The requirements are calculated for each activity, based on the following steps:

1. Calculation of nutrient uptake (N, P and K) on the basis of the target yield and the corresponding crop residue producton and their minimum nutrient concentration. (Note that these elements are expressed in elementary form, i.e. not in P_2O_5 or K_2O);
2. Quantification of the recovery fraction of applied nutrients for each of the three elements and the magnitude of the unavoidable losses through various processes (Figure 3.1, no. 3), for the various soil types;
3. Determination of nutrient availability from natural sources (Figure 3.1, no. 4 and 10), crop residues (e.g. roots and stubble; Figure 3.1, no. 7 and 8) and biological N-fixation (e.g. groundnut; Figure 3.1, no. 9);
4. Derivation of the required nutrient application;
5. The net inputs during fallow are estimated at about 11, 1.3 and 11 kg ha^{-1} yr^{-1} for N, P and K, respectively and the N, P and K-content of manure is 12.7, 2.8 and 13.0 g kg^{-1} DM, respectively (van Duivenbooden, 1991). On the basis of the calculated nutrient requirements, and the technique applied for the activity, the ratio of fallow years to years of cultivation or the manure or chemical fertilizer (N, P and K) requirements are calculated. For details reference is made to van Duivenbooden (1991) and Report 2, Subsection 1.3.1.

For instance, for the semi-intensive millet technique on soil type C1, with a target yield of 960 kg ha^{-1} and a stover production of 2 800 kg ha^{-1} in rainfall zone I in a normal year (precipitation on average 530 mm), it implies a manure requirement of 2 530 kg DM ha^{-1} and a chemical fertilizer requirement of 12 kg ha^{-1} of nitrogen. Application of manure ensures in this case adequate supply of P and K (Table 3.5). The nutrient requirements for the other crop activities are summarized in Table 3.6.

Manure does not have a price in the LP-model and should be produced by livestock activities. Chemical fertilizer is priced separately in the LP-model for each of the macro elements at 450, 1 250 and 450 FCFA kg^{-1} of N, P and K, respectively. In the input-output table, however, it appears as a physical amount (Table 3.5).

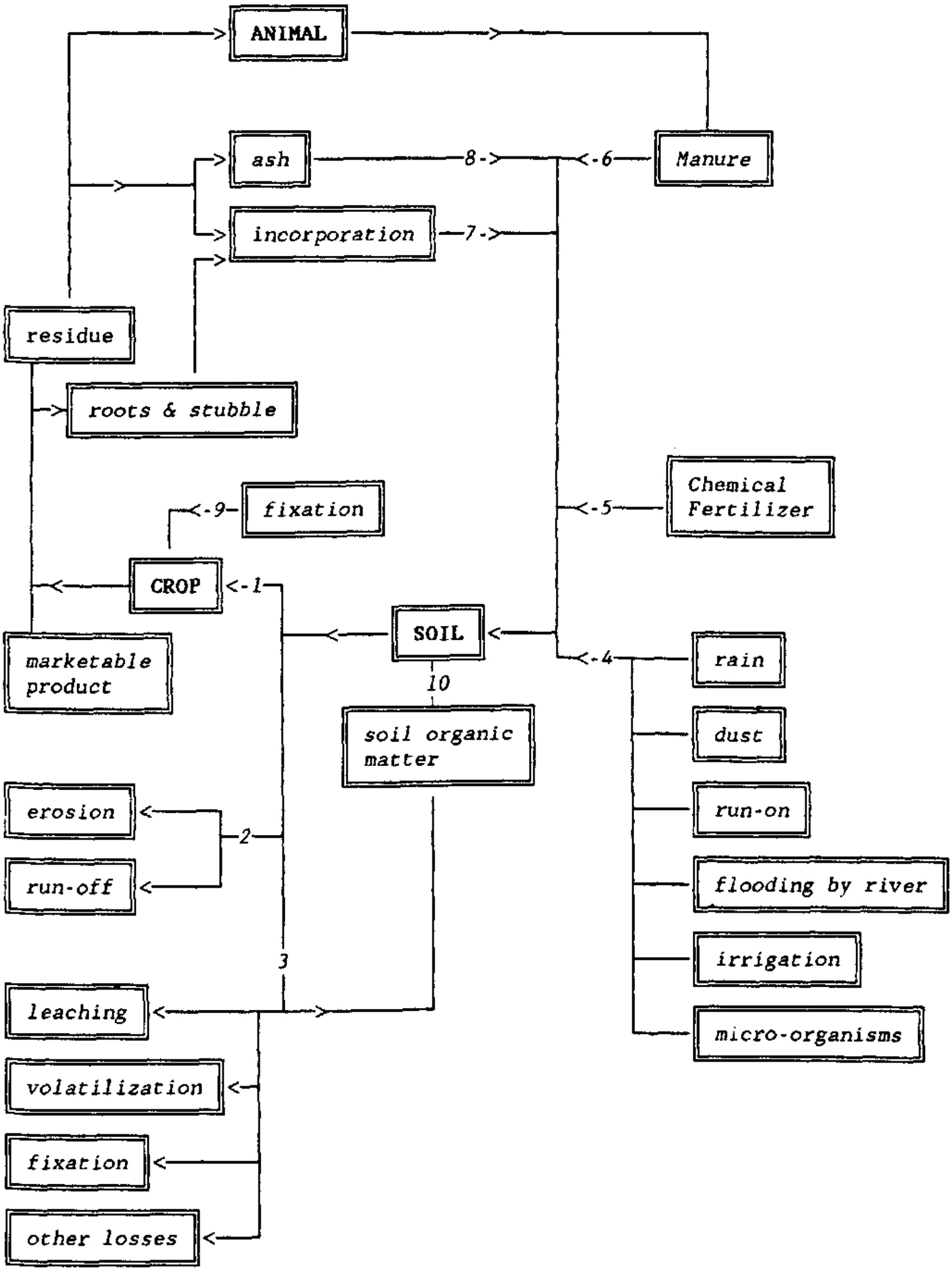

Figure 3.2. *Schematized dynamics of macro nutrient elements (nitrogen, phosphorus and potassium) in the crop production system.*

3.2.3.2 Labour requirements

Labour requirements are defined for the following operations (in chronological order): cleaning of the field, transport of manure, application of manure, application of basic chemical fertilizer, land preparation, soil levelling, sowing, transplanting, weeding (up to 3 times), top dressing (up to 3 times), biocide spraying, dike maintenance, irrigation, bird scaring, guarding, harvesting, threshing and winnowing, transport of produce.

The actual labour requirements are of course a function of crop activity. The labour requirements are quantified for each of the six distinguished periods of the year (Subsection 3.1.3) and described in detail for the various crops in Report 2, Chapters 2 to 10.

As an example, for the semi-intensive millet technique on soil C1, total labour requirements are (77 mnd + 4 At) ha^{-1} yr^{-1} (Table 3.5). The data show that 53% of the human labour, is employed during the 90-day growing period. Total labour requirements for the other crop activities are presented in Table 3.6.

3.2.3.3 Monetary inputs

Monetary inputs are subdivided in capital charges and operating costs. Capital charges refer to annual depreciation of necessary investment items, such as plough, harrow, sowing machine, motorpump, pesticide sprayer or irrigation scheme, including minor items such as small equipment (knifes, etc.). Operating costs include: seeds, fuel for irrigation, dike maintenance (e.g. cement), costs for the hired threshing-machine, and biocides. The value of both monetary input types is crop- and crop technology-dependent, as detailed in Report 2, Chapters 2 to 10.

For instance, capital charges for the semi-intensive millet activity are 2 670 FCFA ha^{-1} yr^{-1} for small equipment and a plough. Operating costs are 310 FCFA ha^{-1} yr^{-1} including seed and pesticides. Consequently, total monetary inputs are 2 980 FCFA ha^{-1} yr^{-1} (Table 3.5). The capital charges and operating costs of the other crop activities are presented in Table 3.6.

3.2.3.4 Oxen and plough requirements

Some activities are defined on the basis of animal traction. As donkey or horse traction is excluded, it refers exclusively to oxen traction. Based on the time required to complete an operation (e.g. land preparation) and the length of the period available for that operation, the required number of oxen per hectare can be calculated for each relevant period (land preparation, first weeding). The maximum value is then used as input for the LP-model. Hence, for one activity this may be the period of weeding, for another the period of land preparation.

Furthermore, accessibility of ploughs and of oxen can be a problem. This is included in the model by prohibiting exchange of ploughs and oxen between agro-ecological zones (subregions). In addition, within a zone exchange is assumed to be restricted, hence, the required number of ploughs and oxen is set 25% higher than in case of full exchange within the subregion.

For instance, for the semi-intensive millet activity, oxen requirements during the period of land preparation are 2/20 * 2 oxen plough^{-1} * 1.25 = 0.25 ox, and during the period of first weeding 2/15 * 2 oxen plough^{-1} * 1.25 = 0.33 ox. Hence, in the model, the latter value is applied. The oxen requirements for the other crop activities are summarized in Table 3.6.

The required number of ploughs is half the value for oxen, with two oxen per plough. Subsequently, taking into account purchase price and life expectancy, depreciation costs are calculated (Table 3.5). The monetary inputs, including other capital charges for the other activities are summarized in Table 3.6.

3.2.4 Input-output table

On the basis of the quantitative considerations presented, it is possible to construct the input-output table for each activity, Table 3.5 giving an example for the various millet activities. In Report 2, Chapters 2 to 10, the other input-output tables are presented and discussed in detail. Similarly to the outputs in Table 3.3, the inputs are summarized in Table 3.6.

Table 3.5. Input-output table of millet production techniques on soil type C1.

CARACTERISTIC	EXTENSIVE				SEMI-INTENSIVE	INTENSIVE
	1	2	3	4	5	6
Animal traction	-	-	+	+	+	+
Manure	-	+	-	+	+	+
Chemical fertilizer	-	-	-	-	+	+
Fallow	+	-	+	-	-	-
INPUTS [ha^{-1} yr^{-1}]						
FALLOW/MANURE/FERTILIZER						
Ratio fallow years/ year cultivated	5	-	6	-	-	-
Manure [kg DM]	0	1 930	0	2 290	2 530	1 930
Fertilizer N [kg]	0	0	0	0	12	96
Fertilizer P [kg]	0	0	0	0	0	12
Fertilizer K [kg]	0	0	0	0	0	56
LABOUR[a] [mnd]						
6 Cleaning the field	5	1	5	1	1	1
6 Transport and appl. of manure	-	17.5	-	21	15.5	12
1 Basic dressing	-	-	-	-	1	1
1 Land preparation	3	3	4.+ 2 At	4.+ 2 At	4.+ 2 At	12.+ 6 At
1 Sowing	5	5	5	5	5	2.+ 1 At
2 Weeding 1	15	15	10.+ 2 At	10.+ 2 At	10.+ 2 At	10. + 2 At
2 Top dressing 1	-	-	-	-	4	4
2 Pesticide spraying 1	-	-	-	-	-	0.5
3 Weeding 2	12	12	12	12	12	12
3 Top dressing 2	-	-	-	-	-	4
3 Pesticide spraying 2	-	-	-	-	-	0.5
4 Harvesting	5	5	6	6	5	12
6 Transport, threshing & winnowing	16.5	16.5	13.5	13.5	19.5	46
Total	61.5	75	55.5 + 4 At	72.5 + 4 At	77.+ 4 At	117.+ 9 At

.../...

Table 3.5. Continued.

CARACTERISTIC	EXTENSIVE				SEMI-INTENSIVE	INTENSIVE
	1	2	3	4	5	6
MONETARY INPUTS [FCFA]						
Capital charges						
Small equipment	700	700	700	700	1 000	1 500
Plough	-	-	1 670	1 670	1 670	5 260
Sowing machine	-	-	-	-	-	1 600
Sprayer	-	-	-	-	-	1 200
subtotal	700	700	2 370	2 370	2 670	9 560
Operating costs						
Seeds	60	60	60	60	60	60
Pesticides	100	100	100	100	250	6 500
subtotal	160	160	160	160	310	6 560
Total	860	860	2 530	2 530	2 980	16 120
OXEN [ox]	-	-	0.33	0.33	0.33	0.75
OUTPUTS [ha^{-1} yr^{-1}][b]						
Grain [kg DM]	500	500	600	600	960	2 390
Straw [kg DM]	1 750[c]	1 750[c]	1 980[c]	1 980[c]	2 800[c]	4 570[d]

[a]) Numbers in front of operations refer to the period of the year (Subsection 3.1.3).
[b]) In a normal year in rainfall zone I (average precipitation in May-October: 530 mm).
[c]) Average N-content is 3.9 g kg^{-1}.
[d]) Average N-content is 5.1 g kg^{-1}.

Table 3.6 Inputs of the various crop activities. Fallow [fallow years per year of cultivation]; chemical fertilizer: N, P, K [kg per ton target yield ha^{-1}], farmyard manure [kg DM kg^{-1} DM target yield ha^{-1}]; total labour [man-day ha^{-1}], capital charges [1000 FCFA ha^{-1}], operating costs [1000 FCFA ha^{-1}] and oxen [number ha^{-1}].

CROP/T[a]	FALLOW	N	P	K	MANURE	LABOUR	CAPITAL CHARGES	OPERATING COSTS	OXEN
Millet/1	4-5	-	-	-	-	62	0.7	0.2	-
Millet/2	-	-	-	-	3-8	75	0.7	0.2	-
Millet/3	6-8	-	-	-	-	56	2.4	0.2	0.33
Millet/4	-	-	-	-	4-9	73	2.4	0.2	0.33
Millet/5	-	15-26	-	6-19	3-5	77	2.7	0.3	0.33
Millet/6	-	44-74	4-6	21-52	1-2	117	9.6	6.6	0.75
Fonio	7	-	-	-	-	46	0.7	3.3	-
Sorghum/1	6	-	-	-	-	39	0.7	0.3	-
Sorghum/2	-	105	15	59	-	52	1.0	0.4	-
Groundnut/1	2	-	4	-	-	83	4.7	19.5	0.50
Groundnut/2	-	22	6	12	-	100	6.2	22.5	0.50
Cowpea/1	3	-	2-7	-	-	82	3.9	12.1	0.33
Cowpea/2	-	33-58	12-14	44-83	1-2	130	8.0	15.1	0.75
Shallot	-	-	-	-	0.2	1 963	2.9	202.5	-
Vegetables	-	-	-	-	0.3	1 389	2.9	53.5	-
Fodder	-	13-16	3-5	14-21	0.3	60	8.0	15.1	0.75
Bourgou	-	26	4	20	0.2	113	37.6	64.1	0.13
OP-rice	5-7	-	-	-	-	55	4.0	7.6	0.50
P-rice/1	-	77	3	31	0.9	104	34.4	14.9	0.50
P-rice/2	-	99	6	52	1.5	117	34.4	27.9	0.50
IR-rice	-	67	5	18	0.6	452	350.0	180.0	0.50

a) indicates intensification level.
Source: Report 2, Chapters 2-10.

3.3 Livestock

3.3.1 Activities

In the Fifth region (and Cercle de Niafunké) cattle, sheep, goats, camels, donkeys, horses, pigs, poultry and wild game are present, ranging from minor importance to very important. As for cropping systems, only the major production systems are included and the degree of differentiation depends on the relative importance of the animal species. Twenty two production techniques are distinguished, based on four criteria: *(i)* animal species (cattle, sheep, goats, donkeys, and camels), *(ii)* main production objective (meat and/or milk or traction/transport), *(iii)* mobility of animals (migrant, semi-mobile or sedentary) and *(iv)* animal target production level (low, intermediate and high) (Table 3.7).

Table 3.7. Defined livestock activities in the LP-model.

ACTIVITY CODE	SPECIES	MAIN PRODUCT	MOBILITY	PRODUCTION LEVEL
B1	cattle	traction	sedentary	low
B2	cattle	meat	semi-mobile	low
B3	cattle	meat	semi-mobile	intermediate
B4	cattle	meat	migrant	low
B5	cattle	meat	migrant	intermediate
B7	cattle	milk	sedentary	intermediate
B8	cattle	milk	sedentary	intermediate
B9	cattle	milk	migrant	intermediate
B10	cattle	milk	migrant	intermediate
B11	cattle	milk	sedentary	semi-intensive
B12	cattle	milk	sedentary	semi-intensive
B13	sheep	meat	sedentary & semi-mobile	low
B14	sheep	meat	sedentary & semi-mobile	intermediate
B15	sheep	meat	migrant	low
B16	sheep	meat	migrant	intermediate
B17	sheep	meat	sedentary	semi-intensive
B18	goats	meat & milk	sedentary & semi-mobile	low
B19	goats	meat & milk	sedentary & semi-mobile	intermediate
B20	goats	meat & milk	migrant	low
B21	goats	meat & milk	migrant	intermediate
B22	donkeys	transport	sedentary	intermediate
B23	camels	transport	migrant	low
B6	vacant			

With regard to mobility, the following definitions are applied:

- **Sedentary**
  The animals stay all year within a 6 km radius of a permanent water point.
- **Semi-mobile**
  During the hot season (February-June) the animals exploit the pastures between 6 and 15 km from a permanent water point. Overnight they stay in temporary camps; they return at least once every three days to the permanent water point to be watered.
- **Migrant**
  During the rainy season (July-October) the animals leave the arable farming area to graze the so-called wet season pastures, i.e. pastures outside a 15 km radius from a permanent water point. During the dry season they stay within that distance.

Regardless of their mobility, all animals exploit crop residues left in the field after harvest during the cold season (November-January). These fields are within a 6 km radius of a permanent water point.

All livestock activities are expressed per Tropical Livestock Unit [TLU], equivalent to an animal of 250 kg liveweight. An average animal converted to TLU for the different species is as follows: 1 cow: 0.7 TLU; 1 donkey: 0.5 TLU; 1 sheep/goat: 0.1 TLU; 1 camel: 1.2 TLU (Le Houérou & Hoste, 1977).

3.3.2 Outputs

As for crops, target production levels are defined. These production values were assessed based on Breman & de Ridder (1991) for cattle and some literature data for the other animal species.

Annual meat production ranges from 22 to 62 kg TLU^{-1} for cattle and from 40 to 100 kg TLU^{-1} for small ruminants. Annual milk production for human consumption varies from 0 to 520 kg TLU^{-1} for cattle and from 100 to 200 kg TLU^{-1} for goats and from 0 to 50 kg TLU^{-1} for sheep (Table 3.8). These values apply to an average animal in the herd. Target yield determines the required forage quantity and quality, i.e. the required diet.

For the donkey and camel breeding activities the main product is the number of these animals. Their production of meat and milk is not considered in the model, but can be easily calculated afterwards. The same holds for by-products of other livestock activities like hides.

A more detailed study on production levels of the various animal species (as described in Report 2, Chapters 12-15), carried out later, resulted in different values for all animals except cattle. However, because of time limitations, it has been decided to run the LP-model with the alternative production values only as a variant (Subsection 6.4.4).

In addition to the main product (e.g. meat), livestock activities produce by-products, manure for example. As its availability is of importance for cropping activities (requirement of sustainability), it is discussed in more detail. The maximum fraction of that manure available for crop activities has been calculated separately for the various animal species:

1. Cattle

   During the rainy season (July-October) sedentary cattle stay on average 12 hours per day in a corral ('au parc'), where 80% of their manure can be recovered. The remainder of the day the animals are grazing, their manure being lost for arable farming. Semi-mobile cattle spend about 6 hours a day in the corral. Migrant cattle are during the rainy season too far away for their manure to be used in crop cultivation.

   During the cold season (November-January, 'saison froide') all cattle, sedentary, semi-mobile and migrant, spend most of their time in the field: about 65% of the manure falls on those fields.

   During the hot season (February-June, 'saison chaude'), finally, sedentary cattle are again on average 12 hours a day in a corral (80% manure recovery), while no manure is recovered during grazing of the pastures around the villages. Migrant and semi-mobile cattle spend about 6 hours per day in the corral as they are grazing pastures further away from the village. Manure recovery is consequently half of that of the sedentary animals.

   Summarizing, 46% of the manure produced by sedentary cattle can, in principle, be utilized in crop cultivation, compared to 31% of that of semi-mobile and 24% of that of migrant cattle.
2. Small ruminants

   Sheep and goats normally do not graze at night and hence both sedentary and semi-mobile animals spend 12 hours a day in the corral, where 80% of the manure can be recovered. Manure recovery during grazing is neglected. The migrant small ruminants spend four months per year outside the arable farming area, the manure produced being lost for cropping activities. Hence, the maximum manure recovery of small ruminants is 46% for sedentary and semi-mobile production techniques and 33% in migrant production techniques.
3. Donkeys and camels

   For donkeys a relatively high recovery of 46% can be attained, as in sedentary production techniques. Manure of camels is not used in arable farming, but part is used as fuel.

The values of manure availability from the various livestock activities are given in Table 3.8.

Monetary output of livestock activities depends on level of physical output, prices and home-consumption of livestock products.

As explained elsewhere (Subsection 4.2.4), home-consumption is defined and calculated at the subregional level, i.e. it represents the minimum requirements for agricultural products within the boundaries of a subregion. That does not exclude trade on local markets nor exchange between producers; it only implies that a certain minimum quantity does not leave the subregion (if enough is produced) or must be imported (if local production is not sufficient). The minimum requirements for animal protein per person have been set at 50 g of meat (liveweight) per day and one kg of milk per week, on average; per individual the ratio milk/meat may vary, amongst others because the availability of milk is not evenly distributed over the population.

The reported producer price of beef is 700 FCFA per kg, equivalent to 320 FCFA per kg liveweight, and for sheep and goat meat 750 FCFA per kg or 340 FCFA per kg liveweight.

Table 3.8. Outputs of livestock activities (kg liveweight, kg milk, number of animals or kg DM of manure, per TLU per year).

ACTIVITY CODE	MAIN PRODUCT	MOBILITY	DIET[a]	MEAT	MILK	ANIMALS	MANURE[b]
Cattle							
B1.	Oxen	sedentary	I	22	0	0.55	442
B2.	Meat	semi-mobile	I	37	0	-	298
B3.	Meat	semi-mobile	II	56	92	-	285
B4.	Meat	migrant	I	37	0	-	230
B5.	Meat	migrant	III	71	219	-	222
B7.	Milk	sedentary	II	54	165	-	444
B8.	Milk	sedentary	III	62	376	-	445
B9.	Milk	migrant	II	54	165	-	232
B10.	Milk	migrant	III	62	376	-	232
B11.	Milk	semi-int.	IV+c	61	520	-	415
B12.	Milk	semi-int.	IV	61	520	-	415
Sheep							
B13.	Meat	sed. & s-m	I	70	-	-	718
B14.	Meat	sed. & s-m	III	100	50	-	688
B15.	Meat	migrant	I	70	-	-	515
B16.	Meat	migrant	III	100	50	-	494
B17.	Meat	sedentary	IV	150	-	-	641
Goats							
B18.	Meat	sed. & s-m	I+b	40	100	-	718
B19.	Meat	sed. & s-m	III+b	75	200	-	688
B20.	Meat	migrant	I+b	40	100	-	515
B21.	Meat	migrant	III+b	75	200	-	494
Other							
B18.	Donkeys	sedentary	II	-	-	2.00	466
B19.	Camels	migrant	I+b	-	-	0.83	-

a) see Table 3.9;
b) available for arable farming.
+b: browse is included; +c: concentrates are included.
Sources: Breman & de Ridder (1991); Veeneklaas, pers. comm.

Milk, because of its perishable nature, is normally either used for home-consumption, bartered, sold or given away within the subregion. Most of it, therefore, cannot be considered an export product in economic sense (leaving the agricultural sector) or in geographical sense. The main exceptions are the milk delivered to the factory in Mopti town and milk sold there directly to city-dwellers. These are included in the model in the semi-intensive livestock activities B11 and B12 (Table 3.8), where cows during the dry season are supplemented with concentrates or high quality crop residues (quality class IV). The sales market, however, is restricted in the model to an upper limit of 2.6 million kg per year. The reported producer price of milk is 180 FCFA per litre.

3.3.3 Inputs

Forage is of course the most important input for livestock activities. In addition to the total quantity required per TLU, specified separately for the wet season and the dry season, the minimum quality requirements are specified for each activity. Four quality classes are distinguished on the basis of nitrogen content (Paragraph 3.2.2.1). Browse is treated as a separate category and is considered a possible forage source for goats and camels only, even though cattle and even sheep may eat small amounts of the aerial biomass at the end of the dry season. The estimated average N-content of browse in the Region is 14 g kg^{-1} DM in the dry season.

In addition to pastures, crop by-products and concentrates are possible sources of forage.

Four possible diets have been distinguished, characterized by average N-contents of 9, 10, 11 and 12 g kg^{-1} DM (Table 3.9) and digestibilities of 52%, 54%, 56% and 59%, respectively.

These diets and their corresponding level of cattle production are described in detail by Breman & de Ridder (1991, Subsection I.3.6), and can be summarized as follows:

The lowest level guarantees the survival of the animal population and opens prospects for meat and manure production; milk production is still so low that it has to be completely reserved for calves. This situation designated level I is the minimum level at which a herd can continue to function. Since the heifers begin reproduction fairly late on and the birth rates are low, the population is barely able to sustain itself. All heifers reaching breeding age are needed for replacement of adult cows that have either died or culled at the age of eleven; increasing herd size through natural reproduction is therefore impossible.

Level II, refers to a situation where the feed situation is slightly better. Here, conditions are such that more than one third of the total milk production can be used for human consumption without seriously jeopardising the calves' chances of survival.

Levels III and IV represent a further improvement in the productivity parameters through the effect of better dietary conditions.

Table 3.9. Composition of livestock forage diets (% of dry matter intake) and average N-content of that diet (g kg^{-1} DM).

	WET SEASON	DRY SEASON		ALL YEAR
		Cattle/sheep	Goats/camels	
Diet I				
Quality class 1	0	33	44	
Quality class 2	0	67	41	
Quality class 3	50	0	0	
Quality class 4	50	0	0	
Browse	-	-	15	
Average N-content	16.0	6.7	6.7	9.0
Diet II				
Quality class 1	0	22		
Quality class 2	0	50		
Quality class 3	50	28		
Quality class 4	50	0		
Browse	-	-		
Average N-content	16.0	8.0		10.0
Diet III				
Quality class 1	0	13		
Quality class 2	0	50		
Quality class 3	30	37		
Quality class 4	70	0		
Browse	-	-		
Average N-content	17.6	8.8	8.8	11.0
Diet IV				
Quality class 1	0	13	13	
Quality class 2	0	50	50	
Quality class 3	50	14	14	
Quality class 4 (incl. concentrates)	50	23	23	
Browse	-	-	-	
Average N-content	16.0	10.7	10.7	12.0

Sources: Breman & de Ridder (1991); Veeneklaas, pers. comm.

The various animal husbandry systems currently practiced in Mali are somewhere within this range of production levels. In the Soudanese region, sedentary systems operate between level I and level II. More to the north, the prospects are in principle more promising: here, most of the systems operate around level II, and sometimes even at level III, except if the animal population is too high. Nomadic systems that alternately use natural pastures in the North during the rainy season and pastures in the Niger Delta or similar flood plains in the dry season, can attain at least level II and even level III, unless over-grazing prevents profiting of the potential benefits of good dry season grazing land. The destruction of the pastures dominated by perennial grasses in the delta area is probably the main reason for the decrease in productivity of these systems. Level IV is only attained in research stations, or occasionally on dairy farms, thanks to the use of large amounts of agricultural by-products.

For cattle, livestock activities have been specified at levels I, II and III for meat as the main production goal and at levels II, III and IV for milk. Migrant activities have in principle access to better forage, hence for these activities some of the better diets are applied. Diet IV is only feasible for semi-intensive milk production around Mopti town. The quality requirement of the diet can be guaranteed by concentrate supplementation during the dry season. For small ruminants, two production levels were specified with diets I and III. For donkeys diet II is applied and for camels the minimum diet I.

The feed requirements for the various livestock activities are presented in Table 3.10, their method of calculation in Report 2, Annex 7. As discussed above for outputs, also the values for the inputs for systems comprising other animals than cattle are subject to adaptations.

In addition to forage, labour and cash are inputs for livestock activities.

Labour requirements are specified for each animal species for the following operations: herding including watering, milking and veterinary care. The values are summarized in Table 3.10 and their derivation is described in more detail in Report 2, Annex 7 for the originial data set.

The monetary inputs consist almost exclusively of veterinary care and possibly concentrates. Their values are summarized in Table 3.10 and their derivation is described in more detail in Report 2, Annex 7 for the original data set. As discussed above for outputs, also the values for systems comprising other animals than cattle are subject to adaptations.

The reported price of concentrates is 38 FCFA per kg, equivalent to 44 FCFA per kg dry matter (Report 2, Chapter 13).

To attain the production levels as specified for the semi-intensive cattle activity, high quality forage only is not sufficient. Additional investments in herd management are needed, not only in terms of veterinary care but also in stables or other structures. Moreover, milk delivery entails transport costs. Reliable data on these expenses are lacking; in the present version of the model an overall monetary input of 20 000 FCFA TLU^{-1} yr^{-1} has been defined for the semi-intensive milk production activity.

In fact, the costs associated with the supply of drinking water should also be included in the monetary inputs of livestock activities. These costs include the depreciation on investments in and maintenance of wells, either with or without storage tanks, which can be substantial. They have been estimated at 15 to 35% of gross revenue of the livestock systems, depending on herd management (sedentary or migrant), animal productivity and type of well (Breman *et al.*, 1987). For a new well the costs would, according to the authors, be around 2 500 to 3 000 FCFA

TLU^{-1} yr^{-1}. These calculations, however, refer to a situation where new wells are drilled to open previously unexploited pastures. In the actual situation in the Region existing wells are utilized, and, moreover, most of the animals exploit during the dry season the natural surface water of the river, the lakes and the remaining pools. Therefore no costs are attributed to drinking water for the various livestock activities.

Table 3.10. Inputs in livestock activities [TLU^{-1} yr^{-1}]; intake of quality diet comprising forage, browse and concentrates [kg DM]; total labour in the wet and dry season [man-day] and money [1000 FCFA].

ACTI-VITY CODE	MAIN PRODUCT	MOBILITY	INTAKE				LABOUR		
			DIET	FORAGE	BROWSE	CONC.	WET	DRY	MONEY
Cattle									
B1.	Oxen	sedentary	I	2 000	-	-	2	8	2.3
B2.	Meat	semi-mobile	I	2 000	-	-	3	8	2.3
B3.	Meat	semi-mobile	II	2 000	-	-	3	9	3.5
B4.	Meat	migrant	I	2 000	-	-	3	8	2.3
B5.	Meat	migrant	III	2 100	-	-	3	9	3.5
B7.	Milk	sedentary	II	2 100	-	-	3	9	2.3
B8.	Milk	sedentary	III	2 200	-	-	4	10	3.5
B9.	Milk	migrant	II	2 100	-	-	3	9	2.3
B10.	Milk	migrant	III	2 200	-	-	4	10	3.5
B11.	Milk	sedentary	IV	1 820	-	380	5	14	22.0
B12.	Milk	sedentary	IV	2 200	-	-	5	14	22.0
Sheep									
B13.	Meat	sed. & s-m.	I	3 250	-	-	13	39	2.3
B14.	Meat	sed. & s-m.	III	3 400	-	-	15	47	3.5
B15.	Meat	migrant	I	3 250	-	-	13	39	2.3
B16.	Meat	migrant	III	3 400	-	-	15	47	3.5
B17.	Meat	sedentary	IV	2 300	-	1 100	15	47	5.0
Goats									
B18.	Meat	sed. & s-m.	I	2 880	370	-	15	39	0.3
B19.	Meat	sed. & s-m.	III	2 630	770	-	21	47	1.5
B20.	Meat	migrant	I	2 880	370	-	15	39	0.3
B21.	Meat	migrant	III	2 630	770	-	21	47	1.5
Donkeys									
B22.	Transport	sedentary	II	2 200	-	-	6	-	0.3
Camels									
B23.	Transport	migrant	I	1 550	200	-	-	-	0.3

Sources: Breman & de Ridder (1991); Veeneklaas, pers. comm.

3.4 Fisheries

The fishing activities are expressed per household engaged in fishing. In this study three types of households, and hence fishing activities, are distinguished on the basis of their main occupation and mobility:

V1. Households practicing fishing as main occupation, migrant (MMF).
V2. Households practicing fishing as main occupation, sedentary (MSF).
V3. Households practicing fishing as a side activity, sedentary (SSF).

The three household types differ in capital endowment and in productivity. In contrast to the activities defined in the preceding sections, target yields could not be derived from available data. Labour involved and the total amount of fish captured have, instead, been used as starting points for defining the input-output table.

3.4.1 Labour involved

Fishing of any importance takes place in only two of the eleven subregions: the Delta Central and the Zone Lacustre. In this study it is estimated that two-thirds of the fishing population have their home-base in the Delta Central and one third in the Zone Lacustre. The total population of these two subregions is about 476 000, representing a labour supply of approximately 219 000 man-years.

According to our information about 28 000 households are in some way involved in fishing activities. Average household size is reported to be 10.3 persons (Report 2, Chapter 16), implying that 290 000 persons, or 61% of the total population of the two subregions, belong to households engaged in fisheries. However, not their entire working time is spent fishing or processing fish. Even those with fisheries as their main occupation practice part-time cropping. It has been assumed in this study that the proportion of the time actually spent on fisheries is 85.5, 74.5 and 37.5% for migrant households with fisheries as main occupation, sedentary households with fisheries as main occupation and households with fisheries as a side activity, respectively. The total labour input in fishing thus amounts to 92 000 man-years or 40% of the total labour supply in the two subregions.

3.4.2 Total fish captured

In addition to labour inputs, fish yields have to be quantified. The total quantities of fish captured in normal and dry years have been derived from observations in the period 1966-1988 (Report 2, Chapter 16). These quantities refer to the catch for a period of three consecutive 'normal' floods and three consecutive 'deficient' floods, respectively. A normal flood is defined as the reference flood (i.e. all TI-soils inundated, Report 1, Chapter 5), a deficient flood as one associated with a dry year with respect to rainfall. Total catch in a normal year is defined as the upper limit to fish production in the Region. All available labour, as specified in the last column of Table 3.11, is then supposed to be employed.

Table 3.11. Population involvement and labour supply [1000 man-year] in the three fishery activities.

ACTIVITY TYPE	NUMBER OF HOUSEHOLDS ENGAGED IN FISHERIES	AVERAGE HOUSEHOLD SIZE [person]	PERSONS [x1000]	LABOUR SUPPLY[a]	TIME SPENT FISHING [%]	LABOUR SUPPLY
Main Migrant	5 409	9.20	49.8	22.9	85.5	19.6
Main Sedentary	17 068	10.56	180.3	82.9	74.5	61.8
Secondary Sedentary	5 659	10.56	59.8	27.5	37.5	10.3
Total	28 136	10.30	289.8	133.3	-	91.7

a) number of persons * 0.46

3.4.3 Fish capture per household

For a proper analysis of the situation, the total catch must be distributed among the three household types. In this study, that distribution is based on the assumption of equal returns on capital for each of the three household types, i.e. proportional to the share of the three different fishing activities in total monetary inputs, for depreciation, maintenance and fuel costs for the motor-boats (Table 3.12). The latter are estimated at 300 000 FCFA per motor-boat per year.

Table 3.12. Value of capital [thousand FCFA per household], monetary inputs for the three fisheries activities [thousand FCFA per household per year].

	ACTIVITY		
	MAIN MIGRANT	MAIN SEDENTARY	SECONDARY SEDENTARY
Value capital	501	402	82
Monetary inputs			
Depreciation	182	155	31
Maintenance	41	32	7
Fuel for motor boats	48	30	6
Total	272	217	44

Catch per fishing activity, i.e. household productivity, can now be calculated under the assumption that labour inputs are independent of the weather regime. In other words, whatever the size of the flood, labour inputs are constant, only household productivity (fish yields per household) will vary (Table 3.13). Basically, the same assumption is applied for inputs in crop activities. These inputs also are independent of the weather regime.

Table 3.13. Monetary inputs [million FCFA], total fish catch [ton] and productivity in the three fishing activities.

ACTIVITY TYPE	MONETARY INPUT	TOTAL CATCH		PRODUCTIVITY [t/househ.]		PRODUCTIVITY [t/man-yr]	
		NORMAL	DRY	NORMAL	DRY	NORMAL	DRY
Main Migrant	1 470	25 333	14 471	4.68	2.68	1.29	0.74
Main Sedentary	3 708	63 899	36 502	3.74	2.14	1.03	0.59
Secondary Sedentary	250	4 302	2 458	0.76	0.43	0.42	0.24
Total	5 428	93 534	53 431	3.32	1.90	1.02	0.58

Under a normal flood, 16 048 km^2 is inundated (at its highest point); the productivity is then 58 kg fresh fish ha^{-1} (when all labour available for fishery is employed). Under a deficient flood up to 7 996 km^2 is inundated, implying a productivity of 67 kg ha^{-1}.

The reported producer price of fresh fish is around 275 FCFA kg^{-1}. Annual home-consumption is set at 326 kg fresh fish per household, i.e. 31-36 kg per capita. That is in total 9172 ton annually or 10% of the catch in a normal year and 17% in a dry year. The assumption of a fixed home-consumption per household, irrespective of the catch, implies that households, for which fishing is not the main occupation, use a relatively larger share for their home-consumption.

On the basis of the data presented, it can be deduced that the maximum value of the fish marketed can be 23.2 billion FCFA (US$ 75 million) in a normal year and 12.2 billion FCFA (US$ 40 million) in a dry year. Monetary inputs are 5.4 billion FCFA (fuel included), but additional operating costs in the form of firewood for smoking fish have to be included, so that maximum gross revenue of the sector is 16.2 and 5.9 billion FCFA in a normal and a dry year, respectively.

Expenditure on firewood has been calculated on the basis of the following data: *(i)* to produce 1 kg of smoked fish, 2.95 kg of fresh fish and 5.8 kg firewood are needed, *(ii)* 70% of the total catch is transformed into smoked fish, *(iii)* the price of firewood is 15 FCFA kg^{-1} and *(iv)* 20% of the fish is smoked using manure.

3.4.4 Input-output table

The monetary inputs and outputs of the three fishery activities are given in Table 3.14. Subsequently, total inputs and outputs of the three fishery activities for a normal and a dry year are quantified (Table 3.15).

Table 3.14. Financial balance of fishery activities (thousand FCFA per household).

	ACTIVITY		
	MAIN MIGRANT	MAIN SEDENTARY	SECONDARY SEDENTARY
Normal flood			
Total catch (fresh)	1 288	1 030	209
Marketable product (fresh)	1197	938	118
Monetary inputs[a]	272	217	44
Firewood	77	62	13
Gross revenue	847	659	61
Low flood			
Total catch (fresh)	736	588	119
Marketable product (fresh)	644	497	28
Monetary inputs[a]	272	217	44
Firewood	44	35	7
Gross revenue	328	244	-23

a) firewood excluded.

Table 3.15. *Inputs and outputs of fishery activities.*

	ACTIVITY		
	MAIN MIGRANT	MAIN SEDENTARY	SECONDARY SEDENTARY
INPUTS [household^{-1} yr^{-1}]			
Labour [man-year]	3.62	3.62	1.81[a)]
Monetary inputs [1000 FCFA]			
- Depreciation equipment	182	155	31
- Maintenance equipment	41	32	7
- Fuel for motor-boats	48	30	6
- Firewood (normal/dry year)	77/44	62/35	13/7
Total (normal/dry year)	348/315	279/252	57/51
OUTPUT [household^{-1} yr^{-1}]			
Fish [ton][b]			
- Normal year	4.68	3.74	0.76
- Dry year	2.68	2.14	0.43

a) employed only during labour period 6: 'rest of the year', see under crop cultivation.
b) smoked and drought fish, but expressed as fresh fish.

4. THE MAIN CONSTRAINTS AND INTERRELATIONS

4.1 Constraints

The optimization model consists of a set of so-called goal variables, representing the various objectives, and a large number of restrictions on and relations between variables. As all relations are linear, the optimum value of any goal variable can be found by Linear Programming (LP) subject to the set of restrictions and relations specified in the model and to the restrictions specified for all other goals.

In this section, the main constraints on variables are discussed as formalized in the optimization model, in the next section the main relations between the variables included in the model are presented. A full account is given in Report 3.

4.1.1 Competition for land.

Both, arable cropping systems and animal husbandry require land. Moreover, if part of the land is to be reserved for wildlife, that excludes agricultural exploitation. The basic restriction incorporated is, that land can be used for one purpose at the time only, thus introducing the competition for land.

Not all land is suitable for arable cropping. In the Region 16 different soil types are distinguished, of which 12 are in principle suitable for arable farming (Report 1). Due to specific conditions, such as severe degradation for instance, part of the potentially suitable land can be excluded from agricultural use. A so-called 'utility index' - ranging from 0 if none, to 1 if all can be used - has been assigned to each soil type in each agro-ecological zone to take this possibility into account.

Not all crops, however, can be cultivated on each of these 12 soil types. Table 3.2 presents a summary of the potential suitability of the various soil types for each of the cropping activities. Moreover, even if a soil type is suitable for a certain crop activity, not all land can in practice be cultivated as the distance from a village may be too large. In fact, we consider land located further than 6 kilometres from a permanent water point unsuitable for arable farming. Its use is restricted to pasture.

In some crop activities, periods of fallow are specified to guarantee sustainability. In those cases, for each km^2 of land under cultivation, a specified number of km^2 must be fallowed.

In summary, available land is reduced to suitable land for arable farming in three steps:

- suitable for any kind of agricultural exploitation (utility index);
- suitable for arable farming (soil type);
- within reasonable distance from a permanent water point (6 km radius).

Land requirements for arable farming follow directly from the level of crop activities: one unit of a crop activity requires one km^2 of a specified soil type plus possibly a specified fallow area. Alternatively, land can be used as pasture or may be left unused. Total land use within a 6 km radius from a water point for each agro-ecological zone and for each soil type should not exceed the available area.

For specific soil types in specific agro-ecological zones a number of additional constraints are defined (for further details see Report 2, Chapters 2-10).

- In the agro-ecological zone Gourma only part of the soil type C2 is considered arable (180 km^2).
- Arable land on soil type D1 is limited to 15% the in agro-ecological zones Sourou and Gourma, 100% in the agro-ecological zones Séno Bankass, Plateau, Delta Central and Méma Dioura and 0% elsewhere.
- For soil type E1a these fraction are 100% in the agro-ecological zones Plateau and Delta Central, 15% in the Gourma and 0% elsewhere.
- Outside polder rice cultivation on soil types E1b, E2b and F3b is limited in area.
- Arable farming on soil tyep E2a in the Gourma is excluded.
- On soil type F1, the area suitable for vegetable growing, including shallots, is limited because of the necessity of nearby located irrigation water. In addition, not all of the remaining soil type F1 can be used for crops.
- Only part of soil type G can be used to cultivate flood retreat sorghum (i.e. 25% of unit TI7, PIRT classification).

Finally, a number of additional constraints for specific crops or crop activities has been defined.

- Because of rotation constraints the total area under groundnut and cowpea in any agro-ecological zone should not exceed 10% of the total millet/sorghum/fonio area of that agro-ecological zone.
- The total area for vegetable cultivation should not comprise more than 2/3 shallot.
- The total area under polder rice cultivation is restricted to the available polder area.
- The total area under irrigated rice cultivation is restricted to the available irrigated area.

Land outside a radius of 6 km from a permanent water point is further subdivided in the area within a 15 km radius from a water point and the area outside that radius. Land of 6 to 15 km from a water point is considered potential pasture for semi-mobile livestock all year round and for migrant livestock during the dry season only. Land further away than 15 km can only be used as wet season pasture because of drinking water restrictions and can only be used for migrant livestock activities.

As an alternative to agricultural use, land could be reserved to protect wildlife. The inner Niger Delta, one of the most extended African wetlands, is an important wintering place for many birds. For that reason the World Conservation Union in its Sahel program 1989 recommends to conserve an area of in total 1 431 km^2 in the Delta for nature protection (IUCN, 1989). In the model this is incorporated as the possibility to exclude a certain area in the Delta Central from exploitation, implying a ban on any agricultural activity (including fishing).

4.1.2 Competition for labour

All activities demand labour input. The unit of measurement of labour is a man-day: the work accomplished by an adult male during one working day. The labour requirement of an activity during a certain period of time is expressed in man, i.e. the quotient of labour [man-day] and time [day]. Hence [man-day] * $[day^{-1}]$ = [man].

The year is divided into six periods, based on the agricultural calendar (Subsection 3.1.3). The first three periods (duration 90 days) coincide with the wet season, the remainder with the dry season. For livestock activities labour requirements are specified for these two seasons separately. For the first two fishery activities, i.e. having fisheries as primary occupation, are considered to require labour input throughout the year. For the third activity, where fishing is a secondary occupation, labour input is required during period 6 only.

For each period and in each agro-ecological zone total labour demand should not exceed the local labour supply (expressed in adult equivalents). Hence, temporary migration between agro-ecological zones is excluded in this version of the model.

From the labour supply the number of emigrants is deducted (Section 5.2).

4.1.3 Oxen and manure restriction

Animal traction on the field (ploughing and weeding) is generally provided by oxen-teams. The unit of measurement of animal traction is an oxen-team day: the work accomplished by a team of oxen during one working day. The input requirement is expressed as the number of oxen-teams necessary to cultivate one km^2 as specified for a certain crop activity. For each agro-ecological zone the total required oxen traction input is calculated. The total number of oxen-teams required in a agro-ecological zone should not exceed the number available. The latter is an output of one of the animal husbandry activities.

For manure, as for oxen, the demand in a agro-ecological zone should not exceed the available supply. In addition to application in arable farming, manure is in some agro-ecological zones used as fuel due to lack of firewood. The supply of manure is a function of the level of livestock activities in the agro-ecological zone.

4.1.4 Forage restriction

Forage is one of the inputs in livestock activities. Forage requirements are further specified according to their temporal and spatial specifications and to their quality. The calculation of pasture forage production and its temporal, spatial and quality specifications are presented in Subsection 4.2.3. Taking into account fodder crops, crop residues and possible imported concentrates, assuming these to be available during the dry season only, an overall picture of forage supply in time and in quality differentiated per agro-ecological zone is obtained. Livestock activities have specified forage requirements and the general constraint must hold that the demand for forage, differentiated in time and quality, in each agro-ecological zone does not exceed its supply.

4.1.5 Upper limit to fish catch

Total catch of fish in the region is subject to an upper limit, depending on the level of the flood. Two levels are distinguished: one associated with normal rainfall and one with a dry year. If part of the Delta is reserved for wildlife protection (Subsection 4.1.1), not all water can be fished, hence the ceiling on total catch will be lower.

4.1.6 Minimum number of transport animals

As means of transport, donkeys and camels are indispensable for daily life in the region. It is, however, difficult to assign them directly to specific agricultural activities. Therefore, we have related the minimum number of donkeys required to the size of the population in each agro-ecological zone. The number of camels is set at a fixed value for the region as a whole, because, due to their mobility, it is hard to attribute them to a specific agro-ecological zone.

In the present version of the model, one donkey is required for each 20 inhabitants; the number of camels is fixed at 13 000 for the region as a whole.

4.2 Relations

4.2.1 Crop yields

Crop yield per unit area depends on the activity (= technology combined with soil type), on rainfall and, sometimes, flood. Expected rainfall itself depends on the rainfall zone in which the activity takes place and on whether it is a dry year or a normal year. In the model, a distinction has been made between the main product of a crop, the grain for cereals, and the so-called by-product, the crop residues that can be used as fodder (see also Paragraph 3.2.2.1).

Yield refers to net yield, i.e. harvest and post-harvest losses have been subtracted, so that it equals consumable or marketable product.

Total production of crop by-products consists of two components, viz. a basic amount per km^2 and an amount depending proportionally on grain yield. Not all crop residues are available for animal consumption. The available fraction is crop-specific. Per crop activity the by-products are classified in four quality classes, based on N-content [$g\ kg^{-1}$] (Paragraph 3.2.2.1).

4.2.2 Crop inputs

Four groups of inputs are defined: labour, monetary inputs, traction and nutrient elements.

Apart from nutrient elements application and the labour requirement during harvest time of millet, inputs depend on activity only, not on yield (note that for the same activity yields may vary according to rainfall).

Monetary inputs are subdivided into operating costs and capital charges (depreciation). The monetary inputs of all crop activities are calculated for each agro-ecological zone.

The required external input of nutrient elements, whether in the form of organic manure or chemical fertilizer, is proportional to the yield of the main product. We distinguish four nutrient inputs: farmyard manure (expressed in dry matter) and the macro-elements N, P, and K in elementary form.

4.2.3 Forage production of pastures

Land used as pasture is subdivided into five categories according to location and grazing regime.

1. Pasture within a 6 km radius from a permanent water point; all year grazing.
2. Pasture from 6 to 15 km from a permanent water point; all year grazing.
3. Pasture from 6 to 15 km from a permanent water point; grazing during the dry season only.
4. Pasture from 6 to 15 km from a permanent water point; grazing during the wet season only.
5. Pasture outside a 15 km radius from a water point; grazing during the wet season only.

As a consequence, in the model forage supply from pastures has a double dimension: location and time. This has direct consequences for the mode of exploitation of this source of forage in livestock activities.

Sedentary animal husbandry activities need pastures within a 6 km radius from a water point both in the dry and the wet season. Semi-mobile livestock grazes during the hot season (February-June) on pastures 6-15 km from a permanent water point. At least once every three days they have to return to the village or a permanent water point to be watered. Migrant systems exploit the wet season pastures (> 15 km), but need during the dry season pastures within a 15 km radius too. The grazing regime opted for in the 6-15 km zone is part of the optimization process.

Pasture land is characterized by soil type and agro-ecological zone. Its forage production is a function of these characteristics. For soil type this is evident. Each agro-ecological zone is located in one of the four rainfall zones which determine, in combination with the weather regime, expected rainfall and hence productivity.

Not only the actual level of fodder availability has been estimated, but also the situation related to the hypothetic existence of a system of effective fire control in the upland part of the region and the practice of mowing grass in the part of the Delta that is inundated during part of the year. Hence, two alternatives are formulated:

1. Fire control and mowing;
2. No fire control nor mowing.

To calculate forage production of pastures a number of assumptions is made. A full account is given in Report 2 (Chapter 11), but we mention here two important ones. First, 35% of the total above ground production of the herb layer is considered available for animal consumption under all year grazing; for wet season grazing this percentage is 50. Secondly, forage production of fallow land is set at half the production of similar rangeland.

Not only the quantity of the forage supply is taken into account but also its quality in terms of N-content. The same classification in four categories is applied as for crop by-products (Paragraph 3.2.2.1).

In addition, the production of woody species available for animal consumption (browse) is calculated (only goats and camels are considered to be consumers of this forage). Moreover, only consumption during the dry season is taken into account.

Summarizing, forage availability from pastures is divided in forage (4 quality classes + browse) within a 6 km radius from a permanent water point (available for sedentary livestock), within a 15 km radius, and outside that radius (wet season pastures for migrant livestock activities only). A further distinction is made on the basis of the period of the year the forage is available.

4.2.4 Subsistence needs

Subsistence needs are defined as the minimum amount of agricultural products required for consumption by the producers and their dependents, within a delimited area or system. 'Subsistence needs' can therefore be defined at different levels: family level, subregional level (level of agro-ecological zone), regional or national level. In this study subsistence needs refer to the subregional level. (Only once, when it appears in one of the goal variables, at the regional level). This means that it can be interpreted as the consumption within the household of agricultural products within the boundaries of a agro-ecological zone. That does not exclude trade of these products on local markets or exchange between producers; it simply implies that a certain minimum quantity does not leave the agro-ecological zone in question (if enough is produced) or must be imported into the agro-ecological zone (if local production is not sufficient).

Subsistence needs include three components:

a) Animal protein intake.
b) Energy intake.
c) Variation in the diet of crop products.

Subsistence needs of fish are defined as a function of the number of households engaged in fisheries. Members of these households are considered to satisfy their minimum animal protein requirement from this fish consumption. Their own consumption of fish is reported to be 326 kg (fresh) fish per household per year (Report 2, Chapter 16).

The minimum subsistence needs of meat, grain and other crop products are set proportional to the number of inhabitants, that is the original population minus emigration. Subsistence needs of grain are expressed as a minimum energy intake per capita. The unit of measurement of energy intake is millet-equivalents. For example, 1 kg rice is equivalent to 1.23 kg millet.

Crop products are the main suppliers of energy in food. According to FAO/WHO standards, average daily intake should be 2 088 Kcal per person, taking into account the age-structure of the population in the region (FAO/WMO, 1973; CRD, 1986). Subtracting the minimum intake of animal protein (see below) it results in a minimum energy intake from crop products of 1 864 Kcal person^{-1} day^{-1} or, in millet-equivalents, 626 g millet per person per day (Mondot-Bernand, 1980). This means that 228 kg millet person^{-1} year^{-1} suffice to supply the minimum energy requirement of an average inhabitant (children included).

Under certain restrictions (see below) the model is free to choose a combination of crop products for own consumption as long as the total energy content is equivalent to at least 228 kg millet per person per year.

A minimum variation in the diet of crop products is however required if one wants to keep it eatable. The minimum annual consumption of different crop products is to some extent arbitrary; in the present model specification we have chosen:

- at least 5 kg peanut per person per year;
- at least 2 kg cowpea per person per year;
- at least 5 kg shallot (fresh weight) per person per year;
- at least 15 kg other vegetables (fresh weight) per person per year;
- at least 10 kg rice per person per year.

The minimum animal protein intake has been set at 25 g meat per person per day and two litres of milk per week. This refers to an average requirement; the distribution milk/meat may vary per individual, one of the reasons being that the availability of milk is not evenly distributed over the population.

4.3 Institutional and socio-economic constraints

In the LP-model, the target production and the distribution of land use between arable crops and livestock, and within the former among the various crop activities on the one hand and the distribution of labour among the various activities, on the other hand, are determined on the basis of regional strategies not taking into account immediate, short-term or medium-term goals of the farmers. In actual farming practice, farmers encounter problems that go far beyond the purely physical constraints as described in detail above. Failure to solve these problems seriously hampers realisation of the production potential, even if the technical constraints are alleviated. However, in reality, such constraints cannot be effectively removed without first alleviating the various socio-economic constraints.

These constraints can be subdivided into structural problems (e.g. availability of labour, lack of rural savings, lack of effective participation of the rural population) and institutional problems (e.g. very tight market in both agricultural produce and inputs, poor communications network, problems of land ownership, lack of technical advisors). Note, however, that this distinction is somewhat academic: the problem of land ownership for example, is as much a structural as an institutional problem and the lack of rural savings, quite apart from the low productivity of current production techniques, is both related to socio-economic structures and technical and administrative institutions.

Solving these problems, whether structural or institutional, is most important because they hamper the implementation of the various technical solutions that emerge from this study. Among the various constraints requiring urgent attention are those relating to land, labour, the lack of rural savings and technical advisors. Such problems cannot be solved unless we introduce certain policy measures.

4.3.1 Land tenure problems

Land tenure in the Region refers to two objects, namely the ownership of arable land and pastures and that of water resources.

Ownership of arable land, i.e. the right of individuals, families or groups to land, or the right to exploit it by growing crops, contrary to that of pastures, appears to be well-established and universally accepted by each social category. As a result, grazing land is being gradually transformed into arable fields (most of these fields in the delta zone is cultivated by 'jowros' or with their permission) and a number of producers find themselves forced onto marginal land. For example, in the Delta Central only 27%, in the Zone Lacustre 14% and in the Plateau 21% of the cultivated area takes the form of owner farms, the rest being cultivated on a share tenancy, tenant farming or lease basis (Report 1, Chapter 8). Contrary to what may seem the case, therefore, actually a critical shortage of land exists, even if this situation is created artificially. At present, this land shortage could also be explained by reduced flood levels (Section 2.3) and lack of rain, and also by the growing population and changing way of life (i.e. an increasing number of pastoralists and fishermen are turning to farming). The main reason, however, is the claimby local prominent citizens, i.e. government officials, traders and traditional 'chiefs' on fertile land, which they reassign in the form of non-owner exploitation.

The appropriation of pastures and watering holes, however, has less and less to do with local customs, even in the delta zone where their controll and management are often hampered by 'official' illegitimate favours and greed on the part of the 'jowros'. The main consequence of this deterioration of the situation in land rights, as far as pastures are concerned, has been the emergence of so-called 'commonland', whose main characteristic is the collective exploitation of pastures by individually appropriated herds. This is one of the reasons for the increase in stock numbers, despite efforts by the authorities' to persuade livestockholders to sell off their stock.

While it is obvious that better land tenure conditions will not in itself lead to more intensive activities, the fact nevertheless remains that lack of stability not only presents an obstacle to intensification but also breeds strife between the various social groups for land rights. Before land can be redistributed among the various production techniques, as a function of target yields and monetary objectives, current social tensions over the issue of land ownership must be resolved.

4.3.2 Labour

Labour is mainly family-based in the Region. Hired labour of any importance is seasonal, when it exists at all, and is only available during the cropping season if some climatic disaster has occurred in one of the agro-ecological zones, or in the neighbouring regions. Two labour-related factors may well hamper the achievement of the technical objectives described.

The first factor is related to the high migration level due to economic reasons and a certain social ritual on the part of young people. Yet another factor is the timing of the departure, which tends to fall in the 5th and 6th period of the year (Subsection 3.1.3) when a high labour demand exists for, among other things, out-of-season rice crops, market gardening and fishing, three labour-intensive sectors. This migration affects not only the quantity of the Region's labour supply but also the quality.

The second factor refers to the fact that workers are not easily interchangeable from one agricultural sector to the other. The surplus labour in pastoral activities, for example, does not automatically offset the shortage in arable farming or fishing activities. Lack of technical expertise, coupled with certain ethnic and/or class-related factors are most likely at the base of this phenomenon. Even if such a transfer is possible, it occurs outside the socio-cultural area, hence the exodus.

4.3.3 Tight market and lack of rural savings

The tight market refers not only to outputs (agricultural produce) but also to inputs. It is linked to the low purchasing power of the local inhabitants (producers as well as consumers), to the sparse and poor quality road network (Cissé & Bâ, 1990), to the Region's limited production capacity and to traditional conservation and storage techniques. Another reason for the tight market is the high cost of agricultural inputs compared with the low monetary profits derived from their use, many of the conditions relating to production and trade being beyond the control of rural inhabitants.

With respect to local savings, the profits made by rural producers may well seem insignificant and thus explain the lack of savings. In reality, however, the latter is not so much the result of low surplus as of the amounts levied by the financial and technical authorities (UICN, 1989). Another reason for the lack of savings is embezzlement by usurious lenders and unscrupulous middlemen (Cissé & Bâ, 1990). Finally, and most importantly, it is due to the fact that farmers, fishermen, stockbreeders, as well as government officials and traders tend to invest the vast majority of agricultural and other surplusses in livestock.

In addition, the failure of banks to adapt to rural practices, their inflexible administrative approach and unattractive interest rates, which do not even keep pace with inflation, are hardly conducive to saving. Little wonder then that local inhabitants prefer to build up their livestock rather than sell it off. The low costs involved in stockbreeding (free pastures and low-cost veterinary services) are another factor in the increase in animal population, with all its negative implications for the environment.

4.3.4 Poor administrative and public information structures

The shortcomings of the administrative and public information structures are expressed in the failure of these structures to meet producers' needs and to organise rural inhabitants in such a way that they begin to take responsibility for themselves (Cissé & Bâ, 1990). The reason for this failure is not only the inadequacy in the number and quality of the agents employed, but also in their distribution. Only a very small number of the extension agents, charged with the vitally important task of educating and organising rural populations, actually come into contact with the inhabitants at village level.

The difficulties encountered by administrators trying to manage both the stock of products needed by local inhabitants and the relevant distribution channels does not only originate from a particular scientific and technical environment in which they operate, but also from a number of internal problems such as the lack of technical facilities, a cumbersome bureaucracy and the fact that the technical advisors are often poorly qualified for their tasks. Such attitudes and behaviour are largely to blame for the poor performance of the various rural organisations set up.

In conclusion, it is important to note that the various constraints listed above manifest themselves in certain types of economic and social practices. In order to remove these constraints, we must first introduce a suitable economic policy which takes account of the current state of production systems and the requirements of potential systems. Such a policy should focus, among other things, on the issue of land ownership, the market for products as well as administrative and technical organisation.

Land ownership problems can only be solved through a policy aiming on one hand at removing the contradiction between current land use regulations, based mainly on traditional law, and modern legislation and on the other hand, at making rural inhabitants responsible for clearly defined rural areas. The task of devising and implementing such a policy is the responsability of the political and administrative authorities.

The problems of a tight market and low purchasing power among rural inhabitants could be solved by increasing the productivity of production systems and finding outlets for products on both domestic and external markets. That requires, however, intensification of production activities, which in turn depends on a more favourable policy for farmers, with respect to the price of fertilizer and transport, thus enabling products to compete. In addition, efforts must be made to find outlets outside the domestic market. Unfortunately, however, influencing these vital conditions is far beyond the scope of the farmers and the powers of the local and regional authorities.

If there is one area where national politics has an important role to play, it is in restructuring administrative and technical supervision, starting with an increase in the number of agents who actually work in cooperation with the farmers, in order to find general solutions to the problems of rural life. In addition, these agents should be distributed according to the importance attached to particular production methods within the various agro-ecological zones.

A combination of political/economic measures is therefore needed in order to implement viable production techniques. Such measures should not only accompany but also serve to highlight the various social and economic practices, which should not be considered rigid situations and activities but as processes which are inherent to the very nature of the systems and the development goals.

5. GOALS

In total twenty variables have been defined that, in principle, can be optimized and on which minimum requirements can be set. In practice, only few of these so-called goal variables are indeed optimized (maximized or minimized); in most cases they serve only to ascertain that predefined minimum or maximum levels are not exceeded.

Within the set of goal variables one can distinguish different groups, as discussed in the following sections.

5.1 Physical production targets in a normal year

With regard to crop production the physical production targets include:

- Total millet, sorghum & fonio production in a normal year with respect to rainfall and flood.
- Total rice production in a normal year.
- Total *marketable* crop production in a normal year. This is total crop production of the region minus the subsistence needs of crop products (Subsection 4.2.4).

All these goal variables are expressed in ton (=1 000 kg) per year.

With respect to animal husbandry the physical production targets include:

- Total meat production, comprising beef, sheep and goat meat.
- Total beef production.
- Total milk production, comprising cow, sheep and goat milk.
- Total herd size, expressed in Tropical Livestock Units [TLU].

The first three goal variables are expressed in ton per year (liveweight for meat).

In the two base scenarios (Sections 6.1 - 6.3) the values of the various goal variables are calculated under the assumption of the absence of effective fire control on natural pastures and no mowing of inundated pastures. The effect of alternative assumptions, which would result in higher forage production but also higher labour and monetary inputs, can, however, be examined.

Moreover, in the two base runs we assume the natural pastures to be degraded to a certain extent (Report 2, Chapter 11). But here also, the effect of alternative assumptions can be relatively easily examined by small adaptations of the model data, for instance by manipulating the so-called utility index (Subsection 4.1.1).

5.2 Monetary targets

A pivotal goal variable in the optimizations is Total Monetary (or Gross) Revenue originating from crop, livestock and fisheries activities in a normal year plus incoming money from emigrants. It includes the balance of all marketable outputs of agriculture (including fisheries) and all inputs as far as they have to be paid for in money.

Monetary revenue is defined as the value of the marketable product of an activity (i.e. total production minus subsistence needs) minus the monetary inputs of that activity. As labour inputs are not priced, they do not appear in this accounting scheme, nor do organic manure and land (except in cases of depreciation costs of polders or irrigation works). Therefore, 'Gross' Revenue is used as a synonym of Monetary Revenue.

Note further that crop by-products produced within the region are not priced either, but are treated similarly to organic manure: in physical terms they are included in the Input-Output framework, taking care that the balance is correct, but they do not appear in the monetary accounting.

Total Monetary Revenue includes the incoming money from emigrants. We reserve the term 'emigration' for those members of the base population that leave the region (or the agricultural sector) and do not return to work in the region during peak labour periods. Emigrated labour does not demand locally grown food, so that subsistence needs can be diminished. Moreover, one can expect that emigrated labour brings in a certain amount of money. In other words, the region can export, in addition to agricultural products, also labour at a certain price.

Emigrants can, by definition, not be employed in any of the agricultural activities in the region. While maximizing Total Gross Revenue, the model weighs the gains in terms of lower subsistence needs and more income from abroad against the loss in terms of lower labour availability for agricultural activities in the region.

In addition to Total Gross Revenue, three other monetary variables have been defined. They refer to monetary inputs and serve mainly to restrict their value.

- Total monetary inputs of crop activities (seed, fertilizer, other operating costs, depreciation of equipment).
- Total monetary inputs of livestock activities (veterinary care, concentrates, etc.).
- Total monetary inputs of crop, livestock and fishery activities (includes, in addition to the above mentioned costs, depreciation and maintenance of fishing equipment and fuel for motor-boats).

All the goal variables in this group are expressed in million FCFA per year.

5.3 Risks in a dry year

Goal variables in this category are, similarly to those referring to monetary inputs, primarily used to restrict their values to desired minima or maxima. The variables relate to physical crop production (in ton per year) and the number of animals at risk, in case of a dry year and a low flood:

- Total millet, sorghum & fonio production in a dry year.
- Total rice production in a dry year.
- Total crop production in a dry year (the sum of the two productions above plus the production of peanut, cowpea and vegetables).

Another objective related to risk avoidance is minimization of the grain deficit in a dry year, that is total grain production (millet, sorghum, fonio, rice, peanut and cowpea) minus the subsistence needs of grains. The unit of measurement is millet-equivalents, the conversion factors being derived from the energy content of the grains of the different crops in relation to millet. For example, 1 kg rice is equivalent to 1.23 kg millet (Subsection 4.2.4).

Grain deficits in a dry year can be defined in two ways: *(i)* the difference between the regional subsistence needs and total production or *(ii)* the sum of sub-regional (agro-ecological zone) grain deficits ignoring the occasional subregional surpluses. In the former case a surplus in one agro-ecological zone can compensate for a deficit in another agro-ecological zone; in the latter case the deficits in any of the agro-ecological zones are minimized. Emphasis on the latter objective will result in a more evenly distributed crop production across the agro-ecological zones in relation to their population sizes.

Finally, with respect to risks, the total number of animals at risk in a dry year is formulated as a goal variable. It is defined as the number of animals, expressed in TLU, for which insufficient feed - quantitatively or qualitatively - is available from pastures, fodder crops and crop by-products in a dry year. Its value may not be equated to mortality in a dry year, as animal migration or imported supplementary feed may offer solace. It represents the number of animals that cannot be supported by the regional forage production in a dry year. Hence, it is defined as the number of animals that can be fed in a normal year minus the number that can be fed in a dry year.

5.4 Employment and emigration

Restricting the number of people leaving the region might be an objective as such. One can formulate this goal in two ways: indirectly, by maximizing agricultural employment (and ensuring that this means gainful employment by, for instance, setting a lower limit to Total Gross Revenue) or, directly, by keeping emigration within limits. ('Emigration' is defined in Section 5.2. Note that the term can indicate leaving the region either physically or economically, i.e. by leaving the agricultural sector). Emigration is expressed in persons.

Total employment is expressed in man-years: the labour input in any of the activities is multiplied by the duration of the period that labour is required (Subsection 4.1.2). A summation over all periods, all activities and all agro-ecological zones results in total labour input over the year or total employment, expressed in man-years.

5.5 Nature reserve

In Subsection 4.1.1 we introduced the possibility of reserving an area in the delta for wildlife protection. When a positive lower limit is set to the goal variable that represents this area, part of the land is not available for crop cultivation or grazing. Moreover, the upper limit of fish catch will be reduced (Subsection 4.1.5), reflecting the impact of the smaller area of surface water that can be fished.

In this way, the influences of a possible objective of creating a nature reserve have been taken into account.

6. DEVELOPMENT SCENARIOS

6.1 The two base scenarios

In the preceding chapters we have treated the possible objectives for development of the Region and the main constraints and relations included in the model. On the basis of these elements it is possible to generate technically feasible scenarios for agricultural land use with their associated production and input levels.

Each scenario is characterized by the goal optimized and the set of restrictions imposed on the other objectives. In other words, a scenario represents the results of the optimization of one goal variable, subject to a particular set of restrictions on the other goal variables and, of course, subject to all model restrictions. Changing these model restrictions, for example the constraints imposed on or certain coefficients, leads to modifications of the base scenario.

In this chapter we will focus on the optimization of one goal in particular, maximization of total gross (or monetary) revenue, under two sets of goal restrictions. One set of restrictions represents a more risk-taking attitude, the other emphasizes avoiding catastrophe under unfavourable weather conditions. Moreover, the latter strategy places a higher premium on restricted emigration. Satisfying these additional requirements implies that the value of the monetary revenue in a normal rainfall year is lower. In technical terms: the feasible area will be more restricted and hence the optimum value of the goal to be maximized will be lower. To what extent this happens, in other words, the price one has to pay for diminishing risks, will be illustrated in the next sections.

First, the two base scenarios, or main development strategies, for the agricultural sector of the Region are introduced.

6.1.1 R-scenario

This more Risky, high-revenue development scenario (R-scenario) is characterized by:

- a high production surplus (in monetary terms) in a normal rainfall year;
- permitted emigration of up to 250 000 persons (almost one fifth of the original population of the Region);
- no strong demands on minimum production levels in either a normal or a dry year;
- acceptation of a relatively large grain deficit and a relatively large number of animals at risk in a dry year.

6.1.2 S-scenario

This Self-Sufficiency, Safety-first development scenario (S-scenario) is characterized by:

- self-sufficiency in basic food, also in dry years (as much as reasonably possible);

- low-risk;
- an even distribution of production over the agro-ecological zones;
- a certain degree of diversification among the main crops;
- restricted emigration;
- high employment.

6.2 Results of the two base scenarios at the regional level

6.2.1 Construction of the S-scenario

In the R-scenario total gross revenue from crop, livestock and fishery activities is maximized under relatively loose restrictions on other objectives. The S-scenario is constructed by successively, in six steps, tightening the restrictions on these objectives. At each step the optimum value that can be attained for total gross revenue decreases.

		Maximum attainable total gross revenue [billion FCFA]
R-scenario		66.7
step 1:	Emigration ≤ 50 000 persons (250 000 in the R-scenario)	45.7
step 2:	Total regional grain deficit in a dry year ≤ 110 000 t millet-equivalents (was ≤ 150 000) and sum grain deficits in agro-ecological zones ≤ 130 000 t millet-equivalents (was ≤ 150 000)	43.1
step 3:	Number of animals at risk in a dry year ≤ 100 000 TLU (was ≤ 400 000)	36.0
step 4:	Rice production in a normal year ≥ 42 000 ton (was ≥ 20 000)	35.2
step 5:	Monetary inputs in crop activities ≤ 15 billion FCFA (was ≤ 20)	33.7
step 6:	Employment ≥ 336 000 man-year (was ≥ 300 000) = S-scenario	32.5

In Table 6.1 the values assumed by the goal variables at each of these steps are presented. The value of the goal optimized is given in row 8 and printed in bold. The restriction introduced at each step is underlined. An "*" denotes a binding restriction: the goal restriction imposed is a constraint on attaining a higher total gross revenue. These binding restrictions are discussed in Subsection 6.2.3.

Table 6.1. Values of the goal variables under increasingly tighter restrictions, going stepwise from the R- to the S-scenario.

Restriction / Goal variable	Value of the goal variables in the R-scenario	(1) R-scenario	(2) Emigration ≤ 50 000 persons	(3) Grain def. ≤ 130 000 & ≤ 110 000 ton	(4) Animals at risk ≤ 100 000 TLU	(5) Rice, normal year ≥ 42 000 ton	(6) Money input crops ≤15 000 mill. FCFA	(7) Employment ≥ 336 000 mn-yr = S-scenario
PRODUCTION, NORMAL YEAR [1000 ton]								
1. Millet, sorghum & fonio	≥ 160	160*	214	290	291	285	282	282
2. Rice	≥ 20	29	29	29	31	42*	42*	42*
3. Marketable crop products	-	45	55	129	133	139	92	101
4. Total meat	-	125	124	122	98	95	90	87
5. Beef	-	66	66	70	60	61	62	56
6. Milk	≥ 204	228	227	232	204*	204*	204*	204*
7. Animals [1000 TLU]	-	1762	1776	1807	1519	1513	1530	1491
MONETARY TARGETS, NORMAL YEAR [10^9 FCFA]								
8. Gross Revenue of crops, livestock and fisheries	-	**66.7**	**45.7**	**43.1**	**36.0**	**35.2**	**33.7**	**32.5**
9. Money inputs crops	≤ 20	6.0	10.9	16.7	16.9	17.1	15.0*	15.0*
10. Money inputs livestock	-	2.2	2.2	2.3	1.9	1.8	1.7	1.6
11. Money inputs crops, livestock and fisheries	-	15.2	17.8	25.9	25.7	25.8	23.6	23.6
PRODUCTION, DEFICITS AND RISKS IN A DRY YEAR [1000 ton]								
12. Millet, sorghum & fonio	-	82	116	155	156	152	151	152
13. Rice	≥ 10	10*	10*	10*	10*	13	12	12
14. Crop products	-	189	226	266	266	265	227	235
15. Regional grain deficit [1000 t millet-equiv.]	≤ 150	141	150	110*	110*	110*	110*	110*
16. Sum grain deficits of agro-e.z. [1000 t m.eq.]	≤ 150	150*	150*	130*	130*	130*	130*	130*
17. Number of animals at risk [1000 TLU]	≤ 400	400*	400*	400*	100*	100*	100*	100*
OTHER								
18. Employment [1000 mn-yr]	≥ 300	336	343	345	300*	302	300*	336*
19. Emigration [1000 persons]	≤ 250	250*	50*	50*	50*	50*	50*	50*

*: binding; _: restriction introduced

6.2.2 Total gross revenue

Total monetary revenue of the agricultural sector in the Region ranges from 66.7 billion FCFA (222 million US$) in the R-scenario to 32.5 billion FCFA (108 million US$) in the S-scenario. This implies a per capita monetary income of 64 000 FCFA (212 US$) per year in the R-scenario, in which emigration of a quarter of a million people is allowed, and of 26 000 FCFA (87 US$) per year in the S-scenario with 50 000 emigrants. Note that in addition to monetary income there is income in kind (Subsection 6.2.4).

The difference in total gross revenue between the two scenarios can largely be explained by the restrictions on emigration and number of animals at risk in a dry year in the S-scenario. Tightening the emigration restriction from 250 000 to 50 000 people, reduces total gross revenue by 21 billion FCFA (compare columns (1) and (2) in Table 6.1, row 8). Adding the restriction that only 100 000 instead of 400 000 TLU may be at risk in a dry year, reduces gross revenue by a further 7.1 billion FCFA (columns (3) and (4) in Table 6.1).

One must keep in mind that the results, both with respect to land use and to income levels, strongly depend on the prices of inputs and outputs that are assumed. In Subsections 6.4.2 and 6.4.3 results obtained under different price regimes will be presented. The prices of inputs and outputs are given below.

A. Prices of inputs

Purchase price of nutrient elements (in elementary form) is 450, 1 250 and 450 FCFA kg^{-1}, for nitrogen, phosphorus and potassium, respectively. Concentrates have a price of 44 FCFA kg^{-1}.

B. Prices of outputs

Producer prices of crop products [FCFA kg^{-1} DM] are 55 for ('hull-less' grains), 56 for sorghum ('hull-less' grains), 70 for rice (paddy) and fonio (hulled grain), 75 for cowpea (shelled) and for groundnut (unshelled). Producer prices are 59 FCFA kg^{-1} fresh weight for shallots (combination of leaf blades and bulbs) and 96 FCFA kg^{-1} fresh weight for the 'other vegetables'.

Producer prices for livestock products are 320 and 340 FCFA kg^{-1} liveweight for beef and small ruminant meat, respectively. Producer price of milk at Mopti is 180 FCFA kg^{-1}, wheras that of fish is 275 FCFA kg^{-1} fresh weight.

Incoming money from emigrants amounts to 75 000 FCFA $person^{-1}$ $year^{-1}$.

The rather low revenues in both scenarios are to a large extent due to the low profitability of arable farming (Table 6.2), which in addition to the unfavorable price ratios, is due to the satisfaction of subsistence needs for grain and the requirement of sustainable exploitation in terms of nutrients. The former requirement implies that only a limited part of the crop products are marketed and thus contribute to income. The requirement of sustainability implies that soil exhaustion is not permitted; application of fertilizer is often necessary to attain target yields, because fallowing and organic manure cannot satisfy the nutrient requirements dictated by export from the field and unavoidable losses. Fertilizer must be paid in money, which reduces monetary income (Table 6.3).

Table 6.2. Breakdown of Total Gross Revenue [10^9 FCFA].

SOURCE	VALUE MARKETABLE OUTPUT	MONETARY INPUTS	GROSS REVENUE
R-scenario			
Livestock	37	2	35
Fisheries	22	7	15
Crops	3	6	-3
Emigration			19
Total			66
S-scenario			
Livestock	24	2	22
Fisheries	21	7	14
Crops	7	15	-8
Emigration			4
Total			32

Table 6.3. Breakdown of Gross Revenue of arable farming [10^9 FCFA].

	R-SCENARIO	S-SCENARIO
INCOME[a]		
Millet	-3.0	2.1
Sorghum	0	0
Fonio	0	0.0
Groundnut	0.8	-0.5
Cowpea	-0.2	0.5
Shallot	4.3	0.9
Other vegetables	0.2	2.4
Rice	1.2	1.5
Total	3.3	6.9
EXPENDITURE		
Fertilizer	3.4	11.0
Other operating costs	1.3	1.9
Capital charges	1.2	2.1
Total	6.0	15.0
Gross revenue	-2.7	-8.1
Value of production used for subsistence needs	15.0	17.9

a) value of production minus subsistence needs.
0: less than 0.5 units.

6.2.3 Shadow prices

As shown in Table 6.1, a number of goal restrictions is binding. Logically, this occurs more frequently in the S-scenario that is characterized by tighter constraints on the goal variables than in the R-scenario. A binding restriction indicates that a more favourable value of the optimized goal variable could have been obtained, if that restriction would not have been imposed. To what extent the restriction limits the value of the goal optimized, is numerically expressed by its shadow price, defined as the change in the value of the goal variable at a relaxation of the restriction by one unit. The dimension of a shadow price is therefore: [unit of the goal variable, in this case million FCFA] / [unit of the restriction].

An example: The shadow price of the restriction 'total rice production ≥ 10 000 ton in a dry year' in the R-scenario is 0.458 million FCFA per ton. This means that if this constraint on rice production would have been relaxed to ≥ 9 999 ton, total gross revenue of the Region would have been 0.458 million FCFA higher. The 'price' of safeguarding one ton of rice production in a dry year is thus 458 000 FCFA. Because this refers to a hypothetical 'if... then...' situation, this does not represent the actual 'price' but is referred to as the 'shadow price' of a restriction.

All model restrictions can, in principle, show non-zero shadow prices. In this subsection we discuss only those of the goal restrictions.

High shadow prices are exhibited by the restriction 'number of animals at risk in a dry year'. In the R-scenario the shadow price is 18 000 FCFA per TLU, in the S-scenario 54 000. The sharp decline in attainable gross revenue when this goal restriction is tightened, is another expression of its importance.

The upper limit to emigration plays a similar role. Its shadow price is 96 000 FCFA per person in the R-scenario and increases to 236 000 in the S-scenario. The direct effect of restricted emigration on gross revenue is the smaller total amount of money generated by the emigrants at 75 000 FCFA per person per year. The higher shadow price implies that an additional effect exists originating from the higher subsistence needs, which is not sufficiently compensated by the higher labour availability in the Region.

The additional binding goal restrictions in the R-scenario are rice production in a dry year (discussed above) and the upper limit to the sum of grain deficits over all agro-ecological zones in a dry year. The shadow price for the latter restriction is, however, low: 2 FCFA per kg millet-equivalent.

This is not the case in the S-scenario, where the restrictions on grain deficits in dry years are tighter. Especially the requirement that total regional grain deficit should not exceed 110 000 ton millet-equivalents, is a major constraint for realizing a higher value of gross revenue. The shadow price of this restriction is 502 FCFA per kg millet-equivalent which exceeds by far the actual producer price of 55 FCFA per kg millet.

Another effective restriction in the S-scenario is the upper limit to total monetary input in crop activities, which was set at 15 billion FCFA to limit the dependence on these inputs. Its shadow price is 3.0 FCFA $FCFA^{-1}$, implying that these inputs are highly profitable. This, however, only applies to additional monetary inputs close to the limit of 15 billion FCFA; the shadow price decreases rapidly if the restriction is further slackened. This is reflected in the increase in gross revenue of only 1.5 billion FCFA when the restriction is slackened to 17.1 billion FCFA (Table 6.1, columns (6) and (5)). Hence, the average shadow price on that trajectory is 0.7.

The last two binding restrictions in the S-scenario are total milk production in a normal year and total employment. Their shadow prices are: 25 FCFA per kg milk and 110 000 FCFA per man-year.

6.2.4 Self-sufficiency in basic food

Can the Region provide the minimum basic food needs of its rural population, presently numbering about 1.3 million? For animal protein, the answer is: yes; for grains, however, hardly.

Subsistence needs for animal protein, set at 175 g of meat (carcass weight) or 600 g of fish (fresh weight) per person per week, can be satisfied easily, also under unfavourable weather conditions. Moreover, in both base scenarios on average 3 liter of milk per person per week is available.

For grains, the picture is different. In the R-scenario, even in years with normal rainfall and flood, an overall grain deficit of 23 000 ton of millet-equivalents exists, compared to a total regional grain production of 215 000 ton of millet-equivalents. In a dry year the deficit increases to 141 000 ton. In this scenario the combined demand of sustainability and maximum total monetary revenue results in *(i)* a relatively small area under cultivation, *(ii)* a rather low level of intensification and *(iii)* a bias towards the most profitable, but not necessarily the most energy-rich crops.

In the S-scenario an upper limit of 110 000 ton of millet-equivalents is set to total grain deficit in the Region in a dry year. At current prices such a deficit would be equivalent to grain imports worth at least 6 billion FCFA (20 million US$). In a normal year a surplus of 65 000 ton of millet-equivalents is produced, at an overall grain production of 349 000 ton. But even in that scenario the Region is not a major grain exporter.

Total production levels, including subsistence needs, for the various commodities in normal years with respect to rainfall and flood, are presented in Figure 6.1.

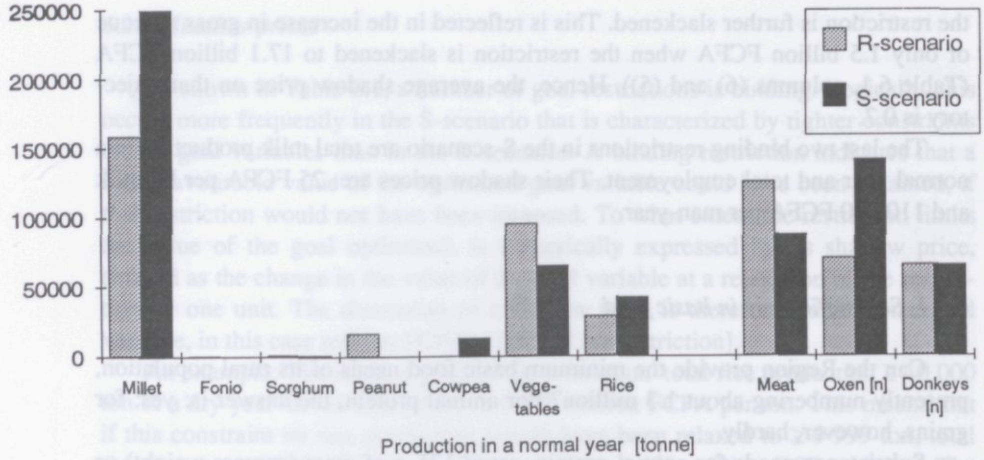

Figure 6.1. Total production of various commodities in a normal year [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

6.2.5 Arable farming

At present, about 4 000 km^2 is under cultivation in the Region, i.e. just under 5% of its total area. In the S-scenario the area under cultivation would expand to 4 600 km^2, whereas in the R-scenario there would be a slight reduction (3 840 km^2). The areas under fallow are 9 000 and 11 000 km^2 in the R-scenario and the S-scenario, respectively.

In terms of land use, millet is in both scenarios by far the major crop (Figure 6.2). In the R-scenario 91% of the cultivated land is under millet; in the S-scenario 85%. Its share in the physical production is somewhat lower, because of the high yields per unit area of vegetables (Table 6.4 and Figure 6.1, but note that vegetable yields are expressed in fresh weight and grain yields in dry matter).

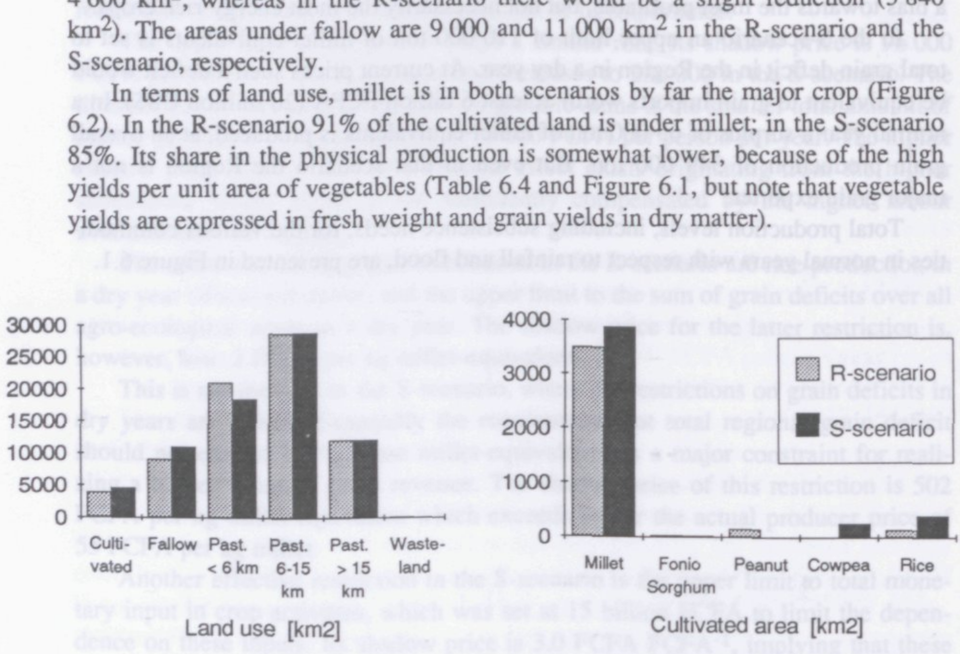

Figure 6.2. Land use (a) and cropping pattern on cultivated land (b) in the two base scenarios [km^2].

Table 6.4. Breakdown [% of weight] of total crop production in a normal year in the two base scenarios.

CROP	PRODUCTION	
	R-SCENARIO	S-SCENARIO
Millet	52.9	69.9
Sorghum	0.3	0.3
Fonio	0.1	0.0
Groundnut	5.5	0.0
Cowpea	0.0	3.3
Shallot[a]	25.8	5.4
Other vegetables[a]	5.9	10.7
Rice	9.5	10.4
Total	100.0	100.0
Total absolute [1000 ton]	300	402

[a]) fresh weight.

The contribution of groundnut to total crop production is 5% in the R-scenario while the crop is absent in the S-scenario. In the latter scenario cowpea contributes 3% to total production. Cowpea cultivation is selected in the optimization when emigration is limited (step 2), groundnut cultivation is no longer selected when the total monetary inputs in crop activities are restricted (step 5). The preference for cowpea in the S-scenario can partly be explained by the very low groundnut yields in dry years which interfere with the stricter limit on grain deficits in dry years in that scenario.

When monetary revenue is maximised, sorghum and fonio are very minor crops, each contributing less than 0.5% to total production. No fodder crops, neither fodder cowpea nor bourgou, are selected, given the prices of fertilizer and meat in these base runs. From the point of view of generating gross revenue, rice is neither an attractive crop. Rice is selected in the two scenarios because of explicit minimum goal restrictions: in the R-scenario on production in dry years, in the S-scenario on production in normal years (Table 6.1, rows 2 and 13). Without these restrictions no rice would be produced (and gross revenue of the Region would be 2.6 billion FCFA higher). Shallots and other vegetables, on the other hand, are profitable crops: the available area for cultivation is fully utilized in both scenarios.

Intensification of arable farming is in most instances not profitable. When no restrictions are set on other goal variables (the R-scenario), only 6% of the total cultivated area is under intensive cultivation, mainly groundnut (Table 6.5). Semi-intensive cultivation, with moderate doses of external nutrients and traditional production techniques, comprises 42% of the arable land. The remaining 52% is under extensive cultivation, i.e. without inorganic fertilizer and with traditional production techniques.

Table 6.5. Breakdown [% of cultivated land] of crops according to the three production levels in the two base scenarios.

CROP	LAND USE	
	R-SCENARIO	S-SCENARIO
Extensive		
Millet	50.8	38.8
Sorghum	0.6	0.5
Fonio	0.1	0.0
Rice	0.6	6.0
Subtotal	52.1	45.3
Semi-intensive		
Millet	38.9	24.9
Cowpea	0.0	6.0
Rice	3.0	2.0
Subtotal	41.9	32.9
Intensive		
Millet	1.0	21.0
Groundnut	4.0	0.0
Other vegetables	0.9	0.7
Rice	0.1	0.1
Subtotal	6.0	21.8
Total	100.0	100.0
Total absolute [km^2]	3 840	4 581

In the S-scenario, where more mouths must be fed and grain deficits in a dry year are more tightly restricted, intensification is much more common. This is reflected in the increase in monetary inputs in crop activities, under tighter restrictions with regard to permitted emigration and grain deficits (Table 6.1, row 9). To guarantee the required minimum grain production also in dry years, 21% of the cultivated area is under intensive millet cultivation. Intensive cowpea or groundnut cultivation appears to be less attractive in view of the multiple claims. When an upper limit is set to total monetary input in crop activities (step 6), they are the first not to be selected anymore.

Summarizing, intensification as such is only profitable for groundnut on a limited area, but may be necessary to achieve the minimum required grain production for subsistence. Intensification of millet is then the selected option. Moreover, the lower risks accepted in the S-scenario in terms of the availability of regionally produced grain, is 'paid for' by higher risks of fluctuations in external prices due to a greater dependency on chemical fertilizer.

In Table 6.6 the difference in intensification level between the R- and the S-scenario is presented in another way. It shows inorganic fertilizer and organic manure application for each crop as a weighted average of the selected production techniques.

Table 6.6. Application of chemical nitrogen and phosphorus fertilizers and manure in the various crop activities in the two base scenarios.

CROP	APPLICATION	
	R-SCENARIO	S-SCENARIO
Nitrogen[a] [kg ha^{-1}]		
Millet, sorghum & fonio	6	27
Groundnut	30	-
Cowpea	-	0
Vegetables	0	0
Rice	191	67
Phosphorus[a] [kg ha^{-1}]		
Millet, sorghum & fonio	1	3
Groundnut	9	-
Cowpea	-	3
Vegetables	0	0
Rice	8	3
Manure [kg DM ha^{-1}]		
Millet, sorghum & fonio	1 000	1 100
Groundnut	0	-
Cowpea	-	0
Vegetables	8 800	7 000
Rice	3 500	1 200

[a]) in elementary form.
0: less than 0.5 units.
-: zero value.

6.2.6 Livestock

According to IUCN (1989), the number of livestock in the region in the period 1977-1987 varied between 450 000 and 1 700 000 TLU. (A Tropical Livestock Unit [TLU] is a 'standard' animal with a liveweight of 250 kg (Subsection 3.3.1)). In June 1987 Resource Inventory and Management Ltd counted in total 1 123 000 TLU, consisting of 846 000 cattle, 228 000 sheep and goats and 49 000 camels and donkeys (RIM, 1987).

The number of animals in the two base scenarios is 1 762 000 TLU in the R-scenario and 1 491 000 in the S-scenario (Table 6.7). Note that these numbers can be supported for the species composition as given in Table 6.7. Dry matter intake per TLU varies with species, hence a different population composition will lead to a different total forage requirement for the same animal density.

Table 6.7. Number [1000 TLU] and % of the total number of animals according to species and to selected diet in the two base scenarios.

	NUMBER			
	R-SCENARIO		S-SCENARIO	
	[No]	[%]	[No]	[%]
SPECIES				
Cattle				
sedentary	228	12.9	296	19.9
semi-mobile	40	2.3	88	5.9
migrant	781	44.4	632	42.3
Subtotal	1 049	59.6	1 016	68.1
Sheep				
sedentary	9	0.5	7	0.5
semi-mobile	398	22.6	201	13.5
migrant	175	9.9	26	1.7
Goats				
semi-mobile	78	4.4	163	10.9
migrant	5	0.3	31	2.1
Subtotal	665	37.7	428	28.7
Donkeys	32	1.8	32	2.1
Camels	16	0.9	16	1.1
Total	1 762	100.0	1 492	100.0
DIET				
I	349	19.8	594	39.8
II	169	9.6	71	4.8
III	1 230	69.8	815	54.6
IV	14	0.8	12	0.8
Total	1 762	100.0	1 492	100.0

Most of the animals can be fed on diet III, representing forage of rather good quality, with an average N-content over the year of 11 g kg^{-1} (Section 3.3). In the S-scenario, however, 40% of the animals are on the minimum diet I, with an average N-content of only 9 g kg^{-1}. In this scenario the number of sedentary animals is relatively high.

Semi-intensive animal husbandry is limited to 7 000 head of cattle for milk production around Mopti-town in both scenarios (which corresponds to the upper limit set to this activity) and 70 000 (S-scenario) or 90 000 (R-scenario) head of sedentary fattened sheep.

Compared to the estimate of the present number of animals, the two base scenarios show a 20% increase in cattle, a stabilization of the number of transport animals and a considerable expansion of the small ruminant population, especially sheep. The latter is mainly the result of the slightly higher price of mutton and goat meat as compared to beef and the relatively high ratio of meat production to dry matter intake of sheep (0.022 and 0.029 kg kg^{-1} I for diet I and III, respectively, Section 3.3). Only for migrant cattle on diet III the conversion efficiency is higher (0.038 kg kg^{-1}) and they are therefore prominently present in both scenarios too.

The forage requirements, associated with this herd size and composition in the Region, are given for a normal year in Table 6.8a. They range from 2.6 to 3.3 million ton in the dry season and from 0.9 to 1.1 million ton in the wet season in the S- and R-scenario, respectively. In the wet season, 43% (S-scenario) or 50 % (R-scenario) should be provided by the wet season pastures (> 15 km). The availability of forage differs between the scenarios, because land use and hence pasture areas are different.

Forced by model restrictions, available forage in normal years is always sufficient to meet the requirements. In dry years, forage availability can fall short of the requirements (Table 6.8b). The degree to which this is allowed to happen is dictated by the number of animals permitted to be at risk in dry years. In the R-scenario this is set at 400 000 TLU, in the S-scenario at 100 000 only. Table 6.8b shows that forage supply of practically all feed categories is insufficient in dry years. Only the availability of browse is not a constraint for the Region as a whole. This does not, however, exclude restrictions at the level of agro-ecological zones.

*Table 6.8a. Available and required forage [1000 ton] in the two base scenarios in a **normal** year.*

	R-SCENARIO				S-SCENARIO			
	AVAILABLE			REQUIRED	AVAILABLE			REQUIRED
	By-products & concentrates	Pasture	Total		By-products & concentrates	Pasture	Total	
Dry season								
Pasture < 15 km[a]								
Quality								
1.Low	430	349	779	640	576	341	917	655
2.Moderate	11	1 014	1 025	1 771	37	937	974	1 440
3.Good	0	2 105	2 105	894	8	1 950	1 958	513
4.Excellent	7	10	17	6	6	11	17	5
Subtotal	448	3 478	3 926	3 311	627	3 239	3 866	2613
Browse	-	115	115	67	-	114	114	103
Wet season								
Pasture < 15 km[a]								
Quality								
1.Low	-	0	0	0	-	0	0	0
2.Moderate	-	0	0	0	-	0	0	0
3.Good	-	339	339	227	-	358	358	232
4.Excellent	-	432	432	331	-	421	421	286
Subtotal	-	771	771	558	-	779	779	518
Pasture > 15 km[a]	-	650	650	569	-	650	650	387

[a]) Distance to a permanent water point

Table 6.8b. Available and required forage [1000 ton] in the two base scenarios in a ***dry*** *year.*

	R-SCENARIO				S-SCENARIO			
	AVAILABLE			REQUIRED	AVAILABLE			REQUIRED
	By-products & concentrates	Pasture	Total		By-products & concentrates	Pasture	Total	
Dry season								
Pasture < 15 km[a]								
Quality								
1.Low	262	115	377	640	356	110	466	655
2.Moderate	5	807	812	1 771	20	746	766	1 440
3.Good	0	1 330	1 330	894	4	1 247	1 251	513
4.Excellent	3	10	13	6	3	11	14	5
Subtotal	270	2 262	2 532	3 311	383	2 114	2 497	2613
Browse	-	115	115	67	-	114	114	103
Wet season								
Pasture < 15 km[a]								
Quality								
1.Low	-	0	0	0	-	0	0	0
2.Moderate	-	0	0	0	-	0	0	0
3.Good	-	79	79	227	-	89	89	232
4.Excellent	-	415	415	331	-	410	410	286
Subtotal	-	494	494	558	-	499	499	518
Pasture > 15 km[a]	-	367	367	569	-	367	367	387

[a]) Distance to a permanent water point

6.2.7 Fisheries

In both base scenarios the maximum allowed quota of fish (93 000 ton in a normal year and 53 000 in a dry year) is indeed caught. In other words, fisheries are profitable compared to other agricultural activities.

The labour productivity of the average fisherman is higher in the R-scenario than in the S-scenario, amounting to 2.5 and 1.9 ton of fresh fish per household per year, respectively. This corresponds with a productivity per man-year of 960 kg and 770 kg of fresh fish per year, respectively. The higher productivity in the R-scenario is the result of the higher proportion of migrant fishermen with fisheries as their main occupation (which have the highest capital endowment, Section 3.4) in the total number of households involved in fishing (Table 6.9).

Total monetary inputs in fisheries are about the same in both scenarios: 7 billion FCFA annually, comprising just over 50% capital charges. With a marketable production worth 22 and 21 billion FCFA in a normal year, remuneration of labour is 155 000 and 115 000 FCFA man-year^{-1} in the R-scenario and the S-scenario, respectively.

Table 6.9. Distribution of households [% of total number of households engaged in fisheries] and total number of households engaged in fisheries in the two base scenarios, according to mobility and main occupation.

ACTIVITY	DISTRIBUTION	
	R-SCENARIO	S-SCENARIO
Fishing main occupation, migrant	44	4
Fishing main occupation, sedentary	0	34
Fishing secondary occupation, sedentary	56	62
Total	100	100
Total number of households	37 500	48 400

6.3 Results of the two base scenarios per agro-ecological zone

6.3.1 Introduction

Land use, production and inputs, as presented in the preceding section, are calculated by the model at the level of the agro-ecological zones also. In this section we give a summary of these results, which in full detail can be found in Annexes A (R-scenario) and B (S-scenario).

As explained in Section 4.1, a large number of restrictions is included in the optimization model. Many of these apply to each agro-ecological zone. In Table 6.10 three groups of restrictions are presented, relating to:

Table 6.10. The occurrence of binding labour, oxen or manure restrictions in each of the agro-ecological zones in the two base scenarios (= binding).*

RESTRICTION	Sourou	Séno Bankass	Plateau	Delta Central	Méma Dioura	Séno Mango	Gourma	Bodara	Zone Lacustre	Hodh	Méma Sourango
R-scenario											
Labour during											
1.Land prep./sowing[a]	.	.	.	.	.	.	.	.	.	.	*
2.First weeding[a]	.	.	*	*	*	*	*	*	*	*	*
3.Rest growing season	.	.	.	.	.	.	.	.	.	.	*
4.Harvest millet	.	.	.	.	.	.	.	.	.	.	.
5.Harvest rice	.	.	.	*	.	.	.	.	.	.	.
6.Rest of the year	.	.	.	*	.	.	.	.	.	.	.
Oxen availability	*	*	*	*	*	*	*	*	*	*	.
Manure availability	*	*	*	.	.	.	*	.	.	.	.
S-scenario											
Labour during											
1.Ploughing/sowing[a]	.	.	.	.	.	.	.	.	.	.	*
2.First weeding[a]	*	.	.	.	*	*	*	*	*	*	*
3.Rest growing season	.	.	.	.	.	.	.	.	.	.	*
4.Harvest millet	.	.	.	.	.	.	.	.	.	.	.
5.Harvest rice	.	.	.	*	.	.	.	.	.	.	.
6.Rest of the year	.	.	.	*	.	.	.	.	.	.	.
Oxen availability	*	*	*	*	*	*	*	*	*	*	.
Manure availability	*	*	*	*	*	.	*	.	*	.	.

[a]) refers to rainfed crops

- The requirement that labour demand per agro-ecological zone should not exceed labour supply, in any of the six periods of the year distinguished (Subsection 3.1.3).
- The requirement that in any agro-ecological zone enough oxen are available (i.e. enough forage to meet their food requirements).
- The requirement that the necessary organic manure for arable farming and for fuel is indeed produced in each agro-ecological zone (i.e. the number animals in that agro-ecological zone should be sufficient).

These restrictions should always be met, however, they are not always binding. Binding means that a restriction constitutes an obstacle for attaining a more favourable value of the goal variable optimized (in this case total gross revenue).

In the R-scenario, labour during the period of the first weeding of millet is binding in all agro-ecological zones, except in the southern ones Sourou and Séno Bankass. In the S-scenario, the exceptions are the agro-ecological zones Séno Bankass, Plateau and Delta Central. Harvest time of rice is a peak labour period in the Delta Central, but also during the dry season ('rest of the year') labour is scarce, contrary to all other agro-ecological zones, due to fishing activities, livestock herding and vegetable cultivation.

The period of land preparation and sowing of millet, just after the first rains, the remainder of the growing season after the first weeding and harvest time of millet are periods during which labour is not a limiting factor. An exception is Méma Sourango for the first two periods, due to the required labour input for herding. No arable farming takes place in this agro-ecological zone, hence, contrary to all other agro-ecological zones, availability of oxen is not restrictive here.

Shadow prices for the oxen restriction are generally higher in the S-scenario than the R-scenario. In the S-scenario they range from 6 900 FCFA per ox in Méma Dioura to 125 000 in the Delta Central. (Shadow prices indicate the additional gross revenue that could have been obtained if the restriction would be relaxed by one unit, in this case one ox, see also Subsection 6.2.3) In the R-scenario the shadow prices for oxen vary from 10 000 FCFA per ox in Méma Dioura and Séno Mango to 20 000 in the Zone Lacustre.

In the R-scenario, the manure restriction is binding in the two southernmost agro-ecological zones, Sourou and Séno Bankass, and on the Plateau and in the Gourma. In the S-scenario, manure is binding, in addition, in the Delta Central, Méma Dioura and the Zone Lacustre. Moreover, the shadow prices are consistently higher in the S-scenario than in the R-scenario. In the S-scenario they range from 6 700 FCFA per ton manure dry matter in Méma Dioura to 216 000 on the Plateau; in the R-scenario from 14 000 FCFA per ton in the Gourma to 17 000 in Sourou.

In the Delta Central, the Zone Lacustre, Bodara and Hodh, manure is used as a substitute for firewood, with its consumption set at 0.5 kg $person^{-1} d^{-1}$. This requirement only is binding in the Delta Central and the Zone Lacustre in the S-scenario, as additional restrictions are imposed.

Another important set of model restrictions, i.e. the requirement that in a normal year demand for forage should not exceed its supply, is analyzed in Table 6.11.

Table 6.11. The occurrence of binding forage[a] restrictions in each of the agro-ecological zones in the two base scenarios in a normal year (= binding).*

RESTRICTION	Sourou	Séno Bankass	Plateau	Delta Central	Méma Dioura	Séno Mango	Gourma	Bodara	Zone Lacustre	Hodh	Méma Sourango
R-scenario											
Wet season											
Total, all qualities	.	.	.	.	.	.	.	.	.	.	.
Quality 2 and higher	.	.	.	.	.	.	.	.	.	.	.
Quality 3 and higher	.	.	.	.	.	.	.	.	.	.	.
Quality 4	*	*	*	*	.	*	*	.	.	.	.
Dry season											
Total, all qualities	.	.	.	.	*	*	.	*	*	*	.
Quality 2 and higher	*	*	*	.	.	.	*	.	*	.	.
Quality 3 and higher	.	*	.	.	*	*	.	*	.	*	*
Quality 4	.	.	.	.	.	.	.	*	*	*	.
Browse	*	*	*	.	.	.	*	.	.	.	.
S-scenario											
Wet season											
Total, all qualities	.	.	.	.	.	.	.	.	.	.	.
Quality 2 and higher	.	.	.	.	.	.	.	.	.	.	.
Quality 3 and higher	.	.	*	.	.	.	*	.	.	.	.
Quality 4	*	*	.	*	.	*	*	.	.	.	.
Dry season											
Total, all qualities	.	.	.	.	.	.	.	.	.	.	.
Quality 2 and higher	*	*	*	.	.	.	*	.	.	.	.
Quality 3 and higher	.	.	.	.	*	*	.	*	.	.	*
Quality 4	.	.	.	.	.	.	.	.	*	.	.
Browse	*	*	*	.	.	.	*	.	.	.	.

a) refers to forage supply within a 15 km radius of a permanent water point.

On the Plateau, for example (third column of Table 6.11), availability of forage of excellent quality, class 4, during the wet season, is restrictive in the R-scenario. (Quality classes of forage are defined in Paragraph 3.3.2.1 and Subsection 3.3.3) In the S-scenario, forage availability of class 3 and higher is binding in the wet season. In the dry season, forage availability of class 2 and higher is restrictive in this agro-ecological zone in both scenarios. In addition, if more browse would have been available a higher gross revenue could have been reached.

The forage restrictions are, at least during the dry season, more frequently binding in the R-scenario than in the S-scenario. In the dry season, for instance, in the S-scenario the total quantity of forage available is not binding in any of the agro-ecological zones, while in the R-scenario it is in Méma Dioura, Séno Mango, Bodara, the Zone Lacustre and Hodh. Apparently, in the S-scenario other restrictions, i.e. the permitted number of animals at risk in a dry year, take over the role of some of the forage restrictions.

Shadow prices of the forage restrictions cover a wide range of values. During the dry season, maximum values of 26 FCFA kg^{-1} forage (R-scenario, Zone Lacustre, quality class 4) and 75 FCFA kg^{-1} (S-scenario, Séno Bankass, quality class 2 and higher) are attained. In the wet season shortage of forage is in some cases even more costly. Maximum shadow prices of 57 FCFA kg^{-1} (R-scenario, Delta Central, quality 4) and even 308 (S-scenario, Delta Central, quality 4) are reached. More browse would lead to greater goal attainment, especially in Séno Bankass: the shadow prices are 5 and 118 FCFA kg^{-1} forage in the R- and the S-scenario, respectively.

Assuming the actual price of concentrates, 44 FCFA kg^{-1} dry matter, as criterion, importing concentrates appears to be profitable in the situations given in Table 6.12.

Additional situations where import would become attractive if the price of imported concentrates would be half the current price are given in Table 6.13.

Table 6.12. Values of the shadow prices for the forage restrictions for situations where they exceed 44 FCFA kg^{-1} in the two base scenarios.

AGRO-ECOLOGICAL ZONE	SHADOW PRICE	SEASON	SCENARIO
Séno Bankass	118	dry	S
Séno Bankass	178	wet	S
Séno Bankass	53	wet	R
Delta Central	308	wet	S
Delta Central	57	wet	R

Table 6.13. Values of the shadow prices for the forage restrictions for situations where they are in the range of 22 to 44 FCFA kg^{-1} in the two base scenarios.

AGRO-ECOLOGICAL ZONE	SHADOW PRICE	SEASON	SCENARIO
Plateau	42	dry	S
Plateau	30	wet	S
Gourma	25	dry	S
Zone Lacustre	23	dry	S
Zone Lacustre	26	dry	R

6.3.2 Sourou

In the S-scenario, Sourou is the main grain producer, though it ranks only third in size, fifth in total population and no rice cultivation of any importance is possible in this agro-ecological zone (see for areas and population sizes of the agro-ecological zones Table 2.10). In a normal year, in this scenario 87 000 ton of millet is produced, or 31% of the total regional production, as a result of a high level of intensification: almost 60% of the 641 km^2 under millet is cultivated under intensive and another 18% under semi-intensive production techniques (Figure 6.3). Average fertilizer application per ha is 65 kg N, 9 kg P and 38 kg K. In addition, on average 1 700 kg of organic manure (dry matter) per ha is applied.

Monetary inputs, including the costs of fertilizer, amount to 68 000 FCFA ha^{-1}, at an average net yield of 1 360 kg grain ha^{-1} (dry matter) in a normal and 700 in a dry year. At a producer price of 55 FCFA per kg, however, millet cultivation is hardly a profitable activity. The main reason for intensification in the S-scenario is safeguarding a certain minimum grain production.

In the R-scenario, where the upper limit on grain deficits in dry years is less strict and subsistence needs are lower, the level of intensification is much lower. Sourou, in this scenario, is still an important grain producer, but is as the main one replaced by Séno Bankass. In the zone, in a normal year, 39 000 ton, or a quarter of the total millet production, is produced. Only 7% of the 553 km^2 under millet is under intensive and 54% under semi-intensive production techniques. Average net yields per ha are consequently considerably lower: 710 kg grain in a normal year and 370 kg in a dry year. The same holds for the inputs: application of fertilizer per ha is on average 15 kg N, 1 kg P and 4 kg K. Manure application is 1 600 kg ha^{-1} and total monetary inputs are 13 000 FCFA ha^{-1}.

All available organic manure, 89 000 ton in the R-scenario and 110 000 ton in the S-scenario, is utilized in arable farming. The size of the herd in the dry season is 163 000 TLU in the R-scenario and 180 000 in the S-scenario, representing the third and second largest herds of all eleven agro-ecological zone. Sourou has, in both scenarios, the highest number of oxen of all agro-ecological zones, with 17 000 in the R-scenario and 37 000 in the S-scenario. These numbers correspond to an oxen density of 28 (R-scenario) and 52 (S-scenario) oxen per 100 ha of cultivated land.

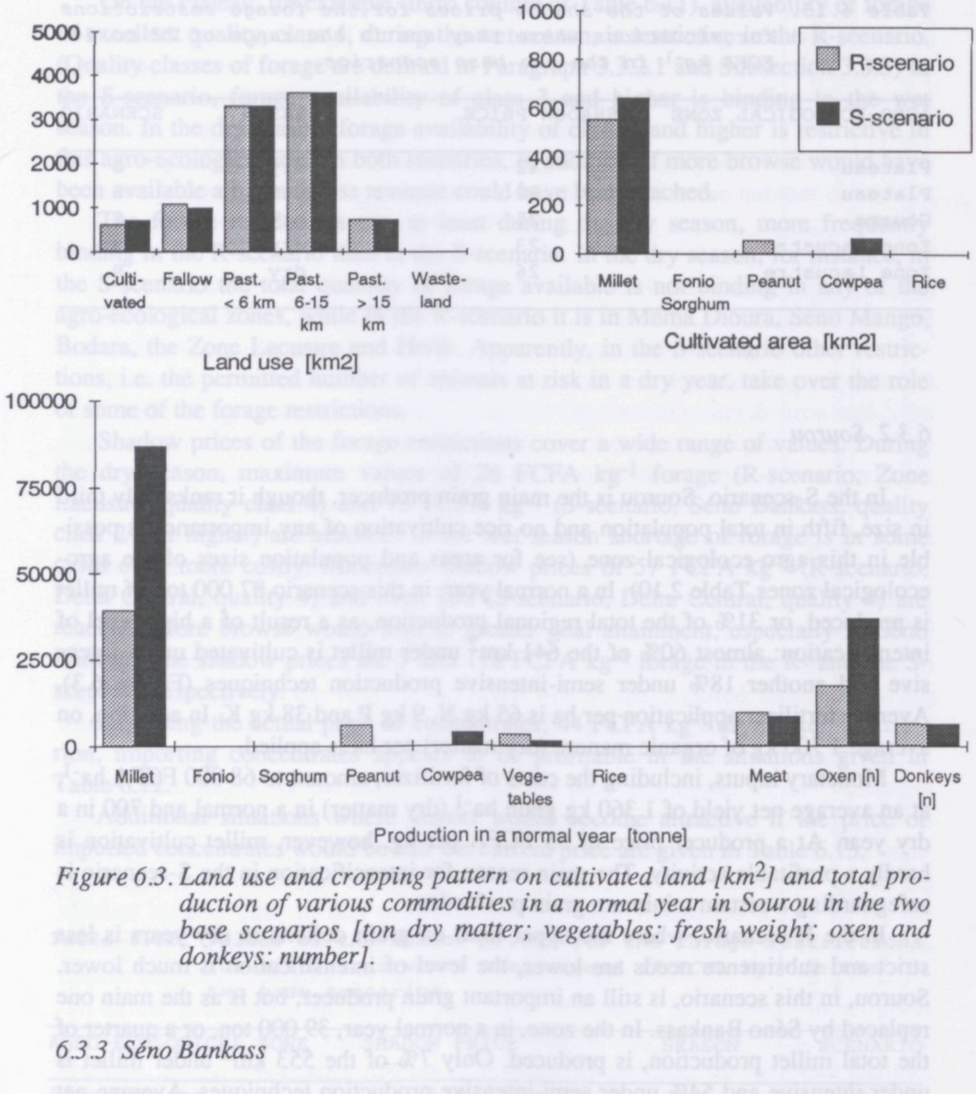

Figure 6.3. Land use and cropping pattern on cultivated land [km²] and total production of various commodities in a normal year in Sourou in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

6.3.3 Séno Bankass

This agro-ecological zone ranks third in population size, with 209 000 inhabitants, but only seventh in area. Labour is therefore relatively abundant and is not limiting in any of the periods distinguished (Table 6.10), not even in the R-scenario with an emigration of 40 000 people.

Availability of (arable) land appears the main bottle-neck for production, as reflected in the extremely small fraction, less than 3%, of the total area within 6 km of a permanent water point, that is used as natural pasture. Herd size (as always defined for the dry season) is consequently small, around 50 000 TLU in both scenarios, and animal production is low. Milk production, for instance, is only 1 150 ton per year, i.e. 0.1 kg per inhabitant per week, compared to an average of 3 kg for the Region as a whole. The main target for animal production is draught oxen, with some small ruminant husbandry as a side line.

Because of the small herd size, only 25 000 (R-scenario) or 28 000 (S-scenario) ton of organic manure is available. As predominantly extensive cultivation is practiced in Séno Bankass in both scenarios, large areas must be fallowed to ensure sustainability. The ratio fallow land/cultivated land is indeed the highest of all agro-ecological zones: 4.1 ha ha^{-1}.

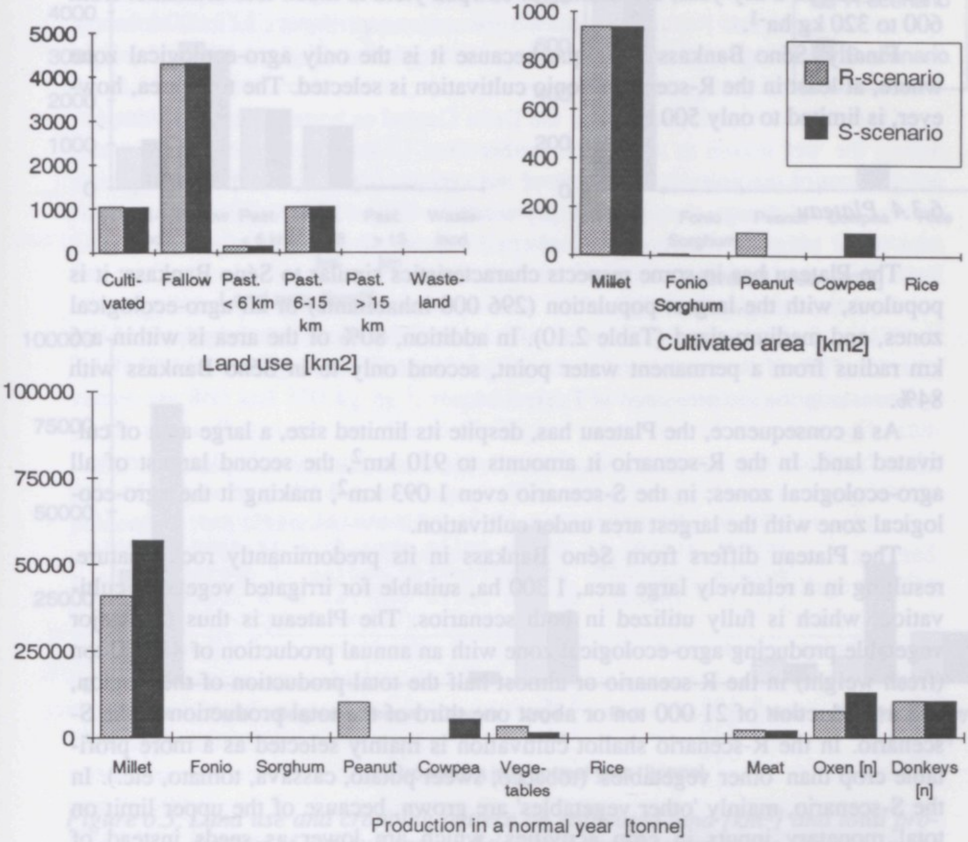

Figure 6.4. Land use and cropping pattern on cultivated land [km^2] and total production of various commodities in a normal year in Séno Bankass in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

The high proportion of land used for arable farming, combined with a large number of permanent water points, results in the largest (R-scenario) or second largest (S-scenario) area under cultivation: in both scenarios just over 1 000 km^2 (Figure 6.4). Note that Séno Bankass is the seventh agro-ecological zone in area and comprises, for instance, only 43% of the Delta Central, the largest agro-ecological zone.

Ten percent of the cultivated area is under cowpea or groundnut, i.e. the maximum permitted proportion in view of the imposed rotation constraints. In the R-scenario only groundnut is selected, that being the most profitable crop in a normal year. In the S-scenario, on the other hand, only cowpea is cultivated. As discussed already in Subsection 6.2.5, the reasons for this shift are the tighter restrictions on maximum allowed grain deficits in dry years and the maximum number of emigrants. While average groundnut yields decrease from 1 100 kg ha^{-1} in a normal year to 200 in a dry year, the decline in cowpea yield is much less dramatic: from 600 to 320 kg ha^{-1}.

Finally, Séno Bankass is unique because it is the only agro-ecological zone where, at least in the R-scenario, fonio cultivation is selected. The total area, however, is limited to only 500 ha.

6.3.4 Plateau

The Plateau has in some respects characteristics similar to Séno Bankass: it is populous, with the largest population (296 000 inhabitants) of all agro-ecological zones, and medium-sized (Table 2.10). In addition, 80% of the area is within a 6 km radius from a permanent water point, second only to in Séno Bankass with 84%.

As a consequence, the Plateau has, despite its limited size, a large area of cultivated land. In the R-scenario it amounts to 910 km^2, the second largest of all agro-ecological zones; in the S-scenario even 1 093 km^2, making it the agro-ecological zone with the largest area under cultivation.

The Plateau differs from Séno Bankass in its predominantly rocky nature, resulting in a relatively large area, 1 300 ha, suitable for irrigated vegetable cultivation, which is fully utilized in both scenarios. The Plateau is thus the major vegetable producing agro-ecological zone with an annual production of 45 000 ton (fresh weight) in the R-scenario or almost half the total production of the Region, and a production of 21 000 ton or about one third of the total production in the S-scenario. In the R-scenario shallot cultivation is mainly selected as a more profitable crop than 'other vegetables' (tobacco, sweet potato, cassava, tomato, etc.). In the S-scenario, mainly 'other vegetables' are grown, because of the upper limit on total monetary inputs in crop activities, which are lower as seeds instead of (shallot) bulbs are purchased.

The large population of the Plateau and the relative scarcity of land, leads in the R-scenario to mass emigration. In the S-scenario this possibility is blocked, resulting in surplus labour, as reflected in the absence of binding labour restrictions (Table 6.10).

The much larger population that must be fed in the S-scenario results in increased intensification. In the S-scenario 42% of the millet area is cultivated under intensive techniques, which are absent in the R-scenario and only 26% of the millet area is then cultivated semi-intensively. This of course, has direct consequences for the yields, which in the R-scenario are 370 kg ha^{-1} in normal years and 180 in dry years, and in the S-scenario 830 and 440 kg ha^{-1}, respectively.

Total grain production on the Plateau in a normal year is 85 000 ton in the S-scenario, compared to 33 000 ton in the R-scenario. In a dry year, however, the subsistence needs for grains are not covered. In the S-scenario the deficit in a dry year is 65 000 (subsistence needs) - 45 000 (grain production) = 20 000 ton of grain; in the R-scenario it is almost identical: 19 000 ton of grain (36 000 - 17 000).

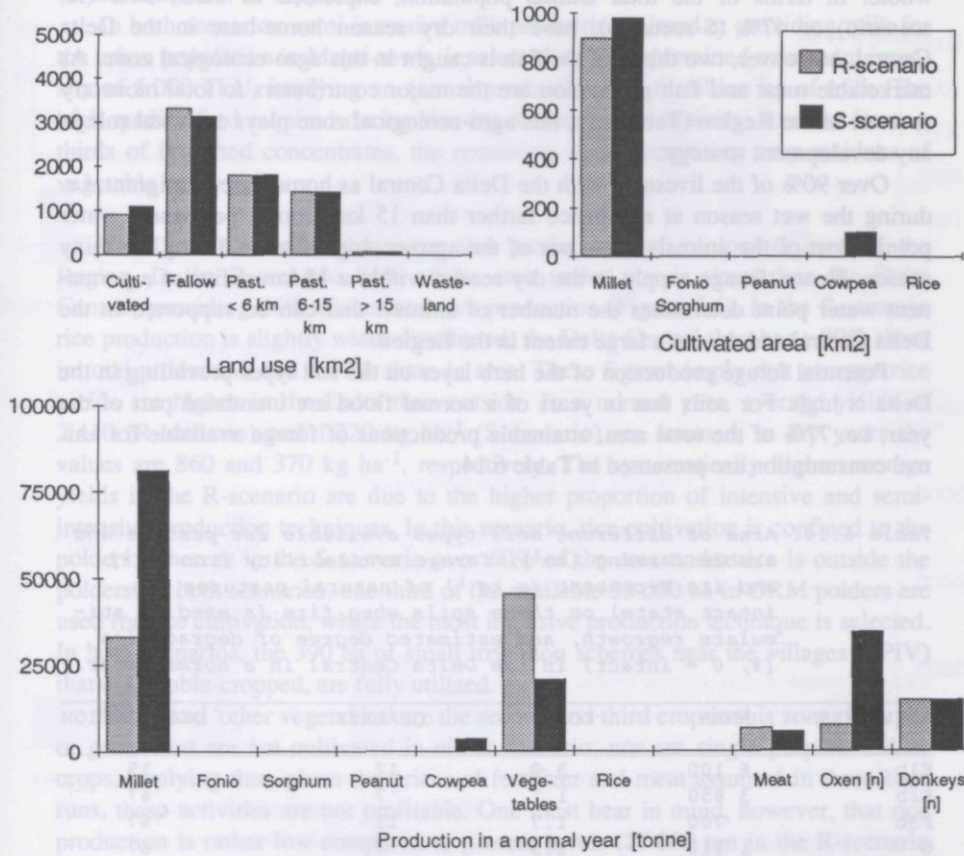

Figure 6.5. Land use and cropping pattern on cultivated land [km²] and total production of various commodities in a normal year in the Plateau in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

Livestock production on the Plateau is comparable to that in Séno Bankass, although at a somewhat larger small ruminant population, especially sheep in the R-scenario, and goats on diet I in the S-scenario. In total 103 000 (R-scenario) and 146 000 TLU (S-scenario) have their dry season home-base on the Plateau. For cattle, the major production target is draught oxen. Milk production is low at 0.7 kg per capita per week in the R-scenario and 0.3 in the S-scenario. Because of the large population the number of donkeys is relatively high.

6.3.5 Delta Central

This agro-ecological zone is crucial for animal production in the region as a whole. In terms of the total animal population, expressed in TLU, 54% (R-scenario) or 47% (S-scenario), have their dry season home-base in the Delta Central. Moreover, two thirds of the fish is caught in this agro-ecological zone. As marketable meat and fish production are the major contributors to total monetary revenue of the Region (Table 6.2), this agro-ecological zone plays a pivotal role in any development strategy.

Over 90% of the livestock with the Delta Central as home base is migrant, i.e. during the wet season at a distance farther than 15 km from a permanent water point. Most of the animals move out of the agro-ecological zone during the rainy season. Hence, forage supply in the dry season within a 15 km radius of a permanent water point determines the number of animals that can be supported in the Delta Central and thus to a large extent in the Region.

Potential forage production of the herb layer on the soil types prevailing in the Delta is high. For soils that in years of a normal flood are inundated part of the year, i.e. 77% of the total area, attainable productions of forage available for animal consumption are presented in Table 6.14.

Table 6.14. Area of different soil types available for pasture and arable farming [km^2]*, forage availability [ton ha^{-1}] and its N-content [g kg^{-1}] of natural pastures (in intact state) on these soils when fire is used to stimulate regrowth, and estimated degree of degradation [%, 0 = intact] in the Delta Central in a normal year.*

SOIL TYPE	AREA	FORAGE	QUALITY	DEGRADATION
E1b	6 100	3.0	12	15
E2b	3 850	1.1	7	67
F3b	700	1.7	11	67
G	1 110	1.3	7	67

Source: Report 2, Chapter 11.

These estimates were obtained under the assumption that fire is used to stimulate regrowth of perennial grasses in the dry season. If the pastures are mowed for conservation, higher available forage production is possible. In the two base runs, however, this option has not been considered, but it can further be examined (Subsection 6.4.6). Furthermore, in the two base scenarios, it has been assumed that soil type E1b is slightly degraded in terms of biomass production, whereas the production level of the other inundated soil types is only one third of their potential, due to overexploitation, deficient floods and their combination.

The data presented in Table 6.14 imply that, if all inundated soils of the Delta would be used as pastures, total forage production would be 1.78 million ton in a normal year. In the two base scenarios, total forage production of pastures, including the rainfed pastures, is 1.76 million ton in the R-scenario and 1.64 in the S-scenario. Crop residues provide another 0.09 (R-scenario) and 0.12 million ton (S-scenario) of forage in the dry season. With this total forage supply, 956 000 TLU of which 82% migrant cattle (R-scenario) or 698 000, of which 91% migrant cattle (S-scenario), can be supported.

In both scenarios, semi-intensive milk production, aimed at providing milk for the urban population in Mopti-town, is selected up to its permitted maximum intensity of 5 000 TLU, implying an annual production of 2.6 million kg of milk. The high quality feed required during the dry season in this activity, consists for two thirds of imported concentrates, the remaining third comprising crop residues of vegetable cultivation.

The Delta Central is the major rice producing agro-ecological zone of the Region. In the R-scenario 84% of the area under rice is situated in the Delta Central, providing 96% of the total rice production (Figure 6.6). In the S-scenario rice production is slightly wider distributed; the Delta Central then has a 89% share in total production and a 77% share in area. These figures imply that average rice yields are higher in the Delta than outside. In a normal year, average yields of 2 410 (R-scenario) and 1 220 kg ha^{-1} (S-scenario) are attained; in dry years the values are 860 and 370 kg ha^{-1}, respectively. The systematically higher average yields in the R-scenario are due to the higher proportion of intensive and semi-intensive production techniques. In this scenario, rice cultivation is confined to the polders, whereas in the S-scenario over 60% of the area under rice is outside the polders. In both scenarios, one third of the available 33 000 ha in ORM polders are used for rice cultivation, where the most intensive production technique is selected. In both scenarios, the 390 ha of small irrigation schemes near the villages (PPIV) that are double-cropped, are fully utilized.

Millet and 'other vegetables' are the second and third crop in this zone. Cowpea or groundnut are not cultivated in either scenario, nor are single purpose fodder crops, implying that, given the prices of fertilizer and meat assumed in these base runs, these activities are not profitable. One must bear in mind, however, that rice production is rather low compared to present levels (27 000 ton in the R-scenario and 38 000 ton in the S-scenario in a normal year), so that competition for inundated land between pasture and rice cultivation is not as strong as in the current situation.

As indicated earlier (Table 6.10), the Delta Central is the only agro-ecological zone where labour availability (or supply) is restricting during the dry season (harvest time of rice and 'remainder of the year'). This is due to the out-of-season rice and vegetable cultivation and the large number of animals present during that time, but also to a large extent to fisheries activities. In the period November-June (except during the harvest time of rice), in the R-scenario for instance, the distribution of the labour supply of 134 000 persons (male adult equivalents) is 9% in arable farming, 34% in animal husbandry and the remaining 57% in fisheries. In the S-scenario this distribution is even more skewed: 10% arable farming, 18% livestock and 72% fisheries. Households involved in fisheries as a secondary occupation, i.e. fishing during the period November-June only, are more frequent in the S-scenario than in the R-scenario (Subsection 6.2.7). Despite the differences in labour input in fisheries in the two scenarios, total catch is the same: 62 000 ton of fresh fish in a normal year and 36 000 ton in a dry year.

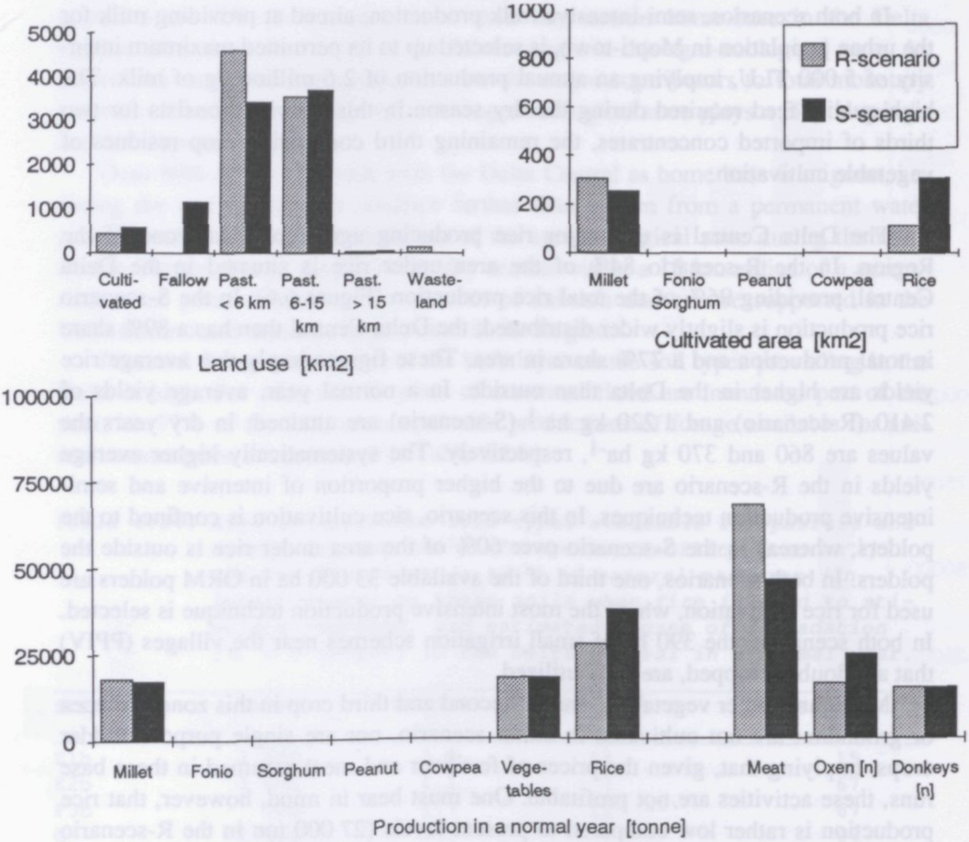

Figure 6.6. Land use and cropping pattern on cultivated land [km²] and total production of various commodities in a normal year in the Delta Central in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

6.3.6 Méma Dioura

Méma Dioura is in many respects (lower) middle class. It ranks eighth in size, seventh in population and grain production, and sixth or eighth in herd size during the dry season.

Millet is the main crop, cultivated under a semi-intensive production technique, resulting in average net yields of 490 kg ha^{-1} in normal and 230 kg in dry years. A small area of 1 600 ha is under rice. The extensive production technique used, depending on natural floods, leads to low and drought-sensitive yields of 480 kg ha^{-1} in a normal year and only 70 kg ha^{-1} in a dry year. No other crops are grown in this agro-ecological zone (Figure 6.7).

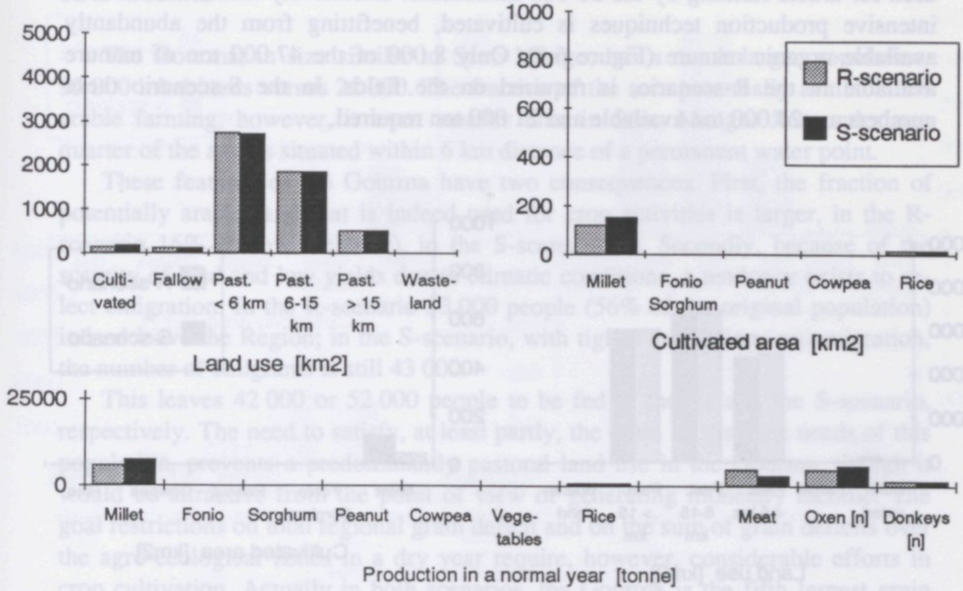

Figure 6.7. Land use and cropping pattern on cultivated land [km²] and total production of various commodities in a normal year in the Méma Dioura in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

Total grain production in a normal year is 6 600 ton in the R-scenario and 8 200 ton in the S-scenario. In dry years, grain production falls to 2 900 and 3 600 ton, respectively. Self-sufficiency in energy from grains for its 30 000 inhabitants would require a production of 6 800 ton millet-equivalents, a level that only in normal years in both scenarios is attained.

The two scenarios differ most markedly in total animal population. In the R-scenario, herd size is 78 000 TLU and in the S-scenario 51 000. The animals are, moreover, slightly more productive in terms of meat in the R-scenario. As a consequence, total meat production in the R-scenario is 61% higher than in the S-scenario (4 700 versus 2 900 ton) with 53% more animals. This represents an additional income of almost 600 million FCFA or 20 000 FCFA per capita in the R-scenario.

The price to be paid is a higher grain deficit in dry years in this scenario (see above) and a lower milk production: 3 300 ton versus 5 100.

6.3.7 Séno Mango

Starting from Séno Mango, in the agro-ecological zones treated, permanent water points become scarce. In Séno Mango only 28% of the land is situated within a 6 km radius of such a point and 44% even outside a 15 km radius. Within a 6 km radius, only 45 (R-scenario) or 120 km^2 (S-scenario) of the 2 500 km^2 available, is used for arable farming by the 21 000 inhabitants. Exclusively millet under semi-intensive production techniques is cultivated, benefitting from the abundantly available organic manure (Figure 6.8). Only 8 000 of the 47 000 ton of manure available in the R-scenario, is required on the fields. In the S-scenario these numbers are 24 000 ton available and 21 000 ton required.

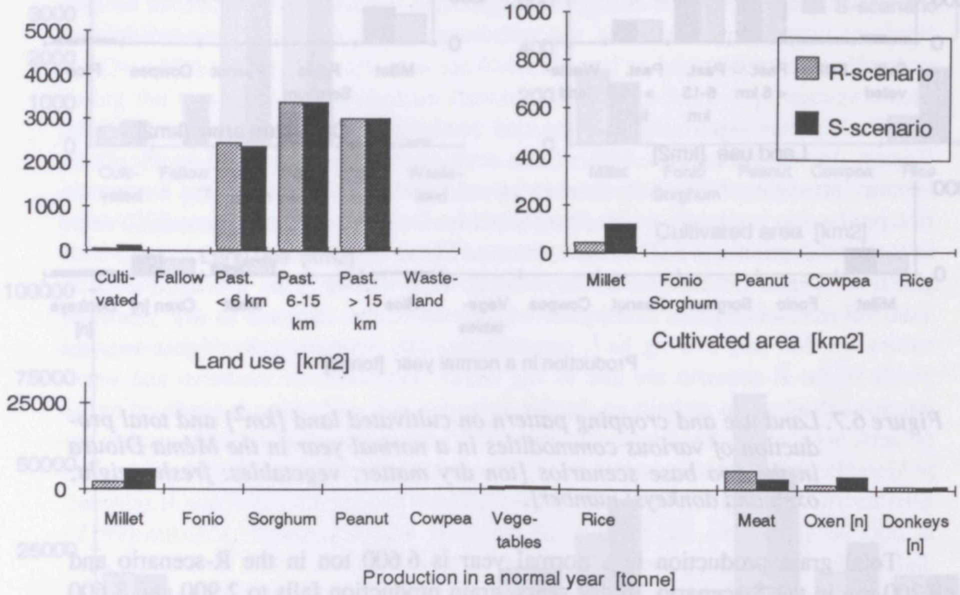

Figure 6.8. Land use and cropping pattern on cultivated land [km^2] and total production of various commodities in a normal year in the Séno Mango in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

The peak period for labour demand is, as in all but the southernmost agro-ecological zones, the period of first weeding of millet (Table 6.10). During that time, total labour requirements are 4 100 (R-scenario) or 11 100 (S-scenario) persons (male adult equivalents). All of the remaining labour supply, 9 500 (R-scenario) or 2 500 persons (S-scenario), is occupied in the livestock sector.

These data already indicate that Séno Mango is a predominantly pastoral agro-ecological zone in both scenarios, ranking fifth with respect to herd size during the dry season. Total animal number is 84 000 TLU in the R-scenario and 76 000 in the S-scenario. The distribution over species differs in the two scenarios as a consequence of the different labour inputs in crop activities. In the R-scenario more labour is available for animal husbandry, so that the more profitable, but also more labour-intensive small ruminant activities are selected. In this scenario cattle-sheep-goats are distributed 27-73-0%; in the S-scenario 98-2-0%. Average production in terms of meat is consequently higher in the R-scenario: 66 kg TLU^{-1} yr^{-1} versus 42. Production in terms of milk, on the other hand, is lower in the R-scenario: 25 kg TLU^{-1} yr^{-1} versus 34.

6.3.8 Gourma

The Gourma, in size similar to Séno Mango, has a much larger population: 95 000 inhabitants versus 21 000. The fraction of the area potentially available for arable farming, however, is even smaller than in Séno Mango. Just under one quarter of the area is situated within 6 km distance of a permanent water point.

These features of the Gourma have two consequences. First, the fraction of potentially arable land that is indeed used for crop activities is larger, in the R-scenario 16% (fallow included), in the S-scenario 19. Secondly, because of the scarcity of land and low yields due to climatic conditions, a tendency exists to select emigration. In the R-scenario 53 000 people (56% of the original population) indeed leave the Region; in the S-scenario, with tighter restrictions on emigration, the number of emigrants is still 43 000.

This leaves 42 000 or 52 000 people to be fed in the R- and the S-scenario, respectively. The need to satisfy, at least partly, the grain subsistence needs of this population, prevents a predominantly pastoral land use in the Gourma, though it would be attractive from the point of view of generating monetary income. The goal restrictions on total regional grain deficit and on the sum of grain deficits over the agro-ecological zones in a dry year require, however, considerable efforts in crop cultivation. Actually in both scenarios, the Gourma is the fifth largest grain producer of all agro-ecological zones with a production in normal years of 9 600 ton or 4.7% of the total grain production of the Region in the R-scenario and 14 500 ton or 4.3% in the S-scenario.

The main crop is millet, but some sorghum is cultivated, as well as some vegetables. The production technique is mainly semi-intensive, on 95% of the area in the R-scenario and 80% in the S-scenario (Figure 6.9), using all available organic manure, i.e. 32 000 ton dry matter in the R-scenario and 44 000 ton in the S-scenario.

With regard to intensification, the same mechanism operates as in some of the other agro-ecological zones (for instance Sourou, Subsection 6.3.2), i.e. a higher level of intensification of arable farming in the S-scenario. In this scenario, 1 900 ha, i.e. 7% of the total area under millet, is cultivated using intensive production techniques (in the R-scenario intensive millet cultivation is absent), providing 16% of the millet production in the agro-ecological zone. On average, in the S-scenario, nutrient application per ha on millet is 13 kg N, 0.7 kg P, 3 kg K and 1 550 kg DM of manure. Monetary inputs, costs of fertilizer included, are on average 11 500 FCFA ha^{-1}. Average yield in a normal year is 520 kg ha^{-1} representing a value of 28 600 FCFA, in a dry year 240 kg ha^{-1} representing a value of at least 13 200 FCFA.

Because of the substantial area under semi-intensive crop cultivation, a considerable number of oxen is necessary, in the R-scenario 6 100, in the S-scenario 9 200. The production objective of cattle husbandry is therefore almost exclusively draught oxen. Small ruminants are provided with a minimum diet (qualitatively) in the S-scenario and a somewhat better diet in the R-scenario. Therefore, a higher meat and milk production is achieved in the R-scenario, despite the smaller herd size: 57 000 TLU versus 68 000. Total annual production is 4 300 and 3 700 ton liveweight and 3 400 and 1 300 ton milk in the R- and the S-scenario, respectively.

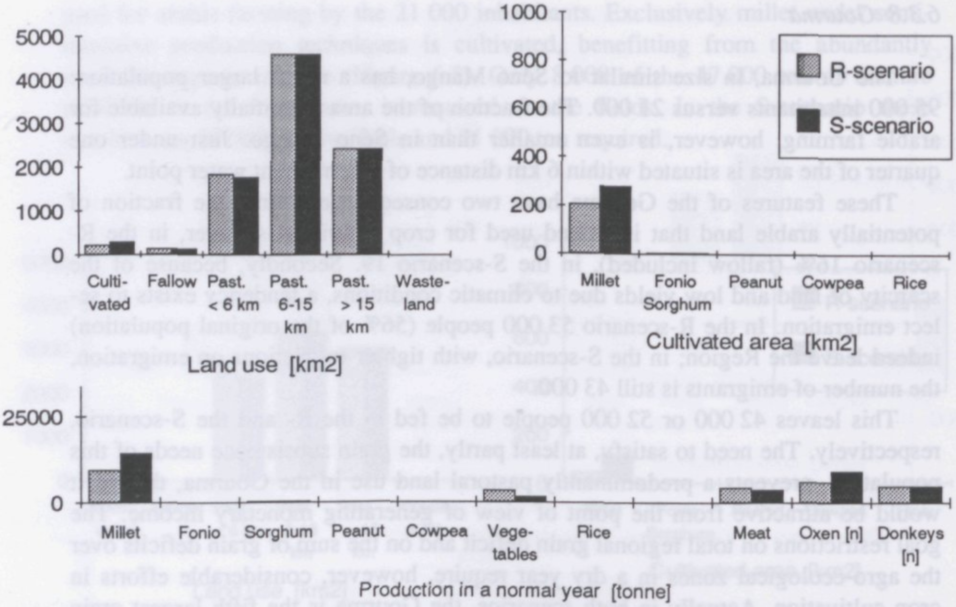

Figure 6.9. Land use and cropping pattern on cultivated land [km²] and total production of various commodities in a normal year in the Gourma in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

6.3.9 Bodara

Bodara is located in the driest of the four rainfall zones distinguished in the Region, which is reflected in both crop yields and pasture production (Figure 6.10).

During the dry season in a normal year only 90 000 ton of forage is available from natural pastures and about 3 500 ton from crop residues, mostly of poor or moderate quality. In dry years, the average quality of available forage is higher, but total availability is only 53 000 ton. The number of animals that can be supported depends on the goal restriction with respect to the permitted number of animals at risk in a dry year. In the S-scenario, representing the more risk-avoiding attitude, no animals at risk are accepted for the Bodara. This results in a herd size of 22 000 TLU, exclusively consisting of small ruminants and some donkeys. In the R-scenario, herd size is 40 000 TLU, but for 16 000 TLU local forage supply is insufficient in dry years. In other words, the price paid in the R-scenario for the production of an additional 1 100 ton liveweight in a normal year, representing approximately 375 million FCFA, is that 40% of the livestock is at risk in a dry year.

In the R-scenario, cattle are reared, albeit to a limited extent. The primary production objective is draught oxen, of which in total 1 600 are present, enabling millet production under the semi-intensive production technique. In the S-scenario that possibility is excluded and only extensive millet cultivation is practiced. To compensate the associated lower yields per ha (150 kg ha^{-1} in a normal year versus

270 kg ha^{-1} in the R-scenario), a larger area is cultivated (6 600 versus 4 800 ha). Total annual millet production in the S-scenario, 1 000 ton in a normal year, is however, still substantially lower than the 1 300 ton in the R-scenario. But in either case it is insufficient to cover the 5 000 ton millet-equivalents for subsistence of the population. In dry years grain deficits will be even higher as complete crop failures may occur on the soil types cultivated in this northern agro-ecological zone.

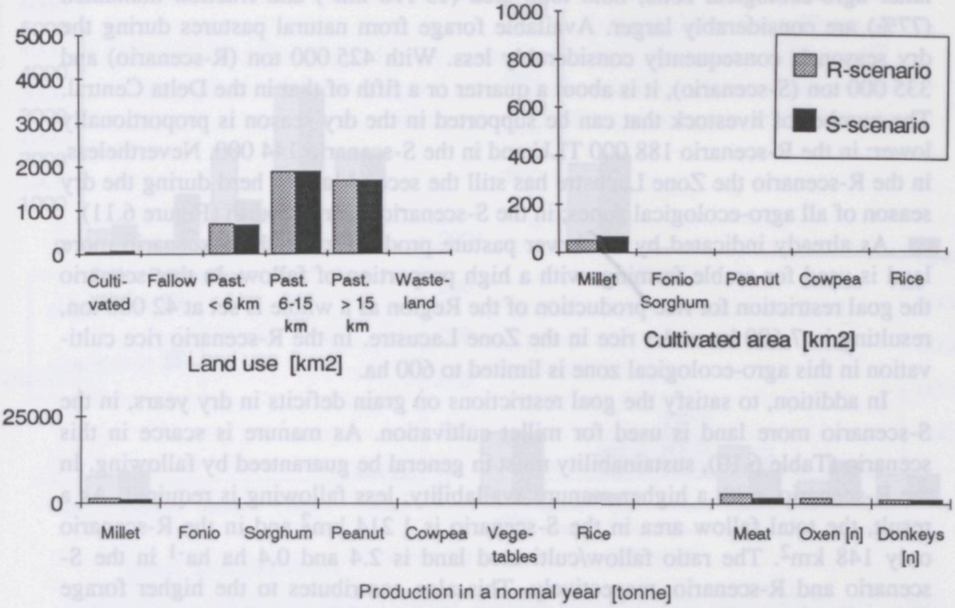

Figure 6.10. Land use and cropping pattern on cultivated land [km^2] and total production of various commodities in a normal year in Bodara in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

6.3.10 Zone Lacustre

The Zone Lacustre, the northern part of the delta, is the second largest agro-ecological zone, 9 920 km^2 in area, and also rather populous, with 185 000 inhabitants. Under a normal flood, 24% of its surface is flooded during part of the year.

In this respect the Zone Lacustre resembles the Delta Central, though in the latter agro-ecological zone, both total area (15 190 km^2) and fraction inundated (77%) are considerably larger. Available forage from natural pastures during the dry season is consequently considerably less. With 425 000 ton (R-scenario) and 335 000 ton (S-scenario), it is about a quarter or a fifth of that in the Delta Central. The number of livestock that can be supported in the dry season is proportionally lower: in the R-scenario 188 000 TLU and in the S-scenario 144 000. Nevertheless, in the R-scenario the Zone Lacustre has still the second largest herd during the dry season of all agro-ecological zones; in the S-scenario it ranks fourth (Figure 6.11).

As already indicated by the lower pasture production, in the S-scenario more land is used for arable farming, with a high proportion of fallow. In that scenario the goal restriction for rice production of the Region as a whole is set at 42 000 ton, resulting in 7 600 ha under rice in the Zone Lacustre. In the R-scenario rice cultivation in this agro-ecological zone is limited to 600 ha.

In addition, to satisfy the goal restrictions on grain deficits in dry years, in the S-scenario more land is used for millet cultivation. As manure is scarce in this scenario (Table 6.10), sustainability must in general be guaranteed by fallowing. In the R-scenario, with a higher manure availability, less fallowing is required. As a result, the total fallow area in the S-scenario is 1 214 km^2 and in the R-scenario only 148 km^2. The ratio fallow/cultivated land is 2.4 and 0.4 ha ha^{-1} in the S-scenario and R-scenario, respectively. This also contributes to the higher forage production in the R-scenario, as fallow land has a 50% lower productivity than rangeland in terms of consumable forage.

Millet, rice and sorghum provide 9 500 (R-scenario) or 14 300 ton (S-scenario) of grain in a normal year and 3 400 and 4 400 ton, respectively in a dry year. These production levels are much lower than subsistence needs, estimated at 42 000 ton millet-equivalents per year. As a consequence, the Zone Lacustre is, after the Delta Central, the second largest grain importer of all agro-ecological zones.

In both scenarios 1 700 ha is used for flood retreat sorghum cultivation under the extensive production technique. With the Gourma (400 ha), the Zone Lacustre is the only agro-ecological zone where flood retreat cultivation of any importance takes place.

Finally, in both scenarios vegetable production occupies 600 ha of land.

For animal production the situation is much more favourable. The agro-ecological zone produces 17 000 ton of meat or 14% of the total regional production in the R-scenario and 10 000 ton or 12% in the S-scenario. In monetary terms, this represents 4.6 (R-scenario) or 2.3 billion FCFA (S-scenario) marketable product. Milk production is 0.9 (R-scenario) and 2 (S-scenario) kg per person per week.

Fish production, finally, is 31 000 ton of fresh fish in a normal year and 18 000 ton in a dry year. After subtracting home consumption, this represents a marketable product in a normal year of 7.1 billion FCFA. Monetary inputs in fisheries in this agro-ecological zone are around 2.3 billion FCFA, so that their gross revenue is about 4.8 billion FCFA. Fisheries is the main occupation in this agro-ecological zone in both scenarios. In the R-scenario 45% of the total working time is spent in fishery activities, 40% in livestock activities and 15% in arable farming; in the S-scenario these values are 57, 26 and 17, respectively.

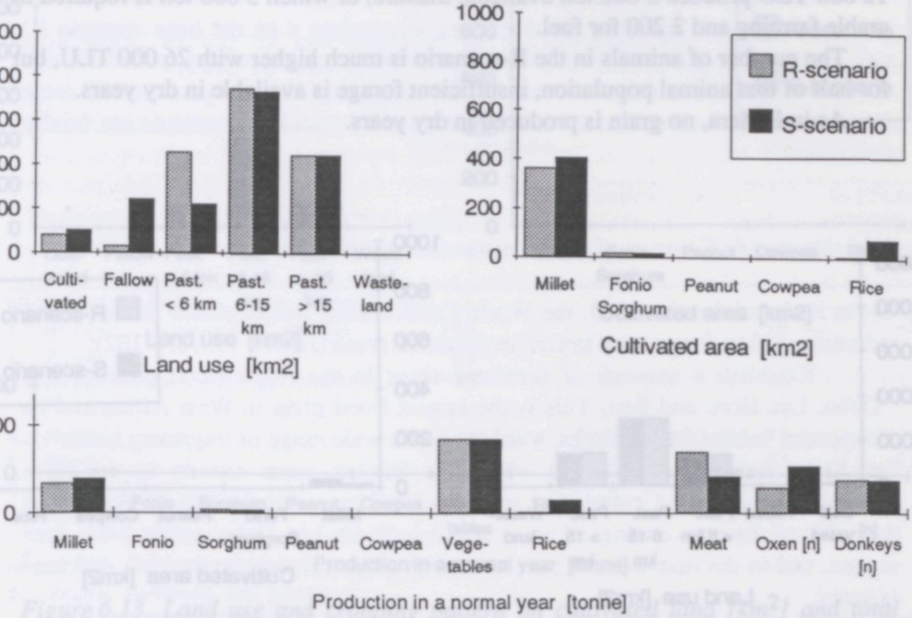

Figure 6.11. Land use and cropping pattern on cultivated land [km²] and total production of various commodities in a normal year in the Zone Lacustre in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

6.3.11 Hodh

Less than one percent of the total population of the Region lives in the agro-ecological zone of Hodh. Its land use pattern is very similar to that of Bodara, with some millet cultivation, 1 500 ha semi-intensive in the R-scenario and 3 300 ha extensive (due to the absence of oxen) in the S-scenario (Figure 6.12). In the latter scenario, sustainability can be fully attained by application of organic manure. The 12 000 TLU produce 8 000 ton available manure, of which 3 000 ton is required in arable farming and 2 200 for fuel.

The number of animals in the R-scenario is much higher with 26 000 TLU, but for half of that animal population, insufficient forage is available in dry years.

As in Bodara, no grain is produced in dry years.

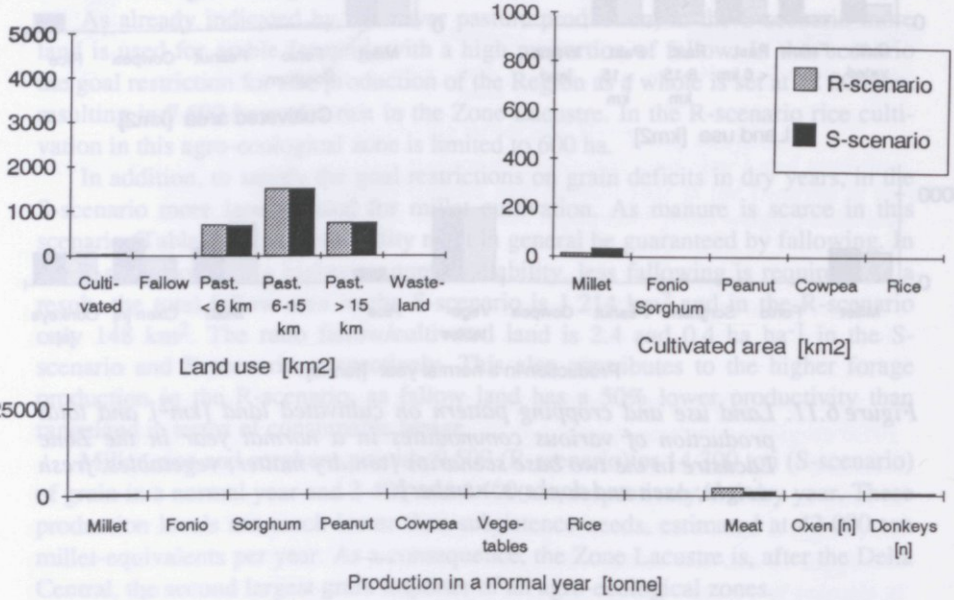

Figure 6.12. Land use and cropping pattern on cultivated land [km²] and total production of various commodities in a normal year in Hodh in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

6.3.12 Méma Sourango

Méma Sourango is the least populous of all agro-ecological zones. The main bottle-neck for exploitation is the scarcity of drinking water. Only 16% of the available 3 100 km^2 is situated within a 6 km distance from a permanent water point, the lowest fraction of all agro-ecological zones (Figure 6.13).

In both scenarios, land use in Méma Sourango is purely pastoral. The number of animals that can be supported at this extreme specialisation is 23 000 TLU. Both in normal and a dry years enough forage is available from pastures to feed these animals during the dry season. The limiting factor for further expansion of the livestock activities is availability of labour (Table 6.10), due to the population size, limited by the scarcity of drinking water.

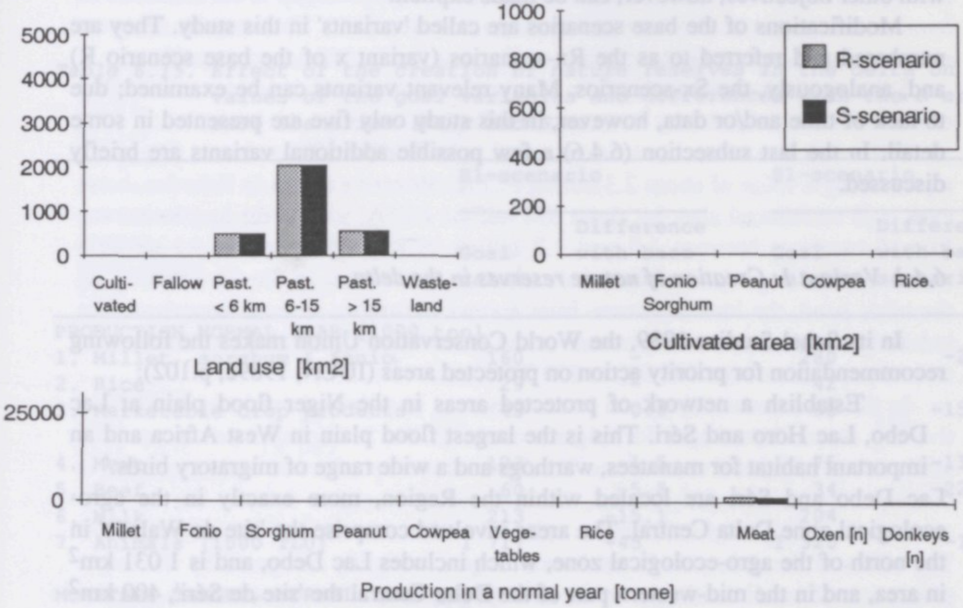

Figure 6.13. Land use and cropping pattern on cultivated land [km^2] and total production of various commodities in a normal year in Méma Sourango in the two base scenarios [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

6.4 Variants

In formulating the two base scenarios, presented in the preceding sections, choices had to be made with respect to the numerical values of technical coefficients and parameters. These choices have been based as much as possible on observations, simulation results and theoretical considerations, but for various reasons they are, and always will be, to some extent arbitrary. One example is the uncertainty about production coefficients, such as those of the livestock production activities (Subsection 6.4.4). Another uncertainty may be related to the exact interpretation of key concepts in this study, such as the situation of pastures in so-called 'dry years' and 'normal years' (Subsection 6.4.5).

Moreover, disputable are always those coefficients that can be affected by policy measures, such as taxes, subsidies and prices. Assuming those to remain constant, as is generally done in the base scenarios, is not always fully satisfactory in a policy-oriented study. One might be interested in the potential effects of instruments in this field, e.g. with respect to intervention prices of outputs or prices of crucial inputs such as fertilizer. Some of these effects are examined in Subsections 6.4.2 and 6.4.3.

Finally, there may be dispute about normative choices such as the desirability of reserving part of the delta for wildlife protection (Subsection 6.4.1). The model and the analysis cannot, of course, be used to judge that desirability; the trade-offs with other objectives, however, can be made explicit.

Modifications of the base scenarios are called 'variants' in this study. They are numbered and referred to as the Rx-scenarios (variant x of the base scenario R) and, analogously, the Sx-scenarios. Many relevant variants can be examined; due to lack of time and/or data, however, in this study only five are presented in some detail. In the last subsection (6.4.6) a few possible additional variants are briefly discussed.

6.4.1 Variant 1: Creation of nature reserves in the delta

In its Sahel Studies 1989, the World Conservation Union makes the following recommendation for priority action on protected areas (IUCN, 1989c; p.102):

> 'Establish a network of protected areas in the Niger flood plain at Lac Debo, Lac Horo and Séri. This is the largest flood plain in West Africa and an important habitat for manatees, warthogs and a wide range of migratory birds.'

Lac Debo and Séri are located within the Region, more exactly in the agro-ecological zone Delta Central. The areas involved comprise the 'site de Walado' in the north of the agro-ecological zone, which includes Lac Debo, and is 1 031 km^2 in area, and in the mid-western part of the Delta Central the 'site de Séri', 400 km^2 in area.

The effect of reserving these areas for nature protection on production and income of the Region is examined in this subsection. For that purpose, the soil types involved must be known. On the basis of the maps provided by IUCN (1989a, 1989b) and the PIRT atlas (PIRT, 1983), we estimated that it involves the following areas:

- soil type E1b	601 km^2
- soil type E2b	300 km^2
- soil type F1	86 km^2
- soil type G	229 km^2
- permanent surface water	215 km^2
Total	1 431 km^2

In the analysis it is assumed that protection of wildlife implies exclusion of all agricultural (including fisheries) activities in the protected area.

It is now relatively easy to examine the impact of the creation of these two nature reserves on goal achievement in the optimization model. The results are presented in Table 6.15, where the designations R1 and S1 refer to the variant of the two base scenarios examined in this subsection. The line in bold refers to the goal variable optimized.

The effect on the values of the goal variables is of course different in the two scenarios, i.e. the impact is much greater in the S-scenario, where more claims are put forward, than in the R-scenario. In the S-scenario, creation of a nature reserve results in a decrease in annual gross (or monetary) revenue in a normal year of 5.5 billion FCFA (18 million US$), whereas in the R-scenario that amounts to 2.1 billion FCFA (7 million US$).

Table 6.15. Effect of the creation of nature reserves in the delta on the values of the goal variables and differences with the R and S base scenarios (R1-R and S1-S).

	R1-scenario		S1-scenario	
	Goal value	Difference with base scenario	Goal value	Difference with base scenario
PRODUCTION NORMAL YEAR [1000 ton]				
1. Millet, sorghum & fonio	160	-	280	-2.1
2. Rice	29	-	42	-
3. Marketable crop products	45	-0.0	85	-15.3
4. Meat	123	-1.5	75	-11.6
5. Beef	60	-5.8	34	-22.0
6. Milk	213	-15.1	204	-
7. Animals [1000 TLU]	1 717	-45	1 320	-171
MONETARY TARGET, NORMAL YEAR [10^9 FCFA]				
8. Gross revenue of crops, livestock & fishery	**64.6**	**-2.1**	**26.9**	**-5.5**
9. Money input crops	6.0	0.0	15.0	-
10.Money input livest.	2.2	-0.1	1.3	-0.3
11.Money input crops, livestock & fishery	14.5	-0.7	22.6	-1.0
PRODUCTION [1000 ton], DEFICITS AND RISKS IN A DRY YEAR				
12.Millet, sorghum & fonio	82	0.3	151	-0.3
13.Rice	10	-	12	0.2
14.Crop products	190	0.3	222	-13.4
15.Regional grain deficit[a]	140	-0.3	110	-
16.Sum sub-reg. grain deficits[a]	150	-	130	-
17.Number of animals at risk [1000 TLU]	400	-	100	-
OTHER				
18.Employment [1000 man-year]	334	-2.2	336	-
19.Emigration [1000 person]	250	-	50	-

a) in 1000 ton millet-equivalents.
-: no difference.

For a fair assessment of these results, one must bear in mind the limitations of this analysis. First, in this study only the impact on the agricultural sector, which by definition is negative, is examined. The creation of nature reserves will have positive effects outside that sector, both in terms of monetary income (tourism) and employment (management). Secondly, as Table 6.16 indicates, the final impact is sensitive to assumptions with regard to the effects on fisheries. In this analysis it *has been assumed that the reduction in total catch is proportional to the reduction in* inundated area due to the creation of nature reserves (9%). This may be an over-estimate due to e.g. mobility of fish in reality, but that is difficult to quantify.

Table 6.16 gives for each of the two scenarios the breakdown per commodity of the reduction in monetary revenue of the Region.

Fish catch in a normal year is estimated to be 8 300-8 500 ton lower (R and S), representing a value of about 2.3 billion FCFA. Monetary inputs in fisheries, however, will be reduced also, by about 670 million FCFA, so that the loss in income from fisheries is between 1.6 and 1.7 billion FCFA, which in the R1-scenario represents the larger part of the total reduction in revenue. In the S1-scenario, on the other hand, the loss in income from animal husbandry is more important. The reduced area of dry season pastures in the Delta Central results in a reduction in animal population from 698 000 to 539 000 TLU.

In the R1-scenario, the Zone Lacustre serves to a limited extent as an alternative dry season home-base for migrant cattle. In the S1-scenario that is not possible, due to additional restrictions. Total annual meat production in that scenario is consequently considerably lower, 12 000 ton liveweight, than in the base S-scenario implying a reduction in the value of marketable meat of 3.4 billion FCFA. The effect of the reduction in total meat output is slightly mitigated by the larger proportion of small ruminants in the total population, whose meat makes a better price than beef (Table 6.15 rows 4 and 5).

Crop production is hardly affected by the creation of a nature reserve in the Delta Central, with the exception of a shift in vegetable cultivation in the Zone Lacustre from shallot to 'other vegetables'. Their high quality crop residues that can be used as fodder, outweigh in the final analysis of conflicting claims in this scenario, the higher yields of shallots.

Table 6.16. Effect of the creation of nature reserves in the delta on monetary revenue in a normal year, differences with the R and S base scenarios (R1-R and S1-S).

SOURCE	Loss in production, marketable product [ton]	[10^6 FCFA] (1)	Reduction in money inputs [10^6 FCFA] (2)	Loss in monetary revenue [10^6 FCFA] (1)-(2)
R1--R				
CROPS				
millet	314	17		
sorghum	-	-		
fonio	3	0		
groundnut	-97	-7		
cowpea	-	-		
vegetables	-	-		
rice	-257	-18		
Subtotal		-8	-18	10
LIVESTOCK				
meat	1 847	511	51	460
milk (not marketable)	15 083	-		
FISHERIES	8 310	2 285	669	1 616
Total		2 788	702	2 086
S1--S				
CROPS				
millet	1 846	102		
fonio	-	-		
sorghum	-	-		
groundnut	-	-		
cowpea	-78	-6		
vegetables	13 380	648		
rice	184	13		
Subtotal		757	-	757
LIVESTOCK				
meat	11 668	3 430	317	3 113
milk (not marketable)	-	-		
FISHERIES	8 490	2 435	663	1 672
Total		6 522	980	5 542

-: no difference.
0: less than 0.5 units.

6.4.2 Variant 2: Reducing the price of fertilizer by 50%

In Subsection 6.2.5, where the intensity of fertilizer application in the two base scenarios was discussed, it was shown that the level of intensification is much higher in the S-scenario than in the R-scenario. These results were based on the market prices of fertilizer reported for the Region (450 FCFA kg^{-1} N and K in elementary form and 1 250 FCFA kg^{-1} P).

Subsidizing industrial fertilizer to increase crop production is often considered a suitable policy instrument. To examine the possible consequences of such a policy, a variant has been run that shows the optimum land use, in terms of maximizing gross revenue, in case the fertilizer prices for the farmer would be reduced by 50%.

As the levels of intensification differ considerably in the two base scenarios, the effect of lower fertilizer prices is also different. In the R2-scenario (= R-scenario with fertilizer prices -50%), it results in a three to six-fold increase in the total amount of fertilizer applied, compared to a 25-50% increase in the S2-scenario, depending on nutrient element (Table 6.17). But even so, the use of nitrogen in the R2-scenario is still lower than in the original S-scenario, but not for the two other nutrient elements, P and K. The increase in the use of these two elements in the R2-scenario, largely due to the introduction of fodder crops, is remarkable.

Table 6.17. Total use of chemical fertilizer in the two base scenarios and with a 50% reduction in the price of fertilizer (R2 and S2).

CROP	FERTILIZER USE			
	R	R2	S	S2
QUANTITY [ton]				
N	5 181	13 084	13 161	16 212
P	305	1 807	1 457	2 192
K	1 586	7 835	7 275	10 111
VALUE [10^9 FCFA]				
N		5.9		7.3
P		2.3		2.7
K		3.5		4.6
Total		11.7		14.5
Hypothetic subsidies [10^9 FCFA]		5.8		7.3
Gain in gross revenue (R2-R and S2-S) [10^9 FCFA]		2.7		9.0
S2-(S without limit on monetary inputs)				6.6

The values of the goal variables in this variant are given in Table 6.18, in 'standard' form. It clearly shows the divergence in the way the two scenarios are affected. In the R2-scenario grain production considerably increases, whereas in the S2-scenario total crop production expands much more moderately. In the latter case, there is even a reduction in millet production, albeit more than compensated by the introduction of sorghum and groundnut and a shift from 'other vegetables' to shallots.

Table 6.18. Effect of a 50% reduction in fertilizer prices on the values of the goal variables and the differences with the R- and S-base scenarios (R2-R and S2-S).

	R2-scenario		S2-scenario	
	Goal value	Difference with base scenario	Goal value	Difference with base scenario
PRODUCTION NORMAL YEAR [1000 ton]				
1. Millet, sorghum & fonio	239	78.6	278	-4.7
2. Rice	29	-	42	-
3. Marketable crop pr.	129	83.7	141	40.1
4. Meat	130	5.3	99	12.4
5. Beef	63	-3.5	57	1.0
6. Milk	217	-11.2	204	-
7. Animals [1000 TLU]	1 789	27	1 502	11
MONETARY TARGET, NORMAL YEAR [10^9 FCFA]				
8. Gross revenue of crops, livestock & fishery	**69.4**	**2.7**	**41.5**	**9.0**
9. Money input crops	9.9	3.9	11.9	-3.1
10.Money input livest.	2.3	0.0	2.0	0.3
11.Money input crops, livestock & fishery	19.2	4.0	20.8	-2.8
PRODUCTION [1000 ton], DEFICITS AND RISKS IN A DRY YEAR				
12.Millet, sorghum & fonio	124	42.3	148	-3.4
13.Rice	10	-	13	0.4
14.Crop products	236	45.8	265	30.2
15.Regional grain deficit[a]	95	-46.2	109	-0.7
16.Sum sub-regional grain deficits[a]	150	-	130	-
17.Number of animals at risk [1000 TLU]	400	-	100	-
OTHER				
18.Employment [1000 man-year]	353	17.0	336	-
19.Emigration [1000 person]	250	-	50	-

a) in 1000 ton millet-equivalents.
-: no difference.

In both scenarios of this variant, but in the S2-scenario in particular, cropping is more diversified: fonio in the R2-scenario, sorghum in the S2-scenario and groundnut, cowpea and fodder crops in both scenarios, each contributing a few percent to total crop production (Table 6.19 and Figure 6.14).

Table 6.19. Breakdown of total crop production [% of weight] in a normal year in the two base scenarios and with a 50% reduction in fertilizer prices (R2 and S2).

CROP	PRODUCTION			
	R	R2	S	S2
Millet	53	55	70	58
Sorghum	0	-	-	3
Fonio	0	1	0	0
Groundnut	5	3	-	3
Cowpea	-	2	3	3
Shallot[a)]	26	18	5	17
Other vegetables[a)]	6	4	11	4
Rice	9	7	10	9
Fodder crops	-	10	-	4
Total	100	100	100	100
Total absolute [1000 ton]	300	427	402	478

a) fresh weight.
-: zero value.
0: less than 0.5 units.

The higher grain production in the R2-scenario is reflected in a considerably lower grain deficit in dry years (Table 6.18, row 15). In fact, with the exception of milk and beef production, all goal variables attain more favourable values in this scenario. The costs involved are illustrated in Table 6.17. The market value of the total amount of inorganic fertilizer in this scenario is 11.7 billion FCFA. As the farmer is confronted with prices half the market value, the subsidies amount to 5.8 billion FCFA per year. The annual increase in total regional monetary revenue is 2.7 billion FCFA and hence a deficit exists of 3.1 billion FCFA, which can thus be interpreted as the costs to the Region to attain the more favourable values of the goal variables (the first two columns of Table 6.18).

For the S2-scenario a similar calculation can be made. At first sight, reducing the price of fertilizer by 50% seems to result in a net profit. This result, however, presents a distorted picture because in the base S-scenario a binding restriction on total monetary inputs in arable farming was introduced (Table 6.1, row 9). In other words, the monetary gains of further intensification (if allowed) counterbalance the costs of fertilizer, even at market prices.

To accurately judge the net costs of subsidizing fertilizer, the expenses (7.3

billion FCFA, Table 6.17) must be compared to the increase in monetary revenue in the S2-scenario vis-à-vis the S-scenario without a restriction on monetary inputs in arable farming. In that case (Table 6.17, last line) the costs appear to be 7.3 - 6.6 = 0.7 billion FCFA. That is much lower than in the R2-scenario, but the advantages in terms of other objectives are much less impressive too (last two columns of Table 6.18).

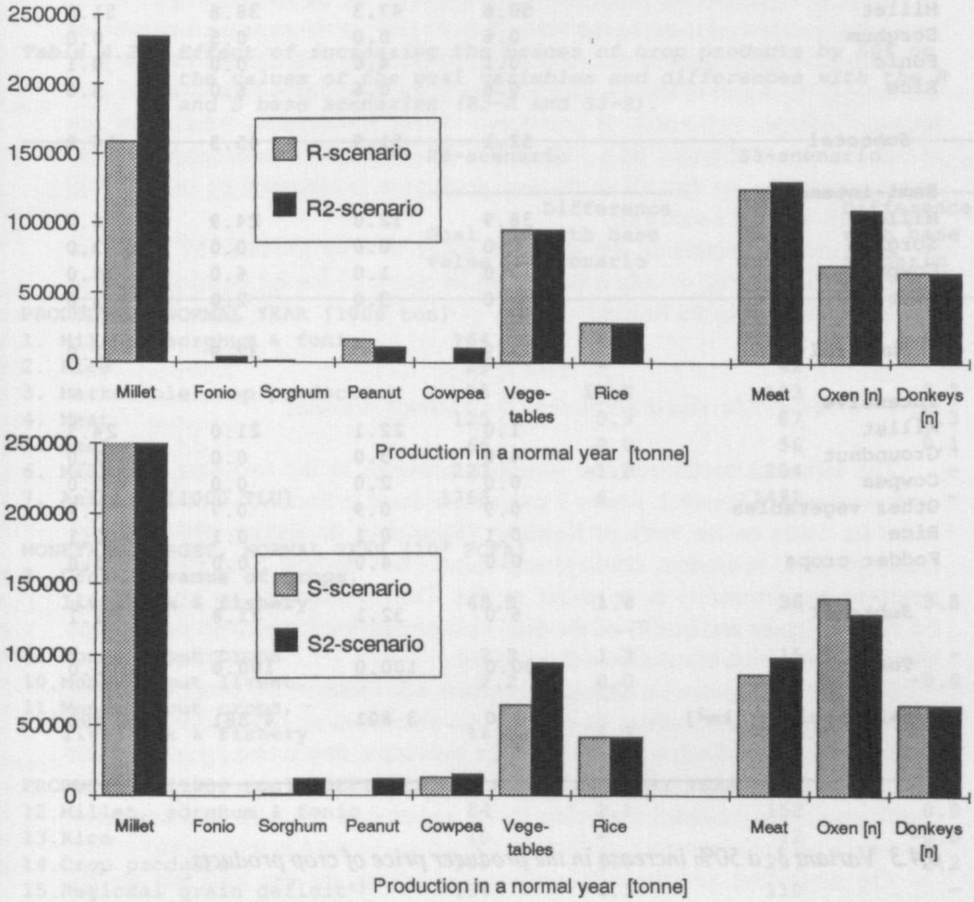

Figure 6.14. Total production of various commodities in a normal year in the Region in the four scenarios R, R2, S and S2 [ton dry matter; vegetables: fresh weight; oxen and donkeys: number].

Table 6.20, finally, presents a breakdown of the area cultivated according to crop species and intensification level. As mentioned earlier, subsidizing fertilizer promotes intensification (especially in the R-scenario) and diversification (especially in the S-scenario). Moreover, fodder crops become profitable at these prices of fertilizer. Only fodder cowpea is selected, bourgou cultivation, even under these conditions, not being profitable.

Table 6.20. Breakdown [% of cultivated land] of crops according to the three production levels in the two base scenarios and with a reduction of 50% in the price of fertilizer (R2 and S2).

CROP	LAND USE			
	R	R2	S	S2
Extensive				
Millet	50.8	47.3	38.8	51.8
Sorghum	0.6	0.0	0.5	0.0
Fonio	0.1	4.0	0.0	0.1
Rice	0.6	0.6	6.0	5.0
Subtotal	52.1	51.9	45.3	56.9
Semi-intensive				
Millet	38.9	12.0	24.9	6.0
Sorghum	0.0	0.0	0.0	3.0
Cowpea	0.0	1.0	6.0	0.0
Rice	3.0	3.0	2.0	3.0
Subtotal	41.9	16.0	32.9	12.0
Intensive				
Millet	1.0	22.1	21.0	24.3
Groundnut	4.0	3.0	0.0	2.0
Cowpea	0.0	2.0	0.0	3.0
Other vegetables	0.9	0.9	0.7	0.7
Rice	0.1	0.1	0.1	0.1
Fodder crops	0.0	4.0	0.0	1.0
Subtotal	6.0	32.1	21.8	31.1
Total	100.0	100.0	100.0	100.0
Total absolute [km^2]	3 840	3 801	4 581	4 496

6.4.3 Variant 3: a 50% increase in the producer price of crop products

An alternative policy to promote arable crop production is intervening in the market prices of agricultural products. One way to do this is the introduction of a so-called guarantee price, a minimum price level for certain products, by the state or an official agency. In fact, for millet a so-called guarantee price exists in the Region and is currently set at 55 FCFA kg^{-1}. In the two base runs this price has functioned as a reference for setting the prices of other cereals.

It is, however, of interest to examine the consequences, in terms of optimum land use, if intervention prices of products of arable farming are set at a higher level, for example +50%, as in this third variant. As a reminder: in the base runs (the R- and the S-scenario) the following prices were assumed [FCFA kg^{-1} DM]:

55 for millet, 56 for sorghum, 70 for rice (paddy) and fonio, 75 for groundnut (unshelled) and cowpea (shelled). For shallot and other vegetables the prices were 59 and 96 FCFA kg^{-1} fresh weight, respectively.

In the variant presented here (the R3- and S3-scenario) all prices were increased by 50%. All other coefficients and restrictions remain unchanged.

Most striking in the results is the limited impact of these price increases on the values of the goal variables (second and fourth column of Table 6.21).

Table 6.21. Effect of increasing the prices of crop products by 50% on the values of the goal variables and differences with the R and S base scenarios (R3-R and S3-S).

	R3-scenario		S3-scenario	
	Goal value	Difference with base scenario	Goal value	Difference with base scenario
PRODUCTION NORMAL YEAR [1000 ton]				
1. Millet, sorghum & fonio	164	4.3	282	0.1
2. Rice	29	-	42	-
3. Marketable crop products	58	12.8	103	2.3
4. Meat	125	0.3	87	-0.3
5. Beef	66	0.0	56	0.1
6. Milk	227	-1.2	204	-
7. Animals [1000 TLU]	1768	6	1491	-
MONETARY TARGET, NORMAL YEAR [10^9 FCFA]				
8. Gross revenue of crops, livestock & fishery	**68.5**	**1.8**	**36.0**	**3.5**
9. Money input crops	7.3	1.3	15.0	-
10. Money input livest.	2.2	0.0	1.6	-0.0
11. Money input crops, livestock & fishery	16.5	1.3	23.6	-0.0
PRODUCTION [1000 ton], DEFICITS AND RISKS IN A DRY YEAR				
12. Millet, sorghum & fonio	84	2.1	152	0.0
13. Rice	10	-	12	-0.0
14. Crop products	195	5.7	237	2.2
15. Regional grain deficit[a)]	134	-6.3	110	-
16. Sum sub-reg. grain deficits[a)]	150	-	130	-
17. Number of animals at risk [1000 TLU]	400	-	100	-
OTHER				
18. Employment [1000 man-year]	339	2.8	336	-
19. Emigration [1000 person]	250	-	50	-

a) in 1000 ton millet-equivalents.
-: no difference.

Of course, total regional gross revenue increases, by 1.8 billion FCFA in the R3-scenario and 3.5 billion in the S3-scenario, because outputs are valued higher and input prices have not changed. The higher revenues in the S3-scenario are due to the higher crop production. The distribution crops-livestock-fish and the composition of crop production, however, show no noticeable changes. As a consequence, land use in the S3-scenario is almost identical to that in the S-scenario. The only, minor, change is a slight expansion of shallot cultivation at the expenxe of 'other vegetables'.

In the R3-scenario, the effects are not negligible, but far from dramatic. Intensive millet cultivation is expanded from 38 to 91 km^2, at the expense, however, of semi-intensive cultivation of this crop. Total production of millet in a normal year is a mere 2.7% higher in the R3-scenario than in the R-scenario. Moreover, 85 km^2 intensive cowpea cultivation is introduced in the R3-scenario, which was not selected in the R-scenario. Rice, vegetables, groundnut, fonio and sorghum cultivation are similar, so that, all in all, crop production is expanded by only 13 000 ton or 4.4% in the R3-scenario.

In summary, increasing the producer prices of crop products by 50%, has almost no (S-scenario) or only a very slight (R-scenario) impact on optimum land use and production in the Region.

6.4.4 Variant 4: Alternative coefficients for livestock activities

The technical coefficients for livestock activities in the two base scenarios were presented in Report 2, Annex 7 and, in less detail in Section 3.3 of this report, based for cattle on the work of Ketelaars (Breman & de Ridder, 1991). Forage intake of small ruminants, donkeys and camels was derived from those figures assuming proportionality to metabolic weight. Their production was estimated on the basis of intake and quality of the diet. Milk production for human consumption and meat production of camels were neglected.

In Report 2 a somewhat different approach was followed for small ruminants, donkeys and camels (Chapters 14 and 15). An alternative set of input-output coefficients has been derived, based on literature data and a simple demographic model for small ruminants. Unfortunately, this new set, referred to as 'alternative livestock coefficients', was completed too late to be included in the two base scenarios. Instead, this set of alternative coefficients is used as variant 4 in this report.

The similarities and the main differences between the two data sets are the following.

In both sets, for cattle the data of Ketelaars (Breman & de Ridder, 1991) have been used. For calculating the alternative livestock coefficients, however, for small ruminants, donkeys and camels, species-specific maintenance energy requirements have been applied. They have been set at 27, 28 and 35 g digestible dry matter (DDM) per kg metabolic weight per day for small ruminants, donkeys and camels, respectively. For cattle a value of 36 g DDM per kg metabolic weight per day is applied.

In addition, in calculating the alternative coefficients, the additional energy requirements for work of donkeys and for work and milk production of camels has been taken into account. The consequence is that the energy intake per unit metabolic weight for these species exceeds that of cattle.

These alternative energy requirements result in different values for dry matter intake per Tropical Livestock Unit (TLU), which are considerably lower for small ruminants, but higher for donkeys and camels (compare Tables 3.10 and 6.22).

Table 6.22. Alternative coefficients of inputs of livestock activities, [TLU^{-1} yr^{-1}]; intake of quality diet, comprising forage, browse and concentrates [kg DM]; total labour in the wet and dry season [man-day] and money [1000 FCFA].

CODE	MAIN PRO-DUCT	MOBILITY	INTAKE				LABOUR		
			DIET	FORAGE	BROWSE	CONC.	WET	DRY	MONEY
Cattle									
B1.	Oxen	sedentary	II	2 010	-	-	2	15	12.9
B2.	Meat	semi-mobile	I	2 000	-	-	3	8	5.4
B3.	Meat	semi-mobile	II	2 000	-	-	3	10	5.4
B4.	Meat	migrant	I	2 010	-	-	3	8	5.4
B5.	Meat	migrant	III	2 100	-	-	3	10	5.4
B7.	Milk	sedentary	II	2 090	-	-	4	12	5.4
B8.	Milk	sedentary	III	2 200	-	-	4	12	5.4
B9.	Milk	migrant	II	2 090	-	-	4	12	5.4
B10.	Milk	migrant	III	2 200	-	-	4	12	5.4
B11.	Milk	sedentary	IV	1 850	-	330	4	13	9.2
B12.	Milk	sedentary	IV	2 180	-	-	4	13	9.2
Sheep									
B13.	Meat	sed. & s-m.	I	2 340	-	-	13	40	6.6
B14.	Meat	sed. & s-m.	III	2 350	-	-	14	43	6.6
B15.	Meat	migrant	I	2 340	-	-	13	40	6.6
B16.	Meat	migrant	III	2 350	-	-	14	43	6.6
B17.	Meat[a]	sedentary	IV	-	-	1 510	5	16	4.2
Goats									
B18.	Meat	sed. & s-m.	I	2 000	350	-	13	39	6.6
B19.	Meat	sed. & s-m.	III	1 740	800	-	14	42	6.6
B20.	Meat	migrant	I	2 000	350	-	13	39	6.6
B21.	Meat	migrant	III	1 740	800	-	14	42	6.6
Donkeys									
B22.	Transport	sedentary	II	2 900	-	-	8	6	5.3
Camels									
B23.	Transport	migrant	II	2 440	440	-	2	14	36.3

a) on 8 months a year basis, see text.
Source: Report 2, Chapters 12-15.

The production levels of small ruminants calculated on the basis of the demographic model are, in general, somewhat higher than those estimated in Section 3.3. Moreover, the oxen activity and the sheep fattening activity (activities B1 and B17), in Report 2 have been defined as activities where young animals are purchased and then trained as draught animal or fattened, respectively. The fattening of sheep is assumed to take place in a period of 8 months; the life expectancy of oxen is set at 10 years. This alternative definition of these two activities has consequences for the technical coefficients. For the oxen, the purchase price of young bulls must be added to monetary inputs, for sheep fattening labour and forage inputs are on a 8 months per year basis.

Finally, in the analysis in Report 2 the costs of salt lickstones as input in all livestock activities has been included. As these are rather costly items (900 FCFA kg^{-1}), total monetary inputs in livestock systems increase considerably.

Summarizing, the set of 'alternative livestock coefficients' differs from the one used in the two base scenarios on the following points:

- All species: higher monetary inputs due to costs of salt lickstones.
- Small ruminants: lower dry matter intake (DMI) per tropical livestock unit (TLU); less manure per TLU available; higher meat production per TLU; no milk available for human consumption of goats on diet I.
- Donkeys: lower DMI per TLU; higher manure availability per TLU; labour inputs also during the dry season.
- Camels: diet II instead of I; higher DMI per TLU; manure available as fuel; some milk available for human consumption as well as some meat production; labour inputs required.
- Oxen: diet II instead of I; higher monetary inputs as a result of purchase of young bulls; higher labour inputs because of animal training.

The alternative technical coefficients of the activities are given in Tables 6.22 (inputs) and 6.23 (outputs). The corresponding input-output coefficients of the two base scenarios are given in Tables 3.8 and 3.10 in Section 3.3.

The values of the goal variables attained with this alternative set of technical coefficients, are given in Table 6.24. Most of the differences with the two base scenarios are obvious.

Total monetary input in livestock activities is substantially higher, among others as a result of including the costs of salt lickstones. The higher production levels of small ruminants per unit forage intake in the S4-scenario do not compensate for these extra costs, so that total monetary revenue is slightly lower than in the base S-scenario. In the R4-scenario, apparently more opportunities exist to profit from the higher productivity of small ruminants. Total herd size is expanded by 100 000 TLU and though the costs of livestock activities increase by 10 billion FCFA, total gross revenue is 2.7 billion FCFA higher.

Table 6.23. Alternative coefficients of outputs of livestock activities, [kg liveweight, kg milk available for human consumption or number of animals per TLU, per year].

CODE	MAIN PRODUCT	MOBILITY	DIET[a]	MEAT	MILK	ANIMALS	MANURE[b]
Cattle							
B1.	Oxen	sedentary	I	0	-	0.77	580
B2.	Meat	semi-mobile	I	37	0	-	300
B3.	Meat	semi-mobile	II	57	93	-	290
B4.	Meat	migrant	I	37	0	-	230
B5.	Meat	migrant	III	71	219	-	220
B7.	Milk	sedentary	II	54	165	-	460
B8.	Milk	sedentary	III	62	377	-	450
B9.	Milk	migrant	II	54	165	-	240
B10.	Milk	migrant	III	62	377	-	230
B11.	Milk	sedentary	IV+c	61	518	-	720
B12.	Milk	sedentary	IV	61	518	-	720
Sheep							
B13.	Meat	sed. & s-m	I	97	0	-	520
B14.	Meat	sed. & s-m	III	121	62	-	480
B15.	Meat	migrant	I	97	0	-	370
B16.	Meat	migrant	III	121	62	-	340
B17[c]	Meat	sedendary	IV+c	89	19		500
Goats							
B18.	Meat	sed. & s-m	I+b	68	0	-	520
B19.	Meat	sed. & s-m	III+b	96	180	-	510
B20.	Meat	migrant	I+b	68	0	-	370
B21.	Meat	migrant	III+b	96	180	-	370
Other							
B18.	Donkeys	sedentary	II	-	-	2.00	610
B19.	Camels	migrant	II+b	75	240	0.83	320

a) see Table 3.7; +b: browse included; +c: concentrates included.
b) kg dry matter TLU^{-1} available for arable farming or fuel.
c) on eight months a year basis, see text.
Source: Report 2, Chapters 12-15.

In both the S4- and the R4- scenario, herd composition changes in favour of sheep (Table 6.25). The alternative coefficients for mutton production are clearly more favourable than those for both beef and goat meat, while the coefficients for sheep milk production are also more favourable than in the base scenarios. In the R- and R4-scenarios goats are introduced only to utilize part of the available browse forage supply. In the S- and S4-scenarios, where the lower limit on milk production is binding, some more goats are selected. In both cases, however, the shift towards sheep results in a lower milk production level (Table 6.24, row 6).

Table 6.24. Effect of alternative coefficients for livestock activities on the values of the goal variables and differences with the R and S base scenarios (R4-R and S4-S)

	R4-scenario		S4-scenario	
	Goal value	Difference with base scenario	Goal value	Difference with base scenario
PRODUCTION NORMAL YEAR [1000 ton]				
1. Millet, sorghum & fonio	160	-	281	-0.5
2. Rice	28	-0.5	42	-
3. Marketable crop products	30	-15.0	86	-14.3
4. Meat	164	39.7	109	22.0
5. Beef	49	-16.8	43	-13.1
6. Milk	201	-27.5	170	-34.0
7. Animals [1000 TLU]	1862	100	1529	38
MONETARY TARGET, NORMAL YEAR [10^9 FCFA]				
8. Gross revenue of crops, livestock & fishery	**69.4**	**2.7**	**30.9**	**-1.6**
9. Money input crops	5.8	-0.1	15.0	-
10. Money input livest.	12.3	10.1	10.9	9.2
11. Money input crops, livestock & fishery	25.1	10.0	32.8	9.2
PRODUCTION [1000 ton], DEFICITS AND RISKS IN A DRY YEAR				
12. Millet, sorghum & fonio	81	-0.8	153	1.2
13. Rice	10	-	11	-0.6
14. Crop products	186	-3.4	222	-13.2
15. Regional grain deficit[a]	145	4.1	110	-
16. Sum sub-reg. grain deficits[a]	150	-	130	-
17. Number of animals at risk [1000 TLU]	400	-	100	-
OTHER				
18. Employment [1000 man-year]	366	30.5	342	5.5
19. Emigration [1000 person]	250	-	50	-

a) in 1000 ton millet-equivalents.
-: no difference.

With the alternative set of technical coefficients a shift in the location of animals during the dry season, from the Delta Central to the Zone Lacustre can be observed (Table 6.26). Hence, it is apparently more profitable to sacrifice some millet cultivation in the Zone Lacustre for pastures and to do the reverse in the Delta Central. However, total production of millet, sorghum, fonio and rice in the Region is hardly affected (Table 6.24, rows 1, 2, 12 and 13).

Table 6.25. Level of livestock activities (specified per species, main production target, mobility) in the R- and S-scenario and with alternative technical coefficents for livestock activities (R4 and S4) [1000 TLU].

SPECIES	NUMBER			
	R	R4	S	S4
Cattle				
- oxen, sedentary	126	67	254	182
- meat, semi-mobile	40	18	88	89
- meat, migrant	781	676	536	498
- milk, sedentary	102	5	42	9
- milk, migrant	0	0	96	64
subtotal	1 049	766	1 016	842
Sheep				
- sedentary	9	17	7	24
- semi-mobile	398	722	201	344
- migrant	175	238	26	116
subtotal	582	977	234	484
Goats				
- semi-mobile	78	71	163	147
- migrant	5	0	31	8
subtotal	83	71	194	155
Donkeys	32	32	32	32
Camels	16	16	16	16
Total	1 762	1 862	1 492	1 529

The large decline in total marketable crop production has different backgrounds in the R4 and S4-scenario. In the R4-scenario it is almost entirely due to the absence of groundnut production which amounted to 16 500 ton in the R-scenario, and is not compensated by the production of 1 000 ton cowpea (which was not selected in the R-scenario). The lower feed requirements per TLU of small ruminants in this variant, allows replacement of intensive peanut cultivation, partly grown for its high quality by-products, by some semi-intensive cowpea cultivation with much lower fertilizer inputs.

In the S4-scenario the decline in total crop production is almost entirely due to a shift from cultivation of shallots to 'other vegetables' with a much lower yield per unit area (16 versus 35 ton ha^{-1}), while the total area of vegetable cultivation remains the same. Expressing vegetable production in fresh weight, where grains are expressed in dry matter, suggests a much greater effect of this shift on total crop production than actually is the case.

Table 6.26. Dry season home base of livestock in the R- and S-scenario and with alternative technical coefficients for livestock activities (R4 and S4) [1000 TLU].

AGRO-ECOLOGICAL ZONE	NUMBER			
	R	R4	S	S4
Sourou	163	180	180	187
Séno Bankass	45	52	55	61
Plateau	103	132	146	149
Delta Central	956	851	698	657
Méma Dioura	78	95	51	60
Séno Mango	84	96	91	86
Gourma	57	75	68	81
Bodara	40	53	22	31
Zone Lacustre	188	265	144	169
Hodh	26	36	12	19
Méma Sourango	23	27	23	28
Total	1 762	1 862	1 491	1 529

6.4.5 Variant 5: Reduced production of inundated pastures following a series of dry years

For the forage production of inundated perennial pastures in the base scenarios, reference is made to Chapter 11 in Report 2. The basic data used in the LP-model are partly given in Table 6.14, where for the Delta Central the flooded area, available forage per unit area, and its quality all for a normal year are given, as well as an indication of the degree of degradation. The latter value is used to correct total forage production either through decreasing the area or through a lower production per unit area.

In formulating the base scenarios it was assumed that the temporal distribution of years with deficient floods is random. Hence, under a deficient flood the area of flooded pastures is not affected, but the production per unit area is lower, and hence total available forage.

The data on flooded area, forage availability and degree of degradation for the base scenarios are summarized in Table 6.27.

An alternative assumption with respect to deficient floods could be that their temporal distribution is not random, but that they occur in sequence.

Actually, five of the six years used to define average flooding height in deficient years (510 cm) occured between 1982 and 1988 and average flooding height over that period is 519 cm (Section 2.3). Hence, as for the fishery activities (Report 2, Chapter 16), it may be assumed that the average flooding height for a normal flood (660 cm) is representative for a sequence of normal floods and the average flooding height for a deficient flood is representative for a sequence of deficient floods. The consequence of that assumption is that under a deficient flood also the flooded area is reduced (Table 2.8, Section 2.3), which also affects the vegetation cover (Report 1, Chapter 5).

Table 6.27. Surfaces [km^2], estimated degree of degradation and forage availability [$t\ ha^{-1}$] of intact natural pastures of the inundated soils of the delta in a normal and a dry year. Base scenarios: R and S.

SOIL TYPE	AREA	DEGRADATION (0%=intact)	FORAGE	
			Crue normale	Crue basse
E1b	7 480	15	3.0	2.0
E2b	4 474	67	1.1	0.7
F3b	752	67	1.7	1.0
G	2 073	67	1.3	0.6
Total	14 779	29	2.1	1.4

To take that into account, it is assumed that after a sequence of deficient floods the natural vegetation on flooded soils has changed, such that it can re-establish itself in its ecological niche, which is determined essentially by flooding height, rather than by edaphic factors. In other words, when flooding height oscillates around a normal value during a sequence of years, the area of the various flooded pasture types stabilizes at a 'normal' value and available forage varies with actual flooding height.

When flooding height oscillates around a low value during a sequence of years, the area of the various flooded pasture types stabilizes around a low value, with forage availibility varying with actual flooding height.

For this variant it is also assumed that under normal flooding conditions forage availability assumes a normal value without degradation effects (optimal situation not taking into account fire and unavoidable losses). Under deficient flooding conditions forage availability from the flooded pastures stabilizes around a lower value. On the soils that are not flooded, the perennial vegetation has disappeared, and because of their heavy texture an annual vegetation cannot establish, hence forage availability is negligible. In Table 6.28 the values of flooded surfaces and forage production under normal and deficient floods as used in variants R5 and S5 are given.

This alternative approach allows taking into account the current situation of degraded soils in the delta, as well as the expansion of rice cultivation. Actually, the data in Table 6.28 show that under deficient floods the area of the various vegetation types decreases, except for the *Oryza* associations (soil type F3b).

Considering a 'dry year' representative for a sequence of dry years and a 'normal year' for a sequence of normal years, implies that the difference in forage production of the flooded pastures between dry and normal years will be larger than in case of a random distribution. As 96% of the flooded land is located in only two agro-ecological zones, the Delta Central and the Zone Lacustre, production is only affected in these two zones. Availability of forage during the dry season in these two agro-ecological zones in the base scenarios and under this variant, is presented in Table 6.29.

Table 6.28. Surfaces and forage availability of natural pastures of the inundated soils of the delta, following a series of normal or a series of dry years. Alternative scenarios: R5 and S5.

SOIL TYPE	NORMAL FLOOD		LOW FLOOD	
	AREA	FORAGE	AREA	FORAGE
E1b	7 480	3.0	2 113	2.0
E2b	4 474	1.1	1 961	0.7
F3b	752	1.7	1 458	1.0
G	2 073	1.3	1 195	0.6
Total	14 779	2.1	6 727	1.2

Table 6.29. Available forage production in the Delta Central and Zone Lacustre during the dry season in the two base scenarios and with alternative coefficients for inundated pasture production (R5 and S5) [1000 ton DM].

FORAGE TYPE	AVAILABILITY			
	R	R5	S	S5
SERIES OF NORMAL YEARS				
Crop residues	130	115	169	152
Pasture, herb layer	2 160	3 296	1 972	2 758
Browse	34	48	8	14
Total	2 324	3 459	2 149	2 924
Difference with R or S [%]		+49		+36
SERIES OF DRY YEARS				
Crop residues	62	53	70	53
Pasture, herb layer	1 389	859	1 258	741
Browse	34	48	8	14
Total	1 485	960	1 336	808
Difference with R or S [%]		-35		-40

Because degradation is not taken into account after a series of normal years, contrary to the situation in the base scenarios (Table 6.27), forage supply in the alternative scenarios is higher (49 and 36% in the R5 en S5 scenario, respectively) following a series of normal years. After a sequence of dry years, however, it is considerably lower in this variant: 35% and 40% in the R5- and the S5-scenario, respectively.

These results have consequences for the feasible development pathways. If the constraints imposed on the goal variables are identical to those in the base scenarios (with the exception of total milk production), total herd size and consequently animal production decrease substantially, as shown in Table 6.30, rows 4-7.

Table 6.30. Effect of lower inundated pasture production following a series of dry years on the values of the goal variables and differences with the R and S base scenarios (R5-R and S5-S).

	R5-scenario		S5-scenario	
	Goal value	Difference with base scenario	Goal value	Difference with base scenario
PRODUCTION NORMAL YEAR [1000 ton]				
1. Millet, sorghum & fonio	160	-	286	4.0
2. Rice	29	+0.6	42	-
3. Marketable crop products	46	+0.6	53	-47.1
4. Meat	110	-14.9	63	-23.9
5. Beef	49	-17.2	24	-32.4
6. Milk	183	-44.9	136	-68.0
7. Animals [1000 TLU]	1 511	-251	1 124	-367
MONETARY TARGET, NORMAL YEAR [10^9 FCFA]				
8. Gross revenue of crops, livestock & fishery	**62.8**	**-3.9**	**21.0**	**-11.5**
9. Money input crops	5.8	-0.2	15.0	-
10.Money input livest.	2.0	-0.3	1.0	-0.7
11.Money input crops, livestock & fishery	14.7	-0.4	22.9	-0.7
PRODUCTION [1000 ton], DEFICITS AND RISKS IN A DRY YEAR				
12.Millet, sorghum & fonio	81	-0.2	154	2.6
13.Rice	10	-	10	-2.1
14.Crop products	190	-0.2	185	-50.2
15.Regional grain deficit[a]	141	0.1	110	-
16.Sum sub-reg. grain deficits[a]	150	-	130	-
17.Number of animals at risk [1000 TLU]	400	-	100	-
OTHER				
18.Employment [1000 man-year]	312	-23.8	336	-
19.Emigration [1000 person]	250	-	50	-

a) in 1000 ton millet-equivalents.
-: no difference.

In general, the impact of the alternative assumptions with regard to flooded pasture production is stronger in the S-scenario than in the R-scenario. Total monetary revenue for instance, decreases by 3.9 billion FCFA in the R5-scenario, but by 11.5 billion FCFA in the S5-scenario (Table 6.30, line 8).

Because of the limited forage supply after a sequence of dry years in this variant, the accepted number of animals at risk in dry years becomes crucial in the optimization. In the S-scenarios this number is set at 100 000 TLU versus 400 000 in the R-scenarios, which explains the greater impact in the S-scenario. Under the assumptions of this variant, animal husbandry is more risky. If extra risk is accepted, the consequences are limited; a more risk-avoiding attitude (the S-scenarios) has more far-reaching consequences.

The sharp decline in total crop production in the S5-scenario, both in normal and dry years, is entirely due to the decrease in vegetable production of over 50 000 ton. This effect, however, is inflated, because vegetable production is expressed in fresh weight, contrary to dry weight for grains. The reduction in vegetable production in the S5-scenario is due to the restricted availability of manure in the Delta Central and the Zone Lacustre: from 258 000 ton in the S-scenario to 176 000 ton in the S5-scenario. Fuel demands 87 000 ton, so that in the S5-scenario only half the amount of that in the S-scenario is available for arable farming. Vegetable cultivation, with a manure requirement of around 10 ton ha^{-1}, is first restricted by this scarcity of manure.

In general, the decrease in availability of manure, caused by the smaller herd size, leads to more emphasis on either extensive or intensive crop cultivation. In semi-intensive techniques relatively large amounts of organic manure are applied, compared to low manure application in the extensive techniques and inorganic fertilizer in the intensive techniques. The proportion of semi-intensive arable farming in the total cultivated area falls from 42% in the R-scenario to 39% in the R5-scenario, and from 33% in the S-scenario to 16% in the S5-scenario.

In both scenarios in this variant, herd size decreases considerably: in the R5-scenario by 251 000 TLU, in the S5-scenario by 367 000. Cattle are especially affected, in particular the migrant production systems with meat as production target (Table 6.31). The Delta Central as dry season home-base can support in this variant about 350 000 TLU less (Table 6.32).

In the R5-scenario the Zone Lacustre can partly take over the role of the Delta Central in this respect, in the S5-scenario other claims are so pressing that this is impossible. Even with a shift from wet season grazing to dry season grazing and a slight expansion of the pasture area in the Zone Lacustre, the subsistence requirements for grain in dry years, prevents expansion of the herd size at the pasture production in this variant. The restricted grain deficit in dry years is partly realized in the S5-scenario by considerable extension of the area of flood retreat sorghum. In the R5-scenario more land in the Zone Lacustre can be used for pastures, because a larger grain deficit in dry years is accepted. In fact, in the R5-scenario only 20% of the area within a radius of 6 km from a permanent water point is cultivated or fallowed, against 59% in the S5-scenario. Here too, accepting greater risks creates more room to manoeuvre and, higher levels of income, in a normal year.

Table 6.31. Livestock activities (specified per species, main production target and mobility) in the R- and S-scenario and with alternative coefficients for inundated pasture production (R5 and S5) [1000 TLU].

SPECIES	NUMBER			
	R	R5	S	S5
Cattle				
- oxen, sedentary	126	122	254	259
- meat, semi-mobile	40	0	88	42
- meat, migrant	781	598	537	0
- milk, sedentary	102	66	42	18
- milk, migrant	0	0	96	251
subtotal	1 049	786	1 017	570
Sheep				
- sedentary	9	9	7	3
- semi-mobile	398	202	201	179
- migrant	175	369	26	152
subtotal	582	580	234	334
Goats				
- semi-mobile	78	76	163	37
- migrant	5	20	31	137
subtotal	83	96	194	174
Donkeys	32	32	32	32
Camels	16	16	16	16
Total	1 762	1511	1 491	1 124

Table 6.32. Dry season home base of livestock in the R- and S-scenario and with alternative coefficients for inundated pasture production (R5 and S5) [1000 TLU].

AGRO-ECOLOGICAL ZONE	NUMBER			
	R	R5	S	S5
Sourou	163	163	180	181
Séno Bankass	45	53	55	58
Plateau	103	105	146	151
Delta Central	956	602	698	341
Méma Dioura	78	51	51	51
Séno Mango	84	67	91	83
Gourma	57	57	68	68
Bodara	40	28	22	26
Zone Lacustre	188	335	144	123
Hodh	26	24	12	14
Méma Sourango	23	27	23	27
Total	1 762	1 511	1 491	1 124

6.4.6 Possible additional variants

To explore the development possibilities of the Region under different assumptions, a large number of relevant variants can be constructed. Due to lack of time and/or reliable data, in this study only five have been treated in some detail. Moreover, additional variants should be chosen not only on the basis of analytical interest, but primarily on the basis of their relevance for the parties with a stake in the development of the Region. In that sense, the results of this study must be considered as preliminary, possibly leading to additional questions and analyses. A few interesting possibilities are suggested here.

6.4.6.1 Pasture production: mowing of inundated pastures

An important option in pasture management is mowing the inundated pastures instead of using fire to stimulate regrowth in the dry season. Total forage availability could thus be increased considerably. Labour, some equipment, storage and transport facilities would, however, be required as additional inputs. Production data under this practice are available (Report 3, Chapter 11), but more information is required on the possible exploitation intensity on a sustainable basis. Also, quantitative information on the additional inputs required under this type of management is lacking.

6.4.6.2 Pasture production: fire control on rainfed pastures

At present, fire, either through natural causes or lighted on purpose, is responsible for considerable losses of biomass in the rainfed pastures. Data on the losses involved are available (Report 3, Chapter 11). Abating these fires would require additional labour and probably heavy equipment to construct, among others, fire lanes. In addition, an extension program may be necessary aimed at restraining farmers to light fire on purpose. Quantitative information on the additional inputs required to realize a substantial reduction in both natural fires and those lighted by man is lacking.

6.4.6.3 Pasture production: improved management

Alternative activities that could be included are those based on improved natural pastures. A wide range of possibilities for pasture improvement could be considered:

- Applying fertilizer.
- Introduction or re-introduction of leguminous species.
- Introduction or re-introduction of perennial grasses.
- Abating wind and/or water erosion.

In addition, a more sophisticated treatment of harvested forage from pastures could be considered, including specific storage practices with or without the addition of urea.

Information on the required inputs and expected production increases of these management techniques is available, albeit fragmentary. Inclusion in a model analysis such as the one used in this study, however, requires complementation of that information and adaptation to the Region-specific conditions.

6.4.6.4 Expansion of the irrigated area

Irrigated crop production in completely controlled irrigation schemes may become an attractive option, especially if limiting grain deficits in dry years is an important objective.

At present, the small village-irrigation schemes ('PPIV') comprise in total 390 ha. Analysis of the model results indicates that expansion would be profitable in both the R- and S-scenarios (but more so in the S-scenario), as indicated by the fact that the upper limit on total irrigated area is binding when total monetary revenue is maximised. This holds for estimated annual charges of 350 000 FCFA ha^{-1}, based on total investments in irrigation works and motor pump of 3.5 million FCFA ha^{-1} and a life expectancy of 10 years (Report 2, Chapter 3).

Expansion of the area under irrigation for vegetable cultivation, currently estimated at 3 300 ha, also appears to be profitable in both the R- and S-scenario, as the shadow price of the restriction on the total area available is positive. For vegetables, however, saturation of the market with its effects on prices, can appreciably affect profitability.

6.4.6.5 Introduction of herbicides

Table 6.10 shows that in nine (R-scenario) or eight (S-scenario) of the eleven agro-ecological zones, labour availability during the period of first weeding of millet is restricting. Introduction of herbicides could alleviate that constraint. The shadow prices of labour provide an indication for the extent to which saving labour would contribute to the value of the goal variable, monetary income, as they represent the increase in gross revenue that can be attained by decreasing labour requirement by one unit (one man-year) during the period of first weeding. The values vary per agro-ecological zone as illustrated in Table 6.33.

Table 6.33. Shadow prices of labour per agro-ecological zone in the two base scenarios during the period of first weeding of millet [1000 FCFA per man].

AGRO-ECOLOGICAL ZONE	SHADOW PRICE OF LABOUR	
	R-SCENARIO	S-SCENARIO
Sourou	-	32
Séno Bankass	-	-
Plateau	0	-
Delta Central	20	-
Méma Dioura	34	162
Séno Mango	34	174
Gourma	0	0
Bodara	14	27
Zone Lacustre	12	41
Hodh	14	29
Méma Sourango	22	106

In Méma Dioura and Séno Mango, in particular in the S-scenario, introduction of herbicides appears to be attractive. Up to 174 000 FCFA could be earned (neglecting the costs of application of herbicide) if labour requirements could be reduced by one man during weeding time. The first weeding of millet requires 10 man-days per ha and the available period is 15 days, so that one man can weed on average 1.5 ha. Dividing the numbers in Table 6.33 by 1.5 provides an indication of the amount of money that could be spent per ha on herbicides to break even in monetary terms.

Note, however, that these shadow prices indicate the marginal gains only: if herbicides were to be applied on a substantial scale, other constraints could become limiting, thus reducing the total gain. To analyse these effects properly, all costs of application of herbicides (extension, training, purchase of the chemicals and depreciation of equipment) should be considered. As an alternative crop activity, the application of herbicides can then be incorporated in the LP-model to assess its profitability.

7. CONCLUSIONS

As indicated in the introduction, one of the major arguments for the present study is the increasing competition for the limited natural resources among the various agricultural activities. Especially the competition between arable farming and animal husbandry for the limited land resources, both in the rainfed and the flooded areas, has led to acute problems. As has been explained elsewhere (van Keulen, 1990), the results of the multiple goal optimization model cannot be used directly to guide regional development planning. Translation is necessary, in a post-model analysis, in which especially those aspects that cannot be translated in 'hard' relations have to be taken into account, to arrive at explicit policy recommendations that will result in the desired developments. In the present study, unfortunately, insufficient time has been available for a thorough post-model analysis including feedback from local 'actors' with a stake in the development of the Region. Hence, the conclusions presented here should be considered tentative, and further elaboration is necessary in a follow-up phase of the project.

7.1 Relation between LP-model results and the actual situation

Although a unique blueprint for the development of the Region (i.e. an overall land use plan) cannot be presented, the results of this study indicate the scope for development under the condition of sustainability. Two such scenarios, characterized by different boundary conditions with respect to goal achievement, have been illustrated (Sections 6.1 through 6.3). The solutions presented are optimum with respect to regional monetary revenue, under the formulated boundary conditions and the constraints imposed.

Both situations, referred to as the R- and the S-scenario, respectively, differ from the actual situation. One of the major reasons is that optimum conditions are assumed, aimed at maximum goal achievement, contrary to 'real-life' situations. Moreover, only physical and technical constraints and relations have been taken into account. Apart from the fact that quantification of the applied relations may be subject of debate, there is a tendency in this type of analyses to over-estimate the potentials vis-à-vis the actual situation. In other words, the results refer to the maximum potentials from a technical point of view. It may be argued that technical innovation has not been taken into account, i.e. the production techniques defined and their technical coefficients are based on present knowledge, but the possibilities for improvements in this respect are fairly well known.

Another important reason for deviation of the results from the present situation is that the defined production techniques are based on sustainable exploitation of the natural resources, which in the present situation is not the case. Hence, exhaustive exploitation of the natural resources under the current conditions provides the opportunity to achieve temporarily higher yields and income than realized under the conditions assumed in the model.

Comparison of model results - the scenarios and the variants - with the present situation is only relevant in relation to the question how a transition can be achieved from the current exhaustive mode of exploitation to one of the selected modes of sustainable exploitation. The differences between the present situation and the prospective one should provide indications for the necessary efforts. It is evident that in such an analysis, in addition to the technical constraints, socio-economic considerations will have to be taken into account. In the last section of this chapter some exploratory remarks are made on that issue.

In the next section the physical and agronomic problems and constraints are treated briefly, while some remarks are made about the economic prospects for the Region.

7.2 Agro-economic prospects

In the preceding chapter, in particular in Subsection 6.2.2, it has been shown that under the present economic conditions, especially the price ratio between inputs and outputs, sustainable exploitation of the natural resources by agricultural activities (including fisheries) leads to low income levels per capita. Depending on the goal restrictions with respect to emigration and risks in dry years, annual per capita income varies between 26 000 FCFA (U$ 87) and 64 000 (U$ 212), or equivalent to a range of 97 000 and 200 000 FCFA (U$ 322 - 662) per labour man-year. Note that apart from this monetary income, human subsistence needs for energy and animal protein are satisfied.

Arable farming

Satisfying the condition of sustainability implies that monetary income from arable farming is negative. In other words, the monetary inputs required for sustainable arable farming exceed the value of the marketable product. Products from arable farming, by far the most important source of energy in the diet of the local population, thus serve to satisfy the food subsistence needs, but hardly contribute to generation of income.

Although this holds for arable farming as a whole, the situation varies when differentiated for the various products. In terms of rentability, rice is most unfavourable, especially under non-controlled or semi-controlled conditions. The performance of millet, sorghum and fonio is hardly better. The same holds for groundnut and cowpea, but as these crops produce high quality forage for animal husbandry as a by-product, they are economically attractive in some parts of the Region. Cultivating vegetables is economically attractive, but because irrigation is required, the available area is limited. If that constraint can be removed, i.e. if the area can be expanded, there is a risk of surplus production, due to market saturation. Because of the perishable nature of most vegetables and the poor transport infrastructure, only a limited market exists, except probably for shallots.

Animal husbandry

Animal husbandry contributes substantially to regional monetary income, especially as a much smaller proportion of total production is required for subsistence needs. Moreover, the most important input in animal husbandry production techniques, the feed from natural pastures, is 'free of charge', i.e. does not carry a monetary component. It should , however, be realized that not all costs associated with animal husbandry have been taken into account in this study, especially the costs of drinking water and the costs associated with the exploitation of dry-season pastures around the villages and the bourgoutieres have been neglected. Therefore, the calculated net returns of animal husbandry may have been somewhat overestimated, but this sector is by far the most important contributor to regional monetary income.

Fisheries

With a contribution of 15 billion FCFA (in a 'normal' year) fisheries is also an important sector for monetary income. However, because of the large number of people employed in the sector, annual income per man-year is limited to 115 000 - 150 000 FCFA (U$ 380 - 500). In this sector, the scope for extension of the 'natural' catch is only limited, and as fish ponds hardly seem economically attractive, because of the required investments in external nutrients, increased productivity should come from a higher labour productivity, i.e. decreasing labour input, combined with a higher capital input.

Emigration

In this study, emigration is defined as expulsion of people from the Region, either in physical or in economic sense, i.e. finding employment outside the agricultural sector. In all scenarios the permitted scope for emigration is fully utilized, implying lack of gainful employment within the Region for a large part of the total population of 1.3 million inhabitants. In practice, that means that if sustainable agricultural production is a condition, permanent pressure exists to leave the agricultural sector if there is a chance for alternative employment with a reasonable income. This not only holds in dry years, but is a continuous phenomenon.

Prices of chemical fertilizer and agricultural products

As arable farming is the basis for food self-sufficiency in the Region, the effects of lower fertilizer prices and higher farm-gate prices for agricultural products on optimal land use, have been investigated.

A 50% reduction in prices of chemical fertilizer results, when maximizing total regional income, in a substantial expansion of grain production in the Region under the R-scenario and in general in more favourable values for the various goal variables. Under the S-scenario, production in the arable farming sector increases less, but it leads to greater differentiation. Regional income increases by 2.7 (R-scenario) or 6.6 (S-scenario) billion FCFA, equivalent to 45 and 90% of the costs associated with the lower fertilizer prices, respectively (Subsection 6.4.2).

Increasing the farm-gate prices by 50% hardly affects optimum land use and production. It may well be, although that has not been investigated in the present study, that a guaranteed bottom price for agricultural products would have a greater effect than a general price increase (Subsection 6.4.3).

Investments

In the input-output analysis the capital charges associated with investments in farm structures and irrigation infrastructures have been partly taken into account, although neglecting the interest charges. Investments in infrastructure (other than irrigation), such as storage facilities, wells for drinking water, or institutional infrastructure, have not been taken into account. During optimization, therefore, macro-economic considerations were not taken into account and farm-economic considerations only to a limited extent with respect to input utilization. The results provide indications for the rentability of some of the investments, such as traction, labour-saving equipment, etc., but cannot be used to judge the economic feasibility of 'public investments'. Indirectly, these can be derived from the requirements for the transition from the current situation to one of sustainable exploitation.

Improved production techniques

In Subsection 6.4.6 a first attempt has been made to analyse the efficacy and economic feasibility of technical innovations. That is directly related to the extent to which such innovations can contribute to the removal of the constraints for regional development as determined in this study. Promising techniques seem the introduction of herbicides to alleviate the labour shortage during the period of first weeding and expansion of the irrigated area to increase yield security, also under unfavourable environmental conditions.

With respect to pasture management, several technical options are open: mowing for conservation, fire control, improvement of natural pastures, etc. The results of the model, however, suggest that total forage availability is not a major constraint for regional development. Uncertainty exists with respect to the current production capacity of the natural pastures in the Region (Subsection 6.4.5), however, total forage availability in 'normal' years seems sufficient to feed about 1.5 million TLU (the most recent estimates on animal population in the Region are about one million TLU). In actual practice, probably constraints play a role that have not been incorporated in the model, such as synchronization and synlocalization of forage demand and supply. In the model, a rather crude classification has been applied, i.e. at the level of an agro-ecological zone and for two periods of the year. Another constraint could be accessibility, either in physical sense, or in terms of grazing rights of the available forage from natural pastures. These possible constraints, should, in addition to the technical possibilities for pasture improvement, be subject of further analysis.

7.3 Political instruments for implementing intervention

7.3.1 Theoretical considerations

The current state of rural production systems in the Region shows all the classic symptoms of underdevelopment: very low productivity, lack of equipment, limited use of external inputs, predominantly traditional cultivation techniques and veterinary care and poor credit facilities. This lack of support for production systems is not only the result of physical, biological and socio-economic causes but also of various constraints of a structural, institutional and cultural nature. Formulation of a development plan will not in itself solve these problems, the main objectives of such a plan being *(i)* to facilitate a rational partitioning of land between the various pastoral, cropping and fishing activities, according to local, regional or national objectives, *(ii)* safeguard the zone's resources while aiming for optimum productivity. In this way, the plan should provide a guarantee for the various investments required to intensify the activities.

The legal basis and organisational framework of development schemes, however, require considerable effort from the National government. Such efforts are of a political, institutional and financial nature and should primarily aim at removing socio-economic constraints:

- political efforts should aim at providing a clear, realistic definition of the objectives to be achieved; they should take account of the various aims at local, regional and national level, aims that seldom concur; once defined, these objectives should be an immediate or medium-term concern of the social partners, if the local population is to become fully involved;
- institutional efforts should not only involve setting up administrative and technical infrastructures (organising markets, road networks, etc.), capable of coping with the objectives defined, but also reshaping legal instruments in line with these objectives (e.g. with regard to land);
- financial policy should take the form of a balanced price policy, between, for example, the various inputs and outputs connected with agricultural production. It will also mean reinvesting in agriculture a substantial portion of the onerous taxes imposed on rural production systems.

For such efforts to be effective, one must take account of village-based organisations (villages being regarded as stable, socio-economic units) and socio-professional organisations in order to win rural inhabitants' support, firstly for the idea of rational management of available resources and later, for their development.

7.3.2 Political actions

The LP-model, as presented, is an instrument whose use enables political decision-makers, on the basis of the relevant objectives, to pinpoint *(i)* the results they can expect to achieve, *(ii)* the various physical bottle-necks in achieving those objectives and *(iii)* the consequences of a particular technical choice for the system as a whole. Describing the process of implementing one or more political improvement or development policies goes beyond the possibilities of the LP-model. What it can do, however, is provide certain indicators for the various initiatives required. Whatever scenario one chooses (scenario R or scenario S) and whatever the technical or monetary objectives selected, efficient management of the available resources (both natural and human) is an essential prerequisite for their achievement. The distribution of land among different land use types as well as the distribution of the available labour among the various activities, restrictions on the number of cattle and a certain level of intensification of agriculture, require *(i)* land management, *(ii)* the producers' acceptance of the objectives and *(iii)* management and organisation of the Region's markets. All of these should lead to a reinterpretation and reformulation of existing legislation, a shift in the relationship between the managers and those who are managed, and a revision of the current economic policy with respect to agricultural inputs and certain taxes.

7.3.2.1 The management of land by rural populations

Many still believe that the mismanagement of natural resources in general, arable land, grazing land, water, etc., is largely due to the nationalisation of land with the consequent breakdown of the authority that social groups exercised in traditional management systems. There is some ground for this point of view, considering that the requirements for monitoring, supervision and control by the authorities and access to resources are often less than satisfactory. In order to remedy the current deficiencies and shortcomings in land use practices, and without questioning the State's right to natural resources, but at the same time accepting major reforms, State institutions must delegate power to rural populations according to the following principles.

Natural resources should be allocated to organised groups (villages, groups of villages, pastoral, agro-pastoral or fishing associations).

The organised groups should comprise, as far as possible, related families or co-residents farming the same land, grazing the same areas with the same watering points or exploiting the same water surfaces for a significant part of the year.

a. The task of deciding who should receive land will not always be easy, particularly in cases where traditional customs and more recent practices have turned pastoral areas and certain farmlands into vital public thoroughfares or places of refuge. Hence the need, when allocating land, to allow for a certain cooperation among pastoral, agro-pastoral or agro-fishing communities.
b. Formal allocation (decision by authorities of the Cercle, confirmed by the Governor with provisional measures at the national level), comprising a

description of the cartographic boundaries and specifications, is an essential prerequisite for proper management of arable and grazing land. The chances of success will be significantly enhanced if the land is allocated, as far as possible, on the basis of existing land use rights, rather than creating new ones.

c. Within the areas allocated, the type of farming - based around families or individuals - should remain the same, but the conditions relating to renting and share-cropping should be transformed into a more equitable system, so that for share-croppers, for example, incentives exist to invest in soil improvement.
d. For purely pastoral areas, allocation should be based on a flexible definition of the boundaries. No new wells should be dug in the area situated outside a 15 km radius from an existing permanent watering point (15% of the Region's territory). This area should be considered common pasture land, whose integrety will be protected by the seasonal nature of the availability of water. The buffer zones in the delta zone should be safeguarded and should have the same status as grazing land situated outside a 15 km radius around a permanent watering hole.

Passage rights of cattle from other areas and extended grazing rights (which require the permission of the allottees) should be registered in each area allotted; these rights will help to keep the herds mobile thus retaining the high production levels associated with transhumance.

For purely pastoral land, there is little point in allocation if the potential beneficiaries have no animals (as for nomad pastoralists who have lost their entire herd and lack the necessary means to start again). For agro-pastoral areas, including for example the delta zone, the allocation of land to organised 'eggirgols' (associations) should be based on a manageable area, and not on land situated between 50 and 100 km from their base (e.g. the Jalli eggirgol in relation to Wallo). For eggirgols without cattle allowing their grazing land to be used by nomadic cattle and cattle from other areas in return for payment, the land should preferably be allocated to resident agro-pastoral groups rather than to the eggirgol itself.

The results that can be expected from this allocation of land are:

a. A reduction in the size of the herds: control over the use of land by the allottees implies respecting the grazing capacity of land in the pastoral zones (Gourma, Séno Mango) and more especially in the agro-pastoral zones (Delta Central, Zone Lacustre, Séno Bankass, Méma Dioura). Initially, this may imply selling off a small portion of the surplus animals in order to arrive at a herd size in accordance with the maximum carrying capacity. Later on, the entire surplus should be sold in order to arrive at the optimum herd size, i.e. aiming at increased production per head rather than simply increasing the number of animals. All of that will probably lead to the development of techniques aimed at regenerating pasture land and cultivating fodder crops.
b. The herds would no longer stray: proper management of the land allotted is impossible without keeping a close watch on the herds, in both pastoral and agro-pastoral areas; the number of watchmen should be in proportion to the size of the herds.
c. Greater stability in terms of land tenure and the intensification of agricultural

activities: the allocation of land in the form described above, will lead to more stable appropriation by villages of land and, within that area, the distribution among families or individuals. Greater stability will in turn facilitate and ultimately lead to integration of agriculture and animal husbandry.

d. Reshaping the 'jowro' function. The function of jowro may be retained, but as chief herdsman or head of the eggirgol rather than as manager of the pastures. As such, his role would be to establish the various stages and dates of departure as well as negotiating passage rights and/or grazing rights with the various visiting pastoral or agro-pastoral associations.

7.3.2.2 Participation by the local population

The concept of 'local participation' usually implies two types of involvement. The first implies that the local inhabitants bear the monetary burden or provide the labour for a particular action (e.g. they help to build dikes or take charge of a well). The second notion implies acceptance by the local population of a given programme and commitment to implementing that programme. In actual fact, it is this latter notion that determines to what degree the former is achieved.

Involvement, as understood here (the second interpretation) is dependent upon at least two conditions. Firstly, solving any structural and institutional problem that could hamper the smooth running of current production systems, and secondly, organising local inhabitants into structures that are genuinely aimed at protecting their interests.

A. Solving problems of a structural nature

The lack of clearly defined boundaries and the limited accessibility of land constitute a serious problem for an increasing proportion of the population in the Region in general and in certain agro-ecological zones in particular (i.e. the Delta Central, the Zone Lacustre, Séno Bankass and the Plateau). The fact is that so-called 'traditional' land use practices are neither governed by the rules imposed by the Dina nor by those of the State of Mali. Kolanuts, that were used to guarantee non-residents or non-owners access to arable fields, grazing land or water are now increasingly replaced by a form of land rent, that changes according to the needs of the 'owners'. This system, however, is often threatened by the very existence of modern legislation, as reflected in the increasing damage caused to fields by herds, or the occupation of grazing land by non-resident animals, or the exploitation of pools by fishermen from other areas, 'armed' with official fishing permits.

Hence, there is general consensus on the need for a more clearly defined land rights system, even if the methods of distribution are not generally agreed upon. The allocation of land to a certain activity, and in particular maintenance of its fertility, would have a much better chance of being understood and adopted by the rural population if ownership of land would be more firmly established.

B. Organising the local population

The Region is home to countless rural organisations, of which only a few are effective, with varying degrees of success. One common cause of failure is the fact that these organisations not really represent the interests of the local population. Another reason is the attitude of the technical and administrative advisers, who often loose goodwill by imposing committees that do not have the support of the local population.

Village groups are not static entities, unaffected by change; any latent tensions can stir them up, causing strife between groups of families for historical as well as more immediate reasons. Even if these tensions do not throw the village into full-scale conflict or outright fights, they can be sufficiently serious to hamper progress of projects. Given these circumstances, programmes should be based on a minimum platform, acceptable to all the parties involved. In this context, the technical options developed on the basis of the LP-model could serve as a starting point for setting up such organisations.

Technical advisers play an important role at this level. They should not only anticipate any latent opposition, but also take that into account when setting up rural organisations, via the establishment of an initial minimum programme. It is important therefore, that the technical advice given, however sound, should not dismiss traditional farming techniques out of hand, but should help the farmers to understand and overcome the constraints and limitations of those techniques. Hence, technical advisers should not be confined to a few specialists in rural organisation, but should comprise a multi-disciplinary team capable of tackling the various problems that could confront a particular organisation. Given the large number and variety of these problems, particular agro-ecological zones such as the Plateau and Sourou, for example, should be assigned agents understanding the problems associated with vegetable crops, as well as the use of fertilizers.

The involvement of local inhabitants in their own development, therefore, requires that they both understand and agree with the proposed programmes. That is only possible if:

- the aims of these programmes reflect those of the local inhabitants, or provide, at least initially, a platform that reduces inter-group rivalries ;
- technical and administrative advisers aim for efficiency;

Such involvement also assumes that the various structural problems hampering rural inhabitants in their efforts to develop production systems have been solved.

7.3.2.3 Control of the markets

One fundamental feature of current production systems is the limited use of external inputs. A number of technical (e.g. lack of expertise in the application of fertilizer, low rainfall) and socio-economic reasons (high costs of the inputs) can explain that situation. However, if viable agricultural production systems (crops, animal husbandry) are to be developed, such inputs are essential, hard to obtain and costly they may be. These inputs include fertilizer and plant protection products as well as improved varieties. One of the reasons that they are seldom used is that they are not economically attractive (unfavourable input/output ratio in montary terms). Hence the need, to control the market both upstream and downstream for a truly effective economic policy:

- By guaranteeing a minimum producer price enabling the farmer to recover his investment, i.e. it should at least be equal to the costs of production; the unfavourable economics of using external inputs are the result of the high costs of production, in combination with the very low prices charged to consumers.
- By making inputs accessible to a larger number of farmers; the current costs of inputs are very high in relation to farmers' purchasing power. Furthermore, the fact that they are monopolised by a small number of State or semi-State organisations implies that there is little likelihood of a reduction in price. The price of inputs, therefore, should be set at an affordable level for the farmers, implying that they should not be obliged to use more than half of their harvest to repay the debts incurred in purchasing the inputs.
- By organising domestic markets within the Region (in Mopti, only the fish market is more or less organised; the livestock market is still not fully organised despite the considerable efforts made in Fatoma and elsewhere) and by seeking other outlets for regional products. This would entail improvements of the road network, revision of official taxes and the abolition of any non-official charges causing a loss to both the State and the farmers.

Technical and administrative advisers play an important role in establishing control over the market, by convincing the rural inhabitants, via their various organisations, of the idea of rational management of resources and equipment, and by assisting in the reversion of the current degradation of the ecosystem.

Allocation of arable land, grazing land and water should not be regarded as an end in itself. Furthermore, the introduction of a wide range of individual rights, combined with the effective allocation of land will only generate the desired response, if major investments are made in both physical (demarcation of village land, grazing territories, etc.) and human resources (change in relation between the farmers - for whom everything is bestowed from above - and the administrators - with their tendency to munificent gestures).

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ANNEXES

a2

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ANNEX B DETAILED RESULTS OF THE S-SCENARIO

ANNEX A. DETAILED RESULTS OF THE R-SCENARIO

A1. Goal variables and goal restrictions

MODEL:MALI5S
OBJECTIVE STATUS = 1 OBJECTIVE VALUE = 66695.21

		RESTRICTION	VALUE IN OPTIMIZATION
(1)TOTAL MILLET/SORGHUM/FONIO PRODUCTION NORMAL YEAR [TON]	≥	160000.	160000. (-0.02597)
(2) TOTAL RICE PRODUCTION NORMAL YEAR [TON]	≥	20000.	28512. (0.00000)
(3) TOTAL MARKETABLE CROP PRODUCTION NORMAL YEAR [TON]	≥	0.	45160. (0.00000)
(4) GROSS REVENUE CROPS, FISH AND MEAT NORMAL YEAR [MILL.FCFA]	≥	0.	66695. (0.00000)
(5) TOTAL EMPLOYMENT [MAN-YEARS]	≥	300000.	335816. (0.00000)
(6) TOTAL MEAT PRODUCTION NORMAL YEAR, FIRE [TON]	≥	23000.	124631. (0.00000)
(7) TOTAL NUMBER OF ANIMALS NORMAL YEAR, FIRE [1000 TLU]	≥	0.	1762. (0.00000)
(8) TOTAL MONEY INPUTS CROP, FISH AND LIVESTOCK ACTIV. [MILLION FCFA]	≤	35000.	15176. (0.00000)
(9) TOTAL GRAIN DEFICIT IN A DRY YEAR [TON MILLET EQUIVALENT]	≤	150000.	140711. (0.00000)

RESTRICTED VARIABLES (PSEUDO GOALS)

(1)TOTAL MILLET/SORGHUM/FONIO PRODUCTION DRY YEAR [TON]	≥	80000.	81561. (0.00000)
(2) TOTAL RICE PRODUCTION DRY YEAR [TON]	≥	10000.	10000. (-0.45797)
(3) TOTAL CROP PRODUCTION DRY YEAR [TON]	≥	100000.	189729. (0.00000)
(4) AREA NATURE RESERVES IN THE DELTA [KM2]	≥	1.	1. (-0.93955)
(5) TOTAL MILK PRODUCTION NORMAL YEAR, FIRE [TON]	≥	204000.	228219. (0.00000)
(6) TOTAL BEEF PRODUCTION NORMAL YEAR, FIRE [TON]	≥	11500.	65998. (0.00000)
(7) TOTAL NUMBER OF ANIMALS AT RISK IN A DRY YEAR, FIRE [1000 TLU]	≤	400.	400. (18.27339)
(8) TOTAL MONEY INPUTS CROP ACTIVITIES [MILLION FCFA]	≤	20000.	5988. (0.00000)
(9) TOTAL MONEY INPUTS LIVESTOCK [MILLION FCFA]	≤	10000.	2230. (0.00000)
(10) SUM SUB-REGIONAL GRAIN DEFICITS DRY YEAR [TON MILLET EQUIV.]	≤	150000.	150000. (0.00191)
(11) EMIGRATION [PERSONS]	≤	250000.	250000. (0.09590)

A2. Land use

LAND USE [KM2]

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	218.	852.	665.	56.	0.	0.	23.	0.	156.	0.	0.	1971.
2. MILLET SEMI-INTENS.	296.	88.	232.	251.	120.	45.	183.	48.	207.	15.	0.	1484.
3. MILLET INTENSIVE	38.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	38.
4. MILLET TOTAL	553.	939.	897.	307.	120.	45.	206.	48.	363.	15.	0.	3493.
5. FONIO	0.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	4.	0.	17.	0.	0.	22.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	553.	945.	897.	307.	120.	45.	211.	48.	381.	15.	0.	3519.
9. PEANUT	55.	94.	0.	0.	0.	0.	0.	0.	0.	0.	0.	150.
10.COWPEA SEMI-INTENS.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	1.	1.	13.	0.	0.	0.	1.	0.	6.	0.	0.	22.
13.OTHER VEGETABLES	0.	0.	0.	11.	0.	0.	0.	0.	0.	0.	0.	11.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	0.	16.	0.	0.	0.	6.	0.	0.	23.
16.RICE, ORM CASIERS	0.	0.	0.	110.	0.	0.	0.	0.	0.	0.	0.	110.
17.RICE IRRIGATED	0.	0.	0.	4.	0.	0.	0.	0.	0.	0.	0.	4.
18.RICE TOTAL	0.	0.	0.	114.	16.	0.	0.	0.	6.	0.	0.	136.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	609.	1040.	910.	431.	136.	45.	212.	48.	393.	15.	0.	3839.
FALLOW	1087.	4295.	3311.	0.	114.	0.	127.	0.	148.	0.	0.	9083.
PASTURES (R≤6 KM)	3308.	150.	1811.	4596.	2743.	2458.	1837.	680.	2288.	700.	496.	21068.
UNUSED (R≤6 KM)	0.	0.	0.	126.	0.	0.	0.	0.	0.	0.	0.	126.
AVAILABLE R≤6 KM	5004.	5485.	6032.	5153.	2992.	2503.	2176.	728.	2829.	715.	496.	34114.
PASTURES 6-15KM ALL Y.	0.	0.	19.	2741.	99.	0.	129.	0.	804.	0.	0.	3793.
PAST. 6-15KM, DRY S.GR	2649.	635.	361.	8.	1451.	3031.	4022.	1441.	129.	980.	1444.	16152.
PAST. 6-15KM, WET S.GR	959.	410.	1053.	807.	297.	366.	431.	442.	2795.	539.	602.	8701.
PASTURES R>15 KM	728.	0.	74.	40.	510.	3040.	2422.	1669.	2222.	745.	558.	12008.
TOTAL	9340.	6530.	7539.	8750.	5350.	8940.	9180.	4280.	8780.	2980.	3100.	74768.
TOTAL AREA AVAILABLE	9340.	6530.	7540.	15190.	5410.	8940.	9180.	4280.	9920.	2980.	3100.	82410.

A3. Production arable farming, normal years and dry years

YIELDS, NORMAL YEARS (TON)

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	9192.	34079.	18622.	2010.	0.	0.	442.	0.	2342.	0.	0.	66685.
2. MILLET SEMI-INTENS.	22820.	6738.	14595.	15937.	5860.	2183.	8988.	1292.	6010.	405.	0.	84829.
3. MILLET INTENSIVE	7302.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7302.
4. MILLET TOTAL	39314.	40817.	33217.	17947.	5860.	2183.	9429.	1292.	8352.	405.	0.	158816.
5. FONIO	0.	151.	0.	0.	0.	0.	0.	0.	0.	0.	0.	151.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	206.	0.	827.	0.	0.	1033.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	39314.	40967.	33217.	17947.	5860.	2183.	9635.	1292.	9179.	405.	0.	160000.
9. PEANUT	6081.	10390.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16470.
10.COWPEA SEMI-INTENS.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	3267.	3500.	45500.	0.	0.	700.	3500.	0.	21000.	0.	0.	77467.
13.OTHER VEGETABLES	107.	0.	0.	17600.	0.	0.	0.	0.	0.	0.	0.	17707.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	0.	780.	0.	0.	0.	307.	0.	0.	1087.
16.RICE, ORM CASIERS	0.	0.	0.	24617.	0.	0.	0.	0.	0.	0.	0.	24617.
17.RICE IRRIGATED	0.	0.	0.	2808.	0.	0.	0.	0.	0.	0.	0.	2808.
18.RICE TOTAL	0.	0.	0.	27425.	780.	0.	0.	0.	307.	0.	0.	28512.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	48768.	54857.	78717.	62972.	6640.	2883.	13135.	1292.	30486.	405.	0.	300156.

YIELDS, DRY YEARS (TON)

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	4623.	20322.	8472.	348.	0.	0.	48.	0.	781.	0.	0.	34593.
2. MILLET SEMI-INTENS.	11854.	3500.	8108.	8949.	2751.	1025.	4219.	0.	2073.	0.	0.	42479.
3. MILLET INTENSIVE	3785.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3785.
4. MILLET TOTAL	20263.	23822.	16580.	9297.	2751.	1025.	4267.	0.	2853.	0.	0.	80856.
5. FONIO	0.	80.	0.	0.	0.	0.	0.	0.	0.	0.	0.	80.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	124.	0.	500.	0.	0.	624.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	20263.	23902.	16580.	9297.	2751.	1025.	4391.	0.	3353.	0.	0.	81561.
9. PEANUT	1106.	1889.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2995.
10.COWPEA SEMI-INTENS.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	3267.	3500.	45500.	0.	0.	700.	3500.	0.	21000.	0.	0.	77467.
13.OTHER VEGETABLES	107.	0.	0.	17600.	0.	0.	0.	0.	0.	0.	0.	17707.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	0.	114.	0.	0.	0.	45.	0.	0.	158.
16.RICE, ORM CASIERS	0.	0.	0.	7034.	0.	0.	0.	0.	0.	0.	0.	7034.
17.RICE IRRIGATED	0.	0.	0.	2808.	0.	0.	0.	0.	0.	0.	0.	2808.
18.RICE TOTAL	0.	0.	0.	9842.	114.	0.	0.	0.	45.	0.	0.	10000.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	24742.	29291.	62080.	36738.	2865.	1725.	7891.	0.	24398.	0.	0.	189729.

A4. Yields per km² arable farming, normal years and dry years

RENDEMENTS, NORMAL YEARS [TON/KM2]

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	42.	40.	28.	36.	0.	0.	19.	0.	15.	0.	0.	34.
2. MILLET SEMI-INTENS.	77.	77.	63.	64.	49.	49.	49.	27.	29.	27.	0.	57.
3. MILLET INTENSIVE	191.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	191.
4. MILLET TOTAL	71.	43.	37.	59.	49.	49.	46.	27.	23.	27.	0.	45.
5. FONIO	0.	30.	0.	0.	0.	0.	0.	0.	0.	0.	0.	30.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	48.	0.	48.	0.	0.	48.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	71.	43.	37.	59.	49.	49.	46.	27.	24.	27.	0.	45.
9. PEANUT	110.	110.	0.	0.	0.	0.	0.	0.	0.	0.	0.	110.
10.COWPEA SEMI-INTENS.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	3500.	3500.	3500.	0.	0.	3498.	3500.	0.	3500.	0.	0.	3500.
13.OTHER VEGETABLES	1598.	0.	0.	1600.	0.	0.	0.	0.	0.	0.	0.	1600.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	0.	48.	0.	0.	0.	48.	0.	0.	48.
16.RICE, ORM CASIERS	0.	0.	0.	224.	0.	0.	0.	0.	0.	0.	0.	224.
17.RICE IRRIGATED	0.	0.	0.	720.	0.	0.	0.	0.	0.	0.	0.	720.
18.RICE TOTAL	0.	0.	0.	241.	48.	0.	0.	0.	48.	0.	0.	209.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	80.	53.	86.	146.	49.	64.	62.	27.	78.	27.	0.	78.

RENDEMENTS,DRY YEARS [TON/KM2]

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	21.	24.	13.	6.	0.	0.	2.	0.	5.	0.	0.	18.
2. MILLET SEMI-INTENS.	40.	40.	35.	36.	23.	23.	23.	0.	10.	0.	0.	29.
3. MILLET INTENSIVE	99.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	99.
4. MILLET TOTAL	37.	25.	18.	30.	23.	23.	21.	0.	8.	0.	0.	23.
5. FONIO	0.	16.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	29.	0.	29.	0.	0.	29.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	37.	25.	18.	30.	23.	23.	21.	0.	9.	0.	0.	23.
9. PEANUT	20.	20.	0.	0.	0.	0.	0.	0.	0.	0.	0.	20.
10.COWPEA SEMI-INTENS.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	3500.	3500.	3500.	0.	0.	3498.	3500.	0.	3500.	0.	0.	3500.
13.OTHER VEGETABLES	1598.	0.	0.	1600.	0.	0.	0.	0.	0.	0.	0.	1600.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	0.	7.	0.	0.	0.	7.	0.	0.	7.
16.RICE, ORM CASIERS	0.	0.	0.	64.	0.	0.	0.	0.	0.	0.	0.	64.
17.RICE IRRIGATED	0.	0.	0.	720.	0.	0.	0.	0.	0.	0.	0.	720.
18.RICE TOTAL	0.	0.	0.	86.	7.	0.	0.	0.	7.	0.	0.	73.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	41.	28.	68.	85.	21.	39.	37.	0.	62.	0.	0.	49.

A5. Production, auto-consumption and marketable product in a normal year. Grain deficits in a dry year

PRODUCTION (1), AUTOCONSUMPTION (2) AND MARKETABLE PRODUCT (3), NORMAL YEAR [TON]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1.MILLET	(1)	39314.	40817.	33217.	17947.	5860.	2183.	9429.	1292.	8352.	405.	0.	158816.
	(2)	23052.	34910.	32916.	59031.	6218.	4352.	8477.	4560.	37837.	2487.	829.	214667.
	(3)	16262.	5907.	301.	-41084.	-357.	-2170.	953.	-3268.	-29484.	-2082.	-829.	-55850.
2.FONIO	(1)	0.	151.	0.	0.	0.	0.	0.	0.	0.	0.	0.	151.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(3)	0.	151.	0.	0.	0.	0.	0.	0.	0.	0.	0.	151.
3.SORGHUM	(1)	0.	0.	0.	0.	0.	0.	206.	0.	827.	0.	0.	1033.
	(2)	0.	0.	0.	0.	0.	0.	124.	0.	500.	0.	0.	624.
	(3)	0.	0.	0.	0.	0.	0.	81.	0.	327.	0.	0.	409.
4.PEANUT	(1)	6081.	10390.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16470.
	(2)	556.	842.	794.	1455.	150.	105.	208.	110.	925.	60.	20.	5225.
	(3)	5525.	9547.	-794.	-1455.	-150.	-105.	-208.	-110.	-925.	-60.	-20.	11245.
5.COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	222.	337.	318.	582.	60.	42.	83.	44.	370.	24.	8.	2090.
	(3)	-222.	-337.	-318.	-582.	-60.	-42.	-83.	-44.	-370.	-24.	-8.	-2090.
6.ONIONS	(1)	3267.	3500.	45500.	0.	0.	700.	3500.	0.	21000.	0.	0.	77467.
	(2)	556.	842.	794.	1455.	150.	105.	208.	110.	925.	60.	20.	5225.
	(3)	2711.	2658.	44706.	-1455.	-150.	595.	3292.	-110.	20075.	-60.	-20.	72242.
7.OTHER VEGETABLES	(1)	107.	0.	0.	17600.	0.	0.	0.	0.	0.	0.	0.	17707.
	(2)	1668.	2527.	2382.	4365.	450.	315.	623.	330.	2775.	180.	60.	15675.
	(3)	-1562.	-2527.	-2382.	13235.	-450.	-315.	-623.	-330.	-2775.	-180.	-60.	2032.
8.FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(3)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9.RICE	(1)	0.	0.	0.	27425.	780.	0.	0.	0.	307.	0.	0.	28512.
	(2)	1112.	1684.	1588.	3950.	300.	210.	415.	220.	1850.	120.	40.	11490.
	(3)	-1112.	-1684.	-1588.	23475.	480.	-210.	-415.	-220.	-1543.	-120.	-40.	17022.
10. TOTAL CROPS	(1)	48768.	54857.	78717.	62972.	6640.	2883.	13135.	1292.	30486.	405.	0.	300156.
	(2)	27167.	41142.	38793.	70838.	7328.	5129.	10137.	5374.	45181.	2931.	977.	254996.
(EXCL. 8.)	(3)	21601.	13715.	39924.	-7865.	-687.	-2247.	2999.	-4082.	-14696.	-2526.	-977.	45160.
11. MEAT	(1)	9804.	2174.	6804.	67569.	4715.	5513.	4344.	2797.	17323.	2176.	1411.	124631.
	(2)	2002.	3032.	2859.	612.	540.	378.	747.	396.	1007.	216.	72.	11861.
	(3)	7802.	-858.	3946.	66957.	4175.	5135.	3597.	2401.	16315.	1960.	1339.	112770.
11. MILK AT MOPTI	(3)	0.	0.	0.	2600.	0.	0.	0.	0.	0.	0.	0.	
DRY YEARS													
GRAIN DEFICIT [MIL.EQ]		4413.	13547.	19632.	52193.	3949.	3763.	5071.	5016.	38767.	2736.	912.	150000.
TOTAL GRAIN DEFICIT 5TH REGION [TON MILLET EQUIVALENT]													140711.

A6. Labour inputs, period 1 (ploughing/sowing time millet) and period 2 (first weeding millet)

INPUTS CROP, LIVESTOCK AND FISH ACTIVITIES, LABOUR: PLOUGHING/SOWING TIME (=1) AND FIRST WEEDING (=2). [MAN]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	9017.	34078.	26614.	2511.	0.	0.	921.	0.	6244.	0.	0.	79385.
AND FONIO	(2)	19906.	85398.	66538.	3738.	0.	0.	2304.	0.	15610.	0.	0.	193494.
MILLET SEMI-	(1)	14818.	4375.	11583.	12540.	5979.	2227.	9171.	2392.	10362.	750.	0.	74197.
INTENSIVE	(2)	27561.	8137.	21545.	23323.	11122.	4142.	17058.	4450.	19275.	1396.	0.	138009.
MILLET	(1)	2867.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2867.
INTENSIVE	(2)	3708.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3708.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	7352.	12561.	0.	0.	0.	0.	0.	0.	0.	0.	0.	19913.
SEMI-INTENSIVE	(2)	3703.	6328.	0.	0.	0.	0.	0.	0.	0.	0.	0.	10031.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(INCL.ONIONS)	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	0.	731.	0.	0.	0.	287.	0.	0.	1018.
HORS CASIERS	(2)	0.	0.	0.	0.	1088.	0.	0.	0.	427.	0.	0.	1515.
RICE	(1)	0.	0.	0.	15715.	0.	0.	0.	0.	0.	0.	0.	15715.
ORM CASIERS	(2)	0.	0.	0.	15385.	0.	0.	0.	0.	0.	0.	0.	15385.
RICE	(1)	0.	0.	0.	897.	0.	0.	0.	0.	0.	0.	0.	897.
IRRIGATED	(2)	0.	0.	0.	456.	0.	0.	0.	0.	0.	0.	0.	456.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	34054.	51014.	38197.	31663.	6710.	2227.	10092.	2392.	16893.	750.	0.	193992.
	(2)	54878.	99863.	88083.	42902.	12210.	4142.	19362.	4450.	35312.	1396.	0.	362598.
LIVESTOCK TOTAL	1	17415.	4839.	15152.	51022.	7289.	9507.	7616.	5670.	29738.	4124.	1840.	154212.
LIVESTOCK TOTAL	2	17415.	4839.	15152.	51022.	7289.	9507.	7616.	5670.	29738.	4124.	1840.	154212.
FULL TIME FISHERMEN		0.	0.	0.	39932.	0.	0.	0.	0.	20049.	0.	0.	59980.
EMIGRATION [MAN-YEARS]		12202.	26363.	89164.	0.	0.	0.	34771.	0.	0.	0.	0.	162500.
LABOUR SUPPLY		84500.	135850.	192400.	133860.	19500.	13650.	61750.	10120.	85100.	5520.	1840.	744090.
SHADOW PRICES	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00531	
SHADOW PRICES	2	0.00000	0.00000	0.00002	0.01966	0.03418	0.03421	0.00002	0.01388	0.01239	0.01388	0.02235	

A7. Labour inputs, period 3 (remainder of the growing season) and period 4 (harvest millet)

INPUTS CROP, LIVESTOCK AND FISH ACTIVITIES, LABOUR: REST GROWING SEASON (=1) AND HARVEST TIME MILLET (=2), [MAN]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	4798.	18969.	14637.	1226.	0.	0.	506.	0.	3434.	0.	0.	43570.
AND FONIO	(2)	11489.	42598.	33269.	3349.	0.	0.	1152.	0.	7805.	0.	0.	99662.
MILLET SEMI-	(1)	6519.	1925.	5096.	5517.	2631.	979.	4035.	1052.	4559.	330.	0.	32643.
INTENSIVE	(2)	14818.	4375.	11583.	12540.	5979.	2227.	9171.	2392.	10362.	750.	0.	74197.
MILLET	(1)	1146.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1146.
INTENSIVE	(2)	4587.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4587.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	85.	0.	344.	0.	0.	429.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	107.	0.	430.	0.	0.	537.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	1382.	2361.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3743.
SEMI-INTENSIVE	(2)	24323.	41558.	0.	0.	0.	0.	0.	0.	0.	0.	0.	65881.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(INCL.ONIONS)	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HORS CASIERS	(2)	0.	0.	0.	0.	162.	0.	0.	0.	63.	0.	0.	225.
RICE	(1)	0.	0.	0.	2197.	0.	0.	0.	0.	0.	0.	0.	2197.
ORM CASIERS	(2)	0.	0.	0.	3296.	0.	0.	0.	0.	0.	0.	0.	3296.
RICE	(1)	0.	0.	0.	152.	0.	0.	0.	0.	0.	0.	0.	152.
IRRIGATED	(2)	0.	0.	0.	195.	0.	0.	0.	0.	0.	0.	0.	195.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	13845.	23255.	19733.	9092.	2631.	979.	4626.	1052.	8337.	330.	0.	83880.
	(2)	55217.	88531.	44852.	19380.	6141.	2227.	10430.	2392.	18660.	750.	0.	248580.
LIVESTOCK TOTAL	1	17415.	4839.	15152.	51022.	7289.	9507.	7616.	5670.	29738.	4124.	1840.	154212.
LIVESTOCK TOTAL	2	15732.	4420.	14073.	45913.	7174.	9416.	7326.	5586.	29510.	4060.	1789.	145001.
FULL TIME FISHERMEN		0.	0.	0.	39932.	0.	0.	0.	0.	20049.	0.	0.	59980.
EMIGRATION [MAN-YEARS]		12202.	26363.	89164.	0.	0.	0.	34771.	0.	0.	0.	0.	162500.
LABOUR SUPPLY		84500.	135850.	192400.	133860.	19500.	13650.	61750.	10120.	85100.	5520.	1840.	744090.
SHADOW PRICES	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02137	
SHADOW PRICES	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	

A8. Labour inputs, period 5 (harvest rice) and period 6 (remainder of the year)

INPUTS CROP, LIVESTOCK AND FISH ACTIVITIES, LABOUR: HARVEST RICE (=1) AND REST OF THE YEAR (=2), [MAN]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
AND FONIO	(2)	1805.	7336.	4828.	1033.	0.	0.	178.	0.	1654.	0.	0.	16834.
MILLET SEMI-	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	4267.	1260.	3336.	3570.	1722.	641.	2641.	689.	2735.	216.	0.	21077.
MILLET	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	902.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	902.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	42.	0.	172.	0.	0.	214.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	132.	226.	0.	0.	0.	0.	0.	0.	0.	0.	0.	358.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	738.	754.	9802.	5874.	0.	150.	754.	0.	4524.	0.	0.	22596.
(INCL.ONIONS)	(2)	738.	754.	9802.	5874.	0.	150.	754.	0.	4524.	0.	0.	22596.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	0.	1300.	0.	0.	0.	510.	0.	0.	1810.
HORS CASIERS	(2)	0.	0.	0.	0.	178.	0.	0.	0.	70.	0.	0.	248.
RICE	(1)	0.	0.	0.	40113.	0.	0.	0.	0.	0.	0.	0.	40113.
ORM CASIERS	(2)	0.	0.	0.	769.	0.	0.	0.	0.	0.	0.	0.	769.
RICE	(1)	0.	0.	0.	2028.	0.	0.	0.	0.	0.	0.	0.	2028.
IRRIGATED	(2)	0.	0.	0.	483.	0.	0.	0.	0.	0.	0.	0.	483.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	738.	754.	9802.	48015.	1300.	150.	754.	0.	5034.	0.	0.	66547.
	(2)	7844.	9576.	17966.	11729.	1900.	791.	3615.	689.	9155.	216.	0.	63481.
LIVESTOCK TOTAL	1	15732.	4420.	14073.	45913.	7174.	9416.	7326.	5586.	29510.	4060.	1789.	145001.
LIVESTOCK TOTAL	2	15732.	4420.	14073.	45913.	7174.	9416.	7326.	5586.	29510.	4060.	1789.	145001.
FULL TIME FISHERMEN		0.	0.	0.	39932.	0.	0.	0.	0.	20049.	0.	0.	59980.
EMIGRATION [MAN-YEARS]		12202.	26363.	89164.	0.	0.	0.	34771.	0.	0.	0.	0.	162500.
LABOUR SUPPLY		84500.	135850.	192400.	133860.	19500.	13650.	61750.	10120.	85100.	5520.	1840.	744090.
SHADOW PRICES	1	0.00000	0.00000	0.00000	0.05572	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	
SHADOW PRICES	2	0.00000	0.00000	0.00000	0.00782	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	
LABOUR INPUT MAN-YEARS		29448.	24203.	37144.	127271.	10012.	10500.	12294.	6631.	72966.	4397.	1802.	336669.
EMIGRATION [PERSONS]		18773.	40558.	137175.	0.	0.	0.	53494.	0.	0.	0.	0.	250000.

A9. Monetary inputs arable farming

INPUTS CROP ACTIVITIES, MONEY: CAPITAL COSTS (=1) AND OTHER CHARGES (=2) [MILLION FCFA]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE AND FONIO	(1)	25.	60.	47.	13.	0.	0.	2.	0.	11.	0.	0.	157.
	(2)	3.	15.	11.	1.	0.	0.	0.	0.	2.	0.	0.	33.
MILLET SEMI-INTENSIVE	(1)	79.	23.	62.	67.	32.	12.	49.	13.	55.	4.	0.	396.
	(2)	9.	3.	7.	8.	4.	1.	6.	1.	6.	0.	0.	46.
MILLET INTENSIVE	(1)	37.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	37.
	(2)	25.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	25.
SORGHUM EXTENSIVE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	2.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
SORGHUM SEMI-INTENSIVE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT SEMI-INTENSIVE	(1)	34.	59.	0.	0.	0.	0.	0.	0.	0.	0.	0.	93.
	(2)	124.	213.	0.	0.	0.	0.	0.	0.	0.	0.	0.	337.
COWPEA SEMI-INTENSIVE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA INTENSIVE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES (INCL.ONIONS)	(1)	0.	0.	4.	3.	0.	0.	0.	0.	2.	0.	0.	10.
	(2)	19.	20.	263.	59.	0.	4.	20.	0.	122.	0.	0.	507.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE HORS CASIERS	(1)	0.	0.	0.	0.	7.	0.	0.	0.	3.	0.	0.	9.
	(2)	0.	0.	0.	0.	12.	0.	0.	0.	5.	0.	0.	17.
RICE ORM CASIERS	(1)	0.	0.	0.	378.	0.	0.	0.	0.	0.	0.	0.	378.
	(2)	0.	0.	0.	307.	0.	0.	0.	0.	0.	0.	0.	307.
RICE IRRIGATED	(1)	0.	0.	0.	137.	0.	0.	0.	0.	0.	0.	0.	137.
	(2)	0.	0.	0.	70.	0.	0.	0.	0.	0.	0.	0.	70.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	175.	142.	112.	598.	38.	12.	51.	13.	72.	4.	0.	1218.
	(2)	181.	251.	281.	444.	16.	5.	26.	1.	136.	0.	0.	1343.

A10. Oxen and manure inputs arable farming

INPUTS CROP ACTIVITIES, OXEN (=1) [NUMBER] AND ORGANIC MANURE (=2) [1000 TON]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	1912.	0.	0.	1842.	0.	0.	0.	0.	0.	0.	0.	3755.
AND FONIO	(2)	0.	0.	0.	15.	0.	0.	0.	0.	22.	0.	0.	37.
MILLET SEMI-	(1)	9780.	2888.	7645.	8276.	3947.	1470.	6053.	1579.	6840.	495.	0.	48973.
INTENSIVE	(2)	80.	24.	51.	62.	21.	8.	31.	5.	37.	1.	0.	318.
MILLET	(1)	2867.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2867.
INTENSIVE	(2)	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	8.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	2764.	4723.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7487.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(INCL.ONIONS)	(2)	1.	1.	13.	7.	0.	0.	1.	0.	6.	0.	0.	29.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	0.	813.	0.	0.	0.	319.	0.	0.	1132.
HORS CASIERS	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	5495.	0.	0.	0.	0.	0.	0.	0.	5495.
ORM CASIERS	(2)	0.	0.	0.	46.	0.	0.	0.	0.	0.	0.	0.	46.
RICE	(1)	0.	0.	0.	195.	0.	0.	0.	0.	0.	0.	0.	195.
IRRIGATED	(2)	0.	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.	2.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	17324.	7610.	7645.	15808.	4759.	1470.	6053.	1579.	7159.	495.	0.	69903.
	(2)	89.	25.	64.	131.	21.	8.	32.	5.	65.	1.	0.	441.
SHADOW PRICES	1	0.01514	0.01395	0.01394	0.01776	0.00993	0.00992	0.01486	0.01231	0.01983	0.01231	0.00818	
SHADOW PRICES	2	0.01738	0.01640	0.01477	0.00000	0.00000	0.00000	0.01431	0.00000	0.00000	0.00000	0.00000	

A11. Fertilizer inputs arable farming

INPUTS CROP ACTIVITIES, FERTILIZER: N (=1), P (=2) AND K (=3). [TON]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
AND FONIO	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MILLET SEMI-	(1)	434.	128.	277.	335.	111.	41.	171.	25.	198.	8.	0.	1728.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MILLET	(1)	409.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	409.
INTENSIVE	(2)	58.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	58.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	164.	281.	0.	0.	0.	0.	0.	0.	0.	0.	0.	445.
SEMI-INTENSIVE	(2)	49.	83.	0.	0.	0.	0.	0.	0.	0.	0.	0.	132.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(INCL.ONIONS)	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HORS CASIERS	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	2363.	0.	0.	0.	0.	0.	0.	0.	2363.
ORM CASIERS	(2)	0.	0.	0.	98.	0.	0.	0.	0.	0.	0.	0.	98.
RICE	(1)	0.	0.	0.	236.	0.	0.	0.	0.	0.	0.	0.	236.
IRRIGATED	(2)	0.	0.	0.	17.	0.	0.	0.	0.	0.	0.	0.	17.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	1007.	409.	277.	2934.	111.	41.	171.	25.	198.	8.	0.	5181.
	(2)	107.	83.	0.	115.	0.	0.	0.	0.	0.	0.	0.	305.
POTASSIUM	(3)	339.	156.	0.	1043.	0.	0.	0.	0.	48.	0.	0.	1586.

A12. Forage production, normal years

FORAGE PRODUCTION [TON], DRY YEARS

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
BYPRODUCTS Q=1	45578.	76523.	56906.	37299.	8104.	2918.	12916.	1483.	20173.	465.	0.	262366.
BYPRODUCTS Q=2	598.	42.	0.	3985.	48.	0.	0.	0.	19.	0.	0.	4691.
BYPRODUCTS Q=3	0.	167.	0.	69.	0.	0.	0.	0.	0.	0.	0.	237.
BYPRODUCTS Q=4	335.	567.	0.	624.	0.	0.	0.	0.	0.	0.	0.	1526.
PASTURES ≤15, W.S. Q=1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES ≤15, W.S. Q=2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES ≤15, W.S. Q=3	29969.	29259.	1226.	0.	1675.	9259.	7302.	0.	0.	0.	0.	78690.
PASTURES ≤15, W.S. Q=4	73417.	26178.	60524.	36044.	29770.	33392.	23111.	18158.	90436.	10287.	14384.	415700.
NO FIRE / MOWING												
PASTURES ≤15, DR.S Q=1	28808.	22924.	89265.	177507.	19868.	5090.	7050.	0.	15412.	0.	0.	365925.
PASTURES ≤15, DR.S Q=2	98769.	88088.	174061.	2901040.	62293.	63817.	62941.	9213.	543622.	1857.	17702.	4023404.
PASTURES ≤15, DR.S Q=3	115708.	1680.	21901.	5075.	43874.	61292.	28837.	42070.	38168.	27088.	26253.	411946.
PASTURES ≤15, DR.S Q=4	0.	0.	0.	0.	1498.	2321.	5844.	43.	0.	197.	111.	10013.
WOODY SPECIES	34147.	4144.	17758.	4564.	5179.	5171.	4621.	1701.	29557.	1297.	6704.	114844.
FIRE												
PASTURES ≤15, DR.S Q=1	22821.	19533.	23753.	29597.	3112.	4072.	5640.	0.	6136.	0.	0.	114664.
PASTURES ≤15, DR.S Q=2	90973.	79724.	79321.	350527.	39281.	57735.	22095.	9213.	58143.	1853.	17702.	806568.
PASTURES ≤15, DR.S Q=3	115708.	1680.	31603.	757481.	42323.	60986.	40124.	42070.	186837.	27070.	25357.	1331238.
PASTURES ≤15, DR.S Q=4	0.	0.	0.	0.	1498.	2321.	5844.	43.	0.	197.	111.	10013.
WOODY SPECIES	34147.	4144.	17758.	4564.	5179.	5171.	4621.	1701.	29557.	1297.	6704.	114844.
PASTURES >15, W.S. Q=1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES >15, W.S. Q=2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES >15, W.S. Q=3	10164.	0.	37.	30.	0.	11890.	0.	0.	0.	0.	0.	22121.
PASTURES >15, W.S. Q=4	34934.	0.	2841.	1551.	26249.	108159.	13840.	58923.	63477.	17914.	16570.	344459.

A13. Forage production, dry years

FORAGE PRODUCTION [TON], NORMAL YEARS

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
BYPRODUCTS Q=1	71754.	107014.	88440.	83297.	14355.	4655.	21059.	3421.	36364.	1074.	0.	431433.
BYPRODUCTS Q=2	844.	78.	0.	9524.	328.	0.	0.	0.	129.	0.	0.	10902.
BYPRODUCTS Q=3	0.	314.	0.	69.	0.	0.	0.	0.	0.	0.	0.	383.
BYPRODUCTS Q=4	1828.	3117.	0.	624.	0.	0.	0.	0.	0.	0.	0.	5569.
PASTURES ≤15, W.S. Q=1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES ≤15, W.S. Q=2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES ≤15, W.S. Q=3	54577.	62478.	29405.	25324.	21925.	43091.	25995.	0.	57655.	777.	17665.	338892.
PASTURES ≤15, W.S. Q=4	63837.	10950.	37932.	14033.	28295.	21924.	20508.	35769.	165857.	17509.	15019.	431632.
NO FIRE / MOWING												
PASTURES ≤15, DR.S Q=1	81423.	83821.	159561.	294732.	46554.	41180.	30661.	0.	44545.	1804.	38086.	822367.
PASTURES ≤15, DR.S Q=2	105317.	64817.	280663.	4589537.	156758.	160028.	114976.	95606.	908242.	54608.	90037.	6620590.
PASTURES ≤15, DR.S Q=3	113787.	1680.	21901.	8731.	11582.	7493.	26687.	6447.	28537.	13609.	6021.	246477.
PASTURES ≤15, DR.S Q=4	0.	0.	0.	0.	1498.	2321.	5844.	43.	0.	197.	111.	10013.
WOODY SPECIES	34147.	4144.	17758.	4564.	5179.	5171.	4621.	1701.	29557.	1297.	6704.	114844.
FIRE												
PASTURES ≤15, DR.S Q=1	62642.	70781.	43259.	42625.	16021.	31484.	22211.	0.	28173.	1514.	31109.	349819.
PASTURES ≤15, DR.S Q=2	90808.	55063.	114263.	185160.	113732.	136632.	42587.	84244.	69812.	48405.	73636.	1014341.
PASTURES ≤15, DR.S Q=3	113787.	1680.	42889.	1527082.	11165.	7462.	50320.	5731.	327014.	12097.	5522.	2104750.
PASTURES ≤15, DR.S Q=4	0.	0.	0.	0.	1498.	2321.	5844.	43.	0.	197.	111.	10013.
WOODY SPECIES	34147.	4144.	17758.	4564.	5179.	5171.	4621.	1701.	29557.	1297.	6704.	114844.
PASTURES >15, W.S. Q=1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES >15, W.S. Q=2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES >15, W.S. Q=3	13860.	0.	1557.	1169.	17499.	117737.	0.	0.	25596.	1500.	21353.	200272.
PASTURES >15, W.S. Q=4	35714.	0.	1571.	598.	23333.	73343.	13840.	119541.	125430.	36057.	20654.	450079.

A14. Livestock activities

LIVESTOCK ACTIVITIES [1000 TLU]

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. CATTLE SED. OXEN 1	31.3	13.7	13.8	28.5	8.6	2.7	10.9	2.9	12.9	0.9	0.0	126.
2. CATTLE SED. MEAT 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
3. CATTLE SED. MEAT 2	0.0	0.0	0.0	0.0	13.6	15.0	0.0	0.0	0.0	0.0	11.2	40.
4. CATTLE MOB. MEAT 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
5. CATTLE MOB. MEAT 3	0.0	0.0	0.0	780.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	781.
6. VACANT												
7. CATTLE SED. MILK 2	60.3	0.0	0.0	14.1	12.6	4.5	3.9	0.0	0.0	0.0	1.8	97.
8. CATTLE SED. MILK 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
9. CATTLE MOB. MILK 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
10.CATTLE MOB. MILK 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
11.CATTLE SED. MILK 4C	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.
12.CATTLE SED. MILK 4	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.
13.SHEEP ≤15 MEAT 1	0.0	15.0	38.2	0.0	38.5	38.5	0.7	17.9	0.0	10.9	9.5	169.
14.SHEEP ≤15 MEAT 3	20.4	0.0	5.2	0.0	0.0	0.0	18.8	5.3	170.4	8.4	0.0	229.
15.SHEEP MOB. MEAT 1	0.0	3.6	0.0	0.0	2.6	20.9	0.0	11.1	0.0	0.0	0.0	38.
16.SHEEP MOB. MEAT 3	0.0	1.7	15.6	104.4	0.0	0.0	11.3	0.0	0.0	3.8	0.0	137.
17.SHEEP SED. MEAT 4	3.1	0.0	0.0	0.0	1.4	1.4	2.5	0.1	0.0	0.3	0.2	9.
18.GOATS ≤15 MEAT 1B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
19.GOATS ≤15 MEAT 3B	44.6	0.0	23.2	0.0	0.0	0.0	6.0	2.2	0.0	1.7	0.0	78.
20.GOATS MOB. MEAT 1B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
21.GOATS MOB. MEAT 3B	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.
22.DONKEY SED. 2	3.3	5.2	7.4	7.3	0.8	0.5	2.4	0.6	4.6	0.3	0.1	32.
23.CAMELS 1B	0.0	0.0	0.0	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.
24.VACANT												
TOTAL	163.	45.	103.	956.	78.	84.	57.	40.	188.	26.	23.	1762.

A15. Livestock production and livestock inputs

LIVESTOCK PRODUCTION

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MEAT [TON]	9804.	2174.	6804.	67569.	4715.	5513.	4344.	2797.	17323.	2176.	1411.	124631.
MILK [TON]	19903.	1168.	5684.	181148.	3328.	2131.	3362.	709.	8519.	948.	1319.	228219.
WOOL [TON]	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EGGS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OXEN [NUMBER]	17324.	7610.	7645.	15808.	4759.	1470.	6053.	1579.	7159.	495.	0.	69903.
DONKEYS [NUMBER]	6500.	10450.	14800.	14550.	1500.	1050.	4750.	1100.	9250.	600.	200.	64750.
CAMELS [NUMBER]	0.	0.	0.	12950.	0.	0.	0.	0.	0.	0.	0.	12950.
MANURE [1000 TON]	89.	25.	64.	249.	43.	47.	32.	25.	125.	17.	11.	729.

LIVESTOCK INPUTS

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
FORAGE W.S.,Q≥1 [TON]	105548.	21900.	66194.	28065.	50220.	43847.	32563.	22719.	153831.	18285.	14384.	557557.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000)	
FORAGE W.S.,Q≥2 [TON]	105548.	21900.	66194.	28065.	50220.	43847.	32563.	22719.	153831.	18285.	14384.	557557.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000)	
FORAGE W.S.,Q≥3 [TON]	105548.	21900.	66194.	28065.	50220.	43847.	32563.	22719.	153831.	18285.	14384.	557557.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000)	
FORAGE W.S.,Q≥4 [TON]	63837.	10950.	37932.	14033.	25110.	21924.	20508.	12638.	105880.	10854.	7192.	330857.
SHADOW PRICES (	0.00414	0.05321	0.00481	0.05713	0.00000	0.00097	0.00623	0.00000	0.00000	0.00000	0.00000)	
FORAGE D.S.,Q≥1 [TON]	282497.	88365.	220691.	1596209.	157099.	182553.	121885.	93439.	461492.	63287.	43170.	3310686.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.00014	0.00014	0.00000	0.00133	0.00352	0.00133	0.00000)	
FORAGE D.S.,Q≥2 [TON]	207267.	60252.	157152.	1369979.	110037.	125835.	98751.	64964.	396955.	48579.	31080.	2670850.
SHADOW PRICES (	0.01076	0.00841	0.00970	0.00000	0.00000	0.00000	0.00960	0.00000	0.00141	0.00000	0.00000)	
FORAGE D.S.,Q≥3 [TON]	58179.	5110.	27820.	564804.	12664.	9783.	34799.	5773.	162979.	12294.	5633.	899839.
SHADOW PRICES (	0.00000	0.00388	0.00000	0.00000	0.00906	0.00906	0.00000	0.00896	0.00000	0.00896	0.01097)	
FORAGE D.S.,Q≥4 [TON]	1828.	0.	0.	624.	825.	826.	1485.	43.	0.	197.	98.	5924.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00854	0.02641	0.00854	0.00000)	
FORAGE WOODY [TON]	34147.	4144.	17758.	3063.	0.	0.	4621.	1701.	0.	1297.	0.	66732.
SHADOW PRICES (	0.00467	0.00498	0.00311	0.00000	0.00000	0.00000	0.00296	0.00000	0.00000	0.00000	0.00000)	
FORAGE W.S.PAST. [TON]	0.	8924.	13263.	505456.	2119.	16964.	9605.	8974.	0.	3235.	0.	568541.
SHADOW PRICE											(	0.00000)
FORAGE CONCENTR. [TON]	0.	0.	0.	1276.	0.	0.	0.	0.	0.	0.	0.	1276.
LABOUR WET SEAS. [MAN]	17415.	4839.	15152.	51022.	7289.	9507.	7616.	5670.	29738.	4124.	1840.	154212.
LABOUR DRY SEAS. [MAN]	15732.	4420.	14073.	45913.	7174.	9416.	7326.	5586.	29510.	4060.	1789.	145001.
MONEY [MILLION FCFA]	135.	22.	84.	1447.	43.	47.	67.	21.	261.	25.	21.	2174.
BOURGOU CULT. [KM2]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

A16. Fisheries

FISHERIES (PRIMARY MIGRANT = 1; PRIMARY SEDENTARY = 2; SECONDARY SED. = 3

NORMAL YEARS

	PRODUCTION [TON]	LABOUR INPUT [HOUSEHOLDS]	LABOUR INPUT [MAN-YEARS]	DEPRECIATION [MILL.CFA]	OTHER COSTS [MILL.CFA]	PRODUCTIVITY [TON/HOUSEHOLD]
FISHING ACTIVITY 1	77543.	16569.	59980.	3016.	2750.	4.680
FISHING ACTIVITY 2	0.	0.	0.	0.	0.	3.740
FISHING ACTIVITY 3	15891.	20910.	37847.	648.	544.	0.760
TOTAL	93435. (0.00000)	37479.	97827.	3664.	3294.	

DRY YEARS

	PRODUCTION [TON]	LABOUR INPUT [HOUSEHOLDS]	LABOUR INPUT [MAN-YEARS]	DEPRECIATION [MILL.CFA]	OTHER COSTS [MILL.CFA]	PRODUCTIVITY [TON/HOUSEHOLD]
FISHING ACTIVITY 1	44405.	16569.	59980.	3016.	2750.	2.680
FISHING ACTIVITY 2	0.	0.	0.	0.	0.	2.140
FISHING ACTIVITY 3	8991.	20910.	37847.	648.	544.	0.430
TOTAL	53396. (0.26003)	37479.	97827.	3664.	3294.	

AUTO-CONSUMPTION FISH [TON] 12218.

ANNEX B. DETAILED RESULTS OF THE S-SCENARIO

B1. Goal variables and goal restrictions

MODEL:MALI5S
OBJECTIVE STATUS = 1 OBJECTIVE VALUE = 32488.13

		RESTRIC TION	VALUE IN OPTIMIZATION
(1)TOTAL MILLET/SORGHUM/FONIO PRODUCTION NORMAL YEAR [TON]	≥	160000.	282247. (0.00000)
(2) TOTAL RICE PRODUCTION NORMAL YEAR [TON]	≥	42000.	42000. (-0.25205)
(3) TOTAL MARKETABLE CROP PRODUCTION NORMAL YEAR [TON]	≥	0.	100617. (0.00000)
(4) GROSS REVENUE CROPS, FISH AND MEAT NORMAL YEAR [MILL.FCFA]	≥	0.	32488. (0.00000)
(5) TOTAL EMPLOYMENT [MAN-YEARS]	≥	336000.	336000. (-0.11014)
(6) TOTAL MEAT PRODUCTION NORMAL YEAR, FIRE [TON]	≥	23000.	86854. (0.00000)
(7) TOTAL NUMBER OF ANIMALS NORMAL YEAR, FIRE [1000 TLU]	≥	0.	1491. (0.00000)
(8) TOTAL MONEY INPUTS CROP, FISH AND LIVESTOCK ACTIV. [MILLION FCFA]	≤	35000.	23629. (0.00000)
(9) TOTAL GRAIN DEFICIT IN A DRY YEAR [TON MILLET EQUIVALENT]	≤	110000.	110000. (0.50180)

RESTRICTED VARIABLES (PSEUDO GOALS)

(1)TOTAL MILLET/SORGHUM/FONIO PRODUCTION DRY YEAR [TON]	≥	80000.	151597. (0.00000)
(2) TOTAL RICE PRODUCTION DRY YEAR [TON]	≥	10000.	12107. (0.00000)
(3) TOTAL CROP PRODUCTION DRY YEAR [TON]	≥	100000.	235008. (0.00000)
(4) AREA NATURE RESERVES IN THE DELTA [KM2]	≥	1.	1. (-2.47733)
(5) TOTAL MILK PRODUCTION NORMAL YEAR, FIRE [TON]	≥	204000.	204000. (-0.02493)
(6) TOTAL BEEF PRODUCTION NORMAL YEAR, FIRE [TON]	≥	11500.	56232. (0.00000)
(7) TOTAL NUMBER OF ANIMALS AT RISK IN A DRY YEAR, FIRE [1000 TLU]	≤	100.	100. (54.10836)
(8) TOTAL MONEY INPUTS CROP ACTIVITIES [MILLION FCFA]	≤	15000.	15000. (3.04227)
(9) TOTAL MONEY INPUTS LIVESTOCK [MILLION FCFA]	≤	10000.	1647. (0.00000)
(10) SUM SUB-REGIONAL GRAIN DEFICITS DRY YEAR [TON MILLET EQUIV.]	≤	130000.	130000. (0.11292)
(11) EMIGRATION [PERSONS]	≤	50000.	50000. (0.23561)

B2. Land use

LAND USE [KM2]

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	154.	804.	567.	5.	0.	0.	23.	66.	140.	33.	0.	1792.
2. MILLET SEMI-INTENS.	114.	0.	0.	237.	152.	120.	236.	0.	265.	0.	0.	1124.
3. MILLET INTENSIVE	373.	133.	415.	13.	0.	0.	19.	0.	0.	0.	0.	954.
4. MILLET TOTAL	641.	937.	982.	255.	152.	120.	278.	66.	405.	33.	0.	3870.
5. FONIO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	4.	0.	17.	0.	0.	22.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	641.	937.	982.	255.	152.	120.	283.	66.	422.	33.	0.	3891.
9. PEANUT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10.COWPEA SEMI-INTENS.	64.	94.	98.	0.	0.	0.	0.	0.	0.	0.	0.	256.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	0.	0.	0.	0.	0.	0.	0.	0.	6.	0.	0.	6.
13.OTHER VEGETABLES	1.	1.	13.	11.	0.	0.	1.	0.	0.	0.	0.	27.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	190.	16.	0.	0.	0.	76.	0.	0.	283.
16.RICE, ORM CASIERS	0.	0.	0.	114.	0.	0.	0.	0.	0.	0.	0.	114.
17.RICE IRRIGATED	0.	0.	0.	4.	0.	0.	0.	0.	0.	0.	0.	4.
18.RICE TOTAL	0.	0.	0.	308.	16.	0.	0.	0.	76.	0.	0.	401.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	706.	1032.	1093.	574.	169.	120.	284.	66.	504.	33.	0.	4581.
FALLOW	990.	4303.	3128.	1154.	114.	0.	128.	0.	1214.	0.	0.	11032.
PASTURES (R≤6 KM)	3308.	150.	1811.	3424.	2710.	2383.	1765.	661.	1111.	682.	496.	18501.
UNUSED (R≤6 KM)	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	1.
AVAILABLE R≤6 KM	5004.	5485.	6032.	5153.	2992.	2503.	2176.	728.	2829.	715.	496.	34114.
PASTURES 6-15KM ALL Y.	0.	0.	19.	2892.	99.	0.	129.	0.	736.	0.	0.	3875.
PAST. 6-15KM, DRY S.GR	2481.	635.	277.	8.	1425.	3081.	3939.	1437.	298.	922.	1791.	16295.
PAST. 6-15KM, WET S.GR	1127.	410.	1136.	807.	323.	316.	513.	446.	2627.	598.	255.	8558.
PASTURES R>15 KM	728.	0.	74.	40.	510.	3040.	2422.	1669.	2222.	745.	558.	12008.
TOTAL	9340.	6530.	7539.	8900.	5350.	8940.	9180.	4280.	8712.	2980.	3100.	74851.
TOTAL AREA AVAILABLE	9340.	6530.	7540.	15190.	5410.	8940.	9180.	4280.	9920.	2980.	3100.	82410.

B3. Production arable farming, normal years and dry years

YIELDS, NORMAL YEARS (TON)

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	6880.	32173.	15815.	142.	0.	0.	445.	996.	2148.	502.	0.	59101.
2. MILLET SEMI-INTENS.	8762.	0.	0.	15066.	7462.	5873.	11546.	0.	7685.	0.	0.	56393.
3. MILLET INTENSIVE	71247.	24894.	65225.	2003.	0.	0.	2353.	0.	0.	0.	0.	165721.
4. MILLET TOTAL	86888.	57066.	81040.	17210.	7462.	5873.	14344.	996.	9833.	502.	0.	281214.
5. FONIO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	206.	0.	827.	0.	0.	1033.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	86888.	57066.	81040.	17210.	7462.	5873.	14549.	996.	10661.	502.	0.	282247.
9. PEANUT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10.COWPEA SEMI-INTENS.	3845.	5625.	3615.	0.	0.	0.	0.	0.	0.	0.	0.	13085.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	0.	0.	0.	0.	0.	700.	0.	0.	21000.	0.	0.	21700.
13.OTHER VEGETABLES	1600.	1600.	20800.	17600.	0.	0.	1600.	0.	0.	0.	0.	43200.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	9130.	780.	0.	0.	0.	3667.	0.	0.	13577.
16.RICE, ORM CASIERS	0.	0.	0.	25615.	0.	0.	0.	0.	0.	0.	0.	25615.
17.RICE IRRIGATED	0.	0.	0.	2808.	0.	0.	0.	0.	0.	0.	0.	2808.
18.RICE TOTAL	0.	0.	0.	37554.	780.	0.	0.	0.	3667.	0.	0.	42000.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	92333.	64291.	105455.	72364.	8242.	6573.	16149.	996.	35327.	502.	0.	402232.

YIELDS, DRY YEARS (TON)

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	3403.	19166.	7265.	35.	0.	0.	49.	0.	716.	0.	0.	30635.
2. MILLET SEMI-INTENS.	4551.	0.	0.	8462.	3502.	2757.	5419.	0.	2650.	0.	0.	27342.
3. MILLET INTENSIVE	36929.	17705.	36144.	1110.	0.	0.	1109.	0.	0.	0.	0.	92996.
4. MILLET TOTAL	44883.	36871.	43409.	9607.	3502.	2757.	6577.	0.	3366.	0.	0.	150973.
5. FONIO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	124.	0.	500.	0.	0.	624.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	44883.	36871.	43409.	9607.	3502.	2757.	6702.	0.	3866.	0.	0.	151597.
9. PEANUT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10.COWPEA SEMI-INTENS.	2050.	3000.	1355.	0.	0.	0.	0.	0.	0.	0.	0.	6405.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	0.	0.	0.	0.	0.	700.	0.	0.	21000.	0.	0.	21700.
13.OTHER VEGETABLES	1600.	1600.	20800.	17600.	0.	0.	1600.	0.	0.	0.	0.	43200.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	1331.	114.	0.	0.	0.	535.	0.	0.	1980.
16.RICE, ORM CASIERS	0.	0.	0.	7319.	0.	0.	0.	0.	0.	0.	0.	7319.
17.RICE IRRIGATED	0.	0.	0.	2808.	0.	0.	0.	0.	0.	0.	0.	2808.
18.RICE TOTAL	0.	0.	0.	11458.	114.	0.	0.	0.	535.	0.	0.	12107.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	48534.	41471.	65564.	38665.	3616.	3457.	8302.	0.	25401.	0.	0.	235008.

B4. Yields per km² arable farming, normal years and dry years

RENDEMENTS, NORMAL YEARS [TON/KM2]

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	45.	40.	28.	30.	0.	0.	19.	15.	15.	15.	0.	33.
2. MILLET SEMI-INTENS.	77.	0.	0.	64.	49.	49.	49.	0.	29.	0.	0.	50.
3. MILLET INTENSIVE	191.	187.	157.	157.	0.	0.	121.	0.	0.	0.	0.	174.
4. MILLET TOTAL	136.	61.	83.	68.	49.	49.	52.	15.	24.	15.	0.	73.
5. FONIO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	48.	0.	48.	0.	0.	48.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	136.	61.	83.	68.	49.	49.	51.	15.	25.	15.	0.	73.
9. PEANUT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10.COWPEA SEMI-INTENS.	60.	60.	37.	0.	0.	0.	0.	0.	0.	0.	0.	51.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	0.	0.	0.	0.	0.	3498.	0.	0.	3500.	0.	0.	3500.
13.OTHER VEGETABLES	1600.	1600.	1600.	1600.	0.	0.	1600.	0.	0.	0.	0.	1600.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	48.	48.	0.	0.	0.	48.	0.	0.	48.
16.RICE, ORM CASIERS	0.	0.	0.	224.	0.	0.	0.	0.	0.	0.	0.	224.
17.RICE IRRIGATED	0.	0.	0.	720.	0.	0.	0.	0.	0.	0.	0.	720.
18.RICE TOTAL	0.	0.	0.	122.	48.	0.	0.	0.	48.	0.	0.	105.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	131.	62.	96.	126.	49.	55.	57.	15.	70.	15.	0.	88.

RENDEMENTS,DRY YEARS [TON/KM2]

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. MILLET EXTENSIVE	22.	24.	13.	7.	0.	0.	2.	0.	5.	0.	0.	17.
2. MILLET SEMI-INTENS.	40.	0.	0.	36.	23.	23.	23.	0.	10.	0.	0.	24.
3. MILLET INTENSIVE	99.	133.	87.	87.	0.	0.	57.	0.	0.	0.	0.	98.
4. MILLET TOTAL	70.	39.	44.	38.	23.	23.	24.	0.	8.	0.	0.	39.
5. FONIO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6. SORGHUM EXTENSIVE	0.	0.	0.	0.	0.	0.	29.	0.	29.	0.	0.	29.
7. SORGHUM SEMI-INTEN.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8. TOTAL M/S/F	70.	39.	44.	38.	23.	23.	24.	0.	9.	0.	0.	39.
9. PEANUT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10.COWPEA SEMI-INTENS.	32.	32.	14.	0.	0.	0.	0.	0.	0.	0.	0.	25.
11.COWPEA INTENSIVE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.ONION	0.	0.	0.	0.	0.	3498.	0.	0.	3500.	0.	0.	3500.
13.OTHER VEGETABLES	1600.	1600.	1600.	1600.	0.	0.	1600.	0.	0.	0.	0.	1600.
14.FODDER CROPS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.RICE, HORS CASIERS	0.	0.	0.	7.	7.	0.	0.	0.	7.	0.	0.	7.
16.RICE, ORM CASIERS	0.	0.	0.	64.	0.	0.	0.	0.	0.	0.	0.	64.
17.RICE IRRIGATED	0.	0.	0.	720.	0.	0.	0.	0.	0.	0.	0.	720.
18.RICE TOTAL	0.	0.	0.	37.	7.	0.	0.	0.	7.	0.	0.	30.
19.VACANT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20.TOTAL	69.	40.	60.	67.	21.	29.	29.	0.	50.	0.	0.	51.

B5. Production, auto-consumption and marketable product in a normal year. Grain deficits in a dry year

PRODUCTION (1), AUTOCONSUMPTION (2) AND MARKETABLE PRODUCT (3), NORMAL YEAR [TON]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1.MILLET	(1)	86888.	57066.	81040.	17210.	7462.	5873.	14344.	996.	9833.	502.	0.	281214.
	(2)	26943.	40346.	58902.	49796.	6218.	4352.	10750.	4560.	37837.	2487.	829.	243018.
	(3)	59946.	16720.	22137.	-32585.	1244.	1521.	3594.	-3563.	-28003.	-1985.	-829.	38196.
2.FONIO	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(3)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3.SORGHUM	(1)	0.	0.	0.	0.	0.	0.	206.	0.	827.	0.	0.	1033.
	(2)	0.	0.	0.	0.	0.	0.	124.	0.	500.	0.	0.	624.
	(3)	0.	0.	0.	0.	0.	0.	81.	0.	327.	0.	0.	409.
4.PEANUT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	650.	1045.	1443.	1455.	150.	105.	262.	110.	925.	60.	20.	6225.
	(3)	-650.	-1045.	-1443.	-1455.	-150.	-105.	-262.	-110.	-925.	-60.	-20.	-6225.
5.COWPEA	(1)	3845.	5625.	3615.	0.	0.	0.	0.	0.	0.	0.	0.	13085.
	(2)	260.	3000.	1355.	582.	60.	42.	105.	44.	370.	24.	8.	5850.
	(3)	3585.	2625.	2261.	-582.	-60.	-42.	-105.	-44.	-370.	-24.	-8.	7235.
6.ONIONS	(1)	0.	0.	0.	0.	0.	700.	0.	0.	21000.	0.	0.	21700.
	(2)	650.	1045.	1443.	1455.	150.	105.	262.	110.	925.	60.	20.	6225.
	(3)	-650.	-1045.	-1443.	-1455.	-150.	595.	-262.	-110.	20075.	-60.	-20.	15475.
7.OTHER VEGETABLES	(1)	1600.	1600.	20800.	17600.	0.	0.	1600.	0.	0.	0.	0.	43200.
	(2)	1950.	3135.	4328.	4365.	450.	315.	787.	330.	2775.	180.	60.	18675.
	(3)	-350.	-1535.	16472.	13235.	-450.	-315.	813.	-330.	-2775.	-180.	-60.	24525.
8.FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(3)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9.RICE	(1)	0.	0.	0.	37553.	780.	0.	0.	0.	3667.	0.	0.	42000.
	(2)	1300.	2090.	2885.	11458.	300.	210.	525.	220.	1850.	120.	40.	20998.
	(3)	-1300.	-2090.	-2885.	26095.	480.	-210.	-525.	-220.	1817.	-120.	-40.	21002.
10. TOTAL CROPS (EXCL. 8.)	(1)	92333.	64291.	105455.	72364.	8242.	6573.	16149.	996.	35327.	502.	0.	402232.
	(2)	31753.	50661.	70356.	69111.	7328.	5129.	12816.	5374.	45181.	2931.	977.	301615.
	(3)	60580.	13630.	35099.	3253.	914.	1444.	3334.	-4377.	-9854.	-2429.	-977.	100617.
11. MEAT	(1)	8492.	2115.	5743.	45995.	2936.	3201.	3745.	1691.	10349.	1178.	1410.	86854.
	(2)	2340.	3762.	5193.	0.	540.	378.	945.	396.	333.	216.	72.	14175.
	(3)	6152.	-1647.	550.	45995.	2396.	2823.	2801.	1295.	10015.	962.	1338.	72679.
11. MILK AT MOPTI	(3)	0.	0.	0.	2600.	0.	0.	0.	0.	0.	0.	0.	
DRY YEARS													
GRAIN DEFICIT [MIL.EQ]		2399.	7331.	20817.	42648.	3198.	2031.	5261.	5016.	37651.	2736.	912.	130000.
TOTAL GRAIN DEFICIT 5TH REGION [TON MILLET EQUIVALENT]													110000.

B6. Labour inputs, period 1 (ploughing/sowing time millet) and period 2 (first weeding millet)

INPUTS CROP, LIVESTOCK AND FISH ACTIVITIES, LABOUR: PLOUGHING/SOWING TIME (=1) AND FIRST WEEDING (=2), [MAN]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	6608.	32172.	22664.	188.	0.	0.	927.	2656.	5672.	1337.	0.	72224.
AND FONIO	(2)	12415.	80431.	56661.	472.	0.	0.	2319.	6641.	13337.	3344.	0.	175620.
MILLET SEMI-	(1)	5689.	0.	0.	11851.	7613.	5993.	11781.	0.	13250.	0.	0.	56177.
INTENSIVE	(2)	10582.	0.	0.	22043.	14161.	11146.	21913.	0.	24645.	0.	0.	104490.
MILLET	(1)	27976.	9984.	31158.	956.	0.	0.	1458.	0.	0.	0.	0.	71532.
INTENSIVE	(2)	36182.	12912.	40297.	1237.	0.	0.	1886.	0.	0.	0.	0.	92514.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	3203.	4687.	4910.	0.	0.	0.	0.	0.	0.	0.	0.	12800.
SEMI-INTENSIVE	(2)	4485.	6562.	6874.	0.	0.	0.	0.	0.	0.	0.	0.	17921.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(INCL.ONIONS)	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	8558.	731.	0.	0.	0.	3437.	0.	0.	12726.
HORS CASIERS	(2)	0.	0.	0.	12743.	1088.	0.	0.	0.	5117.	0.	0.	18948.
RICE	(1)	0.	0.	0.	16352.	0.	0.	0.	0.	0.	0.	0.	16352.
ORM CASIERS	(2)	0.	0.	0.	16009.	0.	0.	0.	0.	0.	0.	0.	16009.
RICE	(1)	0.	0.	0.	897.	0.	0.	0.	0.	0.	0.	0.	897.
IRRIGATED	(2)	0.	0.	0.	456.	0.	0.	0.	0.	0.	0.	0.	456.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	-0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	43476.	46843.	58732.	38802.	8344.	5993.	14166.	2656.	22359.	1337.	0.	242708.
	(2)	63664.	99905.	103832.	52960.	15249.	11146.	26118.	6641.	43099.	3344.	0.	425958.
LIVESTOCK TOTAL	1	20832.	4924.	14190.	29698.	4249.	2503.	7990.	3478.	19674.	2175.	1840.	111553.
LIVESTOCK TOTAL	2	20832.	4924.	14190.	29698.	4249.	2503.	7990.	3478.	19674.	2175.	1840.	111553.
FULL TIME FISHERMEN		0.	0.	0.	44466.	0.	0.	0.	0.	22325.	0.	0.	66792.
EMIGRATION [MAN-YEARS]		0.	0.	4859.	0.	0.	0.	27641.	0.	0.	0.	0.	32500.
LABOUR SUPPLY		84500.	135850.	192400.	133860.	19500.	13650.	61750.	10120.	85100.	5520.	1840.	744090.
SHADOW PRICES	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	
SHADOW PRICES	2	0.03268	0.00000	0.00000	0.00000	0.16220	0.17395	0.00004	0.02734	0.04085	0.02875	0.10611	

B7. Labour inputs, period 3 (remainder of the growing season) and period 4 (harvest millet)

INPUTS CROP, LIVESTOCK AND FISH ACTIVITIES, LABOUR: REST GROWING SEASON (=1) AND HARVEST TIME MILLET (=2), [MAN]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	3385.	17694.	12465.	103.	0.	0.	509.	1461.	3068.	735.	0.	39420.
AND FONIO	(2)	8599.	40215.	28330.	236.	0.	0.	1159.	3320.	7160.	1672.	0.	90691.
MILLET SEMI-	(1)	2503.	0.	0.	5214.	3350.	2636.	5183.	0.	5830.	0.	0.	24716.
INTENSIVE	(2)	5689.	0.	0.	11851.	7613.	5993.	11781.	0.	13250.	0.	0.	56177.
MILLET	(1)	11190.	3993.	12463.	382.	0.	0.	583.	0.	0.	0.	0.	28611.
INTENSIVE	(2)	44762.	15309.	49853.	1530.	0.	0.	2333.	0.	0.	0.	0.	113787.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	85.	0.	344.	0.	0.	429.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	107.	0.	430.	0.	0.	537.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	5126.	7499.	7856.	0.	0.	0.	0.	0.	0.	0.	0.	20481.
SEMI-INTENSIVE	(2)	3844.	5624.	5892.	0.	0.	0.	0.	0.	0.	0.	0.	15360.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(INCL.ONIONS)	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HORS CASIERS	(2)	0.	0.	0.	1900.	162.	0.	0.	0.	763.	0.	0.	2825.
RICE	(1)	0.	0.	0.	2287.	0.	0.	0.	0.	0.	0.	0.	2287.
ORM CASIERS	(2)	0.	0.	0.	3430.	0.	0.	0.	0.	0.	0.	0.	3430.
RICE	(1)	0.	0.	0.	152.	0.	0.	0.	0.	0.	0.	0.	152.
IRRIGATED	(2)	0.	0.	0.	195.	0.	0.	0.	0.	0.	0.	0.	195.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	22204.	29186.	32784.	8138.	3350.	2636.	6360.	1461.	9242.	735.	0.	116096.
	(2)	62894.	61148.	84075.	19142.	7775.	5993.	15380.	3320.	21603.	1672.	0.	283002.
LIVESTOCK TOTAL	1	20832.	4924.	14190.	29698.	4249.	2503.	7990.	3478.	19674.	2175.	1840.	111553.
LIVESTOCK TOTAL	2	19042.	4405.	12720.	24536.	4045.	2438.	7582.	3378.	18294.	2107.	1768.	100314.
FULL TIME FISHERMEN		0.	0.	0.	44466.	0.	0.	0.	0.	22325.	0.	0.	66792.
EMIGRATION [MAN-YEARS]		0.	0.	4859.	0.	0.	0.	27641.	0.	0.	0.	0.	32500.
LABOUR SUPPLY		84500.	135850.	192400.	133860.	19500.	13650.	61750.	10120.	85100.	5520.	1840.	744090.
SHADOW PRICES	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.04657	
SHADOW PRICES	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	

B8. Labour inputs, period 5 (harvest rice) and period 6 (remainder of the year)

INPUTS CROP, LIVESTOCK AND FISH ACTIVITIES, LABOUR: HARVEST RICE (=1) AND REST OF THE YEAR (=2), [MAN]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
AND FONIO	(2)	1213.	6917.	4082.	39.	0.	0.	179.	929.	738.	468.	0.	14565.
MILLET SEMI-	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	1638.	0.	0.	3373.	2192.	1725.	3392.	0.	3498.	0.	0.	15818.
MILLET	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	8803.	3115.	9804.	301.	0.	0.	458.	0.	0.	0.	0.	22481.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	42.	0.	172.	0.	0.	214.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	281.	412.	432.	0.	0.	0.	0.	0.	0.	0.	0.	1125.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	534.	534.	6942.	5874.	0.	150.	534.	0.	4524.	0.	0.	19092.
(INCL.ONIONS)	(2)	534.	534.	6942.	5874.	0.	150.	534.	0.	4524.	0.	0.	19092.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	15215.	1300.	0.	0.	0.	6110.	0.	0.	22625.
HORS CASIERS	(2)	0.	0.	0.	2091.	178.	0.	0.	0.	840.	0.	0.	3109.
RICE	(1)	0.	0.	0.	41739.	0.	0.	0.	0.	0.	0.	0.	41739.
ORM CASIERS	(2)	0.	0.	0.	800.	0.	0.	0.	0.	0.	0.	0.	800.
RICE	(1)	0.	0.	0.	2028.	0.	0.	0.	0.	0.	0.	0.	2028.
IRRIGATED	(2)	0.	0.	0.	483.	0.	0.	0.	0.	0.	0.	0.	483.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	534.	534.	6942.	64856.	1300.	150.	534.	0.	10634.	0.	0.	85484.
	(2)	12469.	10978.	21260.	12961.	2370.	1875.	4605.	929.	9772.	468.	0.	77687.
LIVESTOCK TOTAL	1	19042.	4405.	12720.	24536.	4045.	2438.	7582.	3378.	18294.	2107.	1768.	100314.
LIVESTOCK TOTAL	2	19042.	4405.	12720.	24536.	4045.	2438.	7582.	3378.	18294.	2107.	1768.	100314.
FULL TIME FISHERMEN		0.	0.	0.	44466.	0.	0.	0.	0.	22325.	0.	0.	66792.
EMIGRATION [MAN-YEARS]		0.	0.	4859.	0.	0.	0.	27641.	0.	0.	0.	0.	32500.
LABOUR SUPPLY		84500.	135850.	192400.	133860.	19500.	13650.	61750.	10120.	85100.	5520.	1840.	744090.
SHADOW PRICES	1	0.00000	0.00000	0.00000	0.03995	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	
SHADOW PRICES	2	0.00000	0.00000	0.00000	0.07466	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	
LABOUR INPUT MAN-YEARS		38371.	25096.	42977.	123269.	7605.	5127.	14170.	4788.	71189.	2821.	1786.	337200.
EMIGRATION [PERSONS]		0.	0.	7475.	0.	0.	0.	42525.	0.	0.	0.	0.	50000.

B9. Monetary inputs arable farming

INPUTS CROP ACTIVITIES, MONEY: CAPITAL COSTS (=1) AND OTHER CHARGES (=2) [MILLION FCFA]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	26.	56.	40.	0.	0.	0.	2.	5.	13.	2.	0.	144.
AND FONIO	(2)	2.	13.	9.	0.	0.	0.	0.	1.	2.	1.	0.	29.
MILLET SEMI-	(1)	30.	0.	0.	63.	41.	32.	63.	0.	71.	0.	0.	300.
INTENSIVE	(2)	4.	0.	0.	7.	5.	4.	7.	0.	8.	0.	0.	35.
MILLET	(1)	357.	127.	397.	12.	0.	0.	19.	0.	0.	0.	0.	912.
INTENSIVE	(2)	245.	87.	273.	8.	0.	0.	13.	0.	0.	0.	0.	626.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	2.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	25.	37.	38.	0.	0.	0.	0.	0.	0.	0.	0.	100.
SEMI-INTENSIVE	(2)	78.	113.	119.	0.	0.	0.	0.	0.	0.	0.	0.	310.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	0.	0.	4.	3.	0.	0.	0.	0.	2.	0.	0.	10.
(INCL.ONIONS)	(2)	5.	5.	70.	59.	0.	4.	5.	0.	122.	0.	0.	270.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	76.	7.	0.	0.	0.	31.	0.	0.	113.
HORS CASIERS	(2)	0.	0.	0.	145.	12.	0.	0.	0.	58.	0.	0.	215.
RICE	(1)	0.	0.	0.	393.	0.	0.	0.	0.	0.	0.	0.	393.
ORM CASIERS	(2)	0.	0.	0.	319.	0.	0.	0.	0.	0.	0.	0.	319.
RICE	(1)	0.	0.	0.	137.	0.	0.	0.	0.	0.	0.	0.	137.
IRRIGATED	(2)	0.	0.	0.	70.	0.	0.	0.	0.	0.	0.	0.	70.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	438.	220.	479.	685.	47.	32.	84.	5.	117.	2.	0.	2109.
	(2)	334.	219.	470.	608.	17.	8.	26.	1.	190.	1.	0.	1874.

B10. Oxen and manure inputs arable farming

INPUTS CROP ACTIVITIES, OXEN (=1) [NUMBER] AND ORGANIC MANURE (=2) [1000 TON]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	2978.	0.	0.	0.	0.	0.	0.	0.	613.	0.	0.	3590.
AND FONIO	(2)	0.	0.	0.	0.	0.	0.	0.	5.	0.	3.	0.	8.
MILLET SEMI-	(1)	3755.	0.	0.	7822.	5025.	3955.	7776.	0.	8745.	0.	0.	37078.
INTENSIVE	(2)	31.	0.	0.	59.	26.	21.	40.	0.	47.	0.	0.	223.
MILLET	(1)	27976.	9984.	31158.	957.	0.	0.	1459.	0.	0.	0.	0.	71534.
INTENSIVE	(2)	78.	27.	72.	2.	0.	0.	3.	0.	0.	0.	0.	182.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	2115.	3094.	3241.	0.	0.	0.	0.	0.	0.	0.	0.	8449.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(INCL.ONIONS)	(2)	1.	1.	8.	7.	0.	0.	1.	0.	6.	0.	0.	23.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	9510.	813.	0.	0.	0.	3819.	0.	0.	14142.
HORS CASIERS	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	5718.	0.	0.	0.	0.	0.	0.	0.	5718.
ORM CASIERS	(2)	0.	0.	0.	48.	0.	0.	0.	0.	0.	0.	0.	48.
RICE	(1)	0.	0.	0.	195.	0.	0.	0.	0.	0.	0.	0.	195.
IRRIGATED	(2)	0.	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.	2.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	36823.	13078.	34399.	24202.	5838.	3955.	9234.	0.	13177.	0.	0.	140707.
	(2)	110.	28.	80.	118.	26.	21.	44.	5.	53.	3.	0.	486.
SHADOW PRICES	1	0.02211	0.02596	0.04375	0.12422	0.00693	0.00708	0.05878	0.02276	0.03246	0.03417	0.00805	
SHADOW PRICES	2	0.06942	0.21580	0.12482	0.04277	0.00672	0.00000	0.07769	0.00000	0.01237	0.00000	0.00000	

B11. Fertilizer inputs arable farming

INPUTS CROP ACTIVITIES, FERTILIZER: N (=1), P (=2) AND K (=3), [TON]

		SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MILLET EXTENSIVE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
AND FONIO	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MILLET SEMI-	(1)	166.	0.	0.	317.	142.	112.	219.	0.	254.	0.	0.	1210.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MILLET	(1)	3990.	1369.	3653.	112.	0.	0.	132.	0.	0.	0.	0.	9255.
INTENSIVE	(2)	570.	124.	522.	16.	0.	0.	19.	0.	0.	0.	0.	1251.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EXTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SORGHUM	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEANUT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SEMI-INTENSIVE	(2)	23.	34.	29.	0.	0.	0.	0.	0.	0.	0.	0.	86.
COWPEA	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTENSIVE	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VEGETABLES	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(INCL.ONIONS)	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FODDER CROPS	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HORS CASIERS	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RICE	(1)	0.	0.	0.	2459.	0.	0.	0.	0.	0.	0.	0.	2459.
ORM CASIERS	(2)	0.	0.	0.	102.	0.	0.	0.	0.	0.	0.	0.	102.
RICE	(1)	0.	0.	0.	236.	0.	0.	0.	0.	0.	0.	0.	236.
IRRIGATED	(2)	0.	0.	0.	17.	0.	0.	0.	0.	0.	0.	0.	17.
VACANT	(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CROPS TOTAL	(1)	4156.	1369.	3653.	3124.	142.	112.	351.	0.	254.	0.	0.	13161.
	(2)	593.	158.	551.	135.	0.	0.	19.	0.	0.	0.	0.	1457.
POTASSIUM	(3)	2422.	1344.	2218.	1149.	0.	0.	80.	0.	61.	0.	0.	7275.

B12. Forage production, normal years

FORAGE PRODUCTION [TON], NORMAL YEARS

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
BYPRODUCTS Q=1	106046.	126881.	124496.	103438.	17770.	12525.	29528.	3553.	49636.	1789.	0.	575663.
BYPRODUCTS Q=2	8233.	4232.	8180.	13924.	328.	0.	334.	0.	1540.	0.	0.	36770.
BYPRODUCTS Q=3	2114.	3090.	2882.	69.	0.	0.	6.	0.	0.	0.	0.	8162.
BYPRODUCTS Q=4	960.	1378.	1937.	624.	0.	0.	57.	0.	0.	0.	0.	4956.
PASTURES ≤15, W.S. Q=1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES ≤15, W.S. Q=2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES ≤15, W.S. Q=3	63416.	62707.	33798.	25670.	22623.	39280.	24832.	0.	64313.	372.	20801.	357811.
PASTURES ≤15, W.S. Q=4	66590.	10784.	39055.	14297.	29226.	19633.	24832.	35873.	147184.	19337.	14865.	421677.
NO FIRE / MOWING												
PASTURES ≤15, DR.S Q=1	72843.	83926.	156747.	236364.	46149.	42140.	31455.	0.	29612.	1832.	36684.	737750.
PASTURES ≤15, DR.S Q=2	98355.	64954.	275410.	4192717.	154329.	159909.	108724.	94876.	685068.	53926.	87172.	5975439.
PASTURES ≤15, DR.S Q=3	112327.	1680.	21705.	33768.	11582.	7493.	26687.	6280.	28516.	11310.	6021.	267371.
PASTURES ≤15, DR.S Q=4	0.	0.	0.	0.	1498.	2321.	5844.	43.	0.	197.	634.	10536.
WOODY SPECIES	34128.	4124.	17711.	6819.	5166.	5141.	4592.	1694.	26364.	1290.	6704.	113732.
FIRE												
PASTURES ≤15, DR.S Q=1	57728.	70870.	40820.	46366.	15684.	32086.	22358.	0.	23779.	1540.	30011.	341243.
PASTURES ≤15, DR.S Q=2	86495.	55189.	109760.	141527.	111573.	136337.	36627.	83595.	56577.	47707.	71442.	936829.
PASTURES ≤15, DR.S Q=3	112327.	1680.	42693.	1449018.	11165.	7462.	50320.	5582.	254476.	10053.	5522.	1950299.
PASTURES ≤15, DR.S Q=4	0.	0.	0.	0.	1498.	2321.	5844.	43.	0.	197.	634.	10536.
WOODY SPECIES	34128.	4124.	17711.	6819.	5166.	5141.	4592.	1694.	26364.	1290.	6704.	113732.
PASTURES >15, W.S. Q=1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES >15, W.S. Q=2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES >15, W.S. Q=3	13860.	0.	1557.	1169.	17499.	117737.	0.	0.	25596.	1500.	21353.	200272.
PASTURES >15, W.S. Q=4	35714.	0.	1571.	598.	23333.	73343.	13840.	119541.	125430.	36057.	20654.	450079.

B13. Forage production, dry years

FORAGE PRODUCTION [TON], DRY YEARS

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
BYPRODUCTS Q=1	72236.	91692.	87669.	40470.	10245.	7851.	18563.	2059.	24000.	1037.	0.	355821.
BYPRODUCTS Q=2	5830.	3010.	6144.	4822.	48.	0.	247.	0.	225.	0.	0.	20326.
BYPRODUCTS Q=3	1235.	1804.	1420.	69.	0.	0.	6.	0.	0.	0.	0.	4535.
BYPRODUCTS Q=4	583.	827.	1310.	624.	0.	0.	57.	0.	0.	0.	0.	3401.
PASTURES ≤15, W.S. Q=1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES ≤15, W.S. Q=2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES ≤15, W.S. Q=3	43597.	29167.	1226.	148.	1675.	8362.	5061.	0.	0.	0.	0.	89236.
PASTURES ≤15, W.S. Q=4	68741.	26316.	64842.	36282.	30817.	30218.	26162.	18219.	83630.	10393.	14230.	409850.
NO FIRE / MOWING												
PASTURES ≤15, DR.S Q=1	22117.	22555.	89265.	140132.	19868.	5438.	7922.	0.	8438.	0.	0.	315735.
PASTURES ≤15, DR.S Q=2	98506.	88597.	167869.	2653661.	61349.	64132.	61734.	9187.	404935.	2759.	16971.	3629702.
PASTURES ≤15, DR.S Q=3	114248.	1680.	21705.	17007.	42930.	60926.	25932.	41704.	36753.	25930.	25460.	414277.
PASTURES ≤15, DR.S Q=4	0.	0.	0.	0.	1498.	2321.	5844.	43.	0.	197.	634.	10536.
WOODY SPECIES	34128.	4124.	17711.	6819.	5166.	5141.	4592.	1694.	26364.	1290.	6704.	113732.
FIRE												
PASTURES ≤15, DR.S Q=1	17548.	19161.	23753.	29371.	3112.	4351.	6337.	0.	6136.	0.	0.	109769.
PASTURES ≤15, DR.S Q=2	91351.	80166.	73693.	310215.	38404.	57920.	20679.	9187.	44757.	2741.	16971.	746084.
PASTURES ≤15, DR.S Q=3	114248.	1680.	31407.	718386.	41446.	60646.	37402.	41704.	149407.	25914.	24625.	1246866.
PASTURES ≤15, DR.S Q=4	0.	0.	0.	0.	1498.	2321.	5844.	43.	0.	197.	634.	10536.
WOODY SPECIES	34128.	4124.	17711.	6819.	5166.	5141.	4592.	1694.	26364.	1290.	6704.	113732.
PASTURES >15, W.S. Q=1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES >15, W.S. Q=2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASTURES >15, W.S. Q=3	10164.	0.	37.	30.	0.	11890.	0.	0.	0.	0.	0.	22121.
PASTURES >15, W.S. Q=4	34934.	0.	2841.	1551.	26249.	108159.	13840.	58923.	63477.	17914.	16570.	344459.

B14. Livestock activities

LIVESTOCK ACTIVITIES [1000 TLU]

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
1. CATTLE SED. OXEN 1	66.5	23.6	62.1	43.7	10.5	7.1	16.7	0.0	23.8	0.0	0.0	254.
2. CATTLE SED. MEAT 1	0.0	0.0	0.0	0.0	0.0	48.6	0.0	0.0	0.0	0.0	0.0	49.
3. CATTLE SED. MEAT 2	0.0	0.0	0.0	0.0	11.8	15.0	0.0	0.0	0.0	0.0	12.1	39.
4. CATTLE MOB. MEAT 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
5. CATTLE MOB. MEAT 3	0.0	0.0	0.0	537.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	537.
6. VACANT												
7. CATTLE SED. MILK 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
8. CATTLE SED. MILK 3	0.0	0.0	0.0	0.0	8.7	3.1	0.0	0.0	24.2	0.0	1.2	37.
9. CATTLE MOB. MILK 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
10.CATTLE MOB. MILK 3	0.0	0.0	0.0	95.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.
11.CATTLE SED. MILK 4C	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.
12.CATTLE SED. MILK 4	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.
13.SHEEP ≤15 MEAT 1	39.4	8.5	8.4	0.0	14.6	0.0	34.3	14.3	0.0	0.0	8.4	128.
14.SHEEP ≤15 MEAT 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	57.4	10.0	0.0	73.
15.SHEEP MOB. MEAT 1	0.0	6.3	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.
16.SHEEP MOB. MEAT 3	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
17.SHEEP SED. MEAT 4	1.6	0.0	0.0	0.0	1.4	1.4	2.3	0.1	0.0	0.3	0.2	7.
18.GOATS ≤15 MEAT 1B	48.1	0.0	38.1	0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	99.
19.GOATS ≤15 MEAT 3B	21.6	0.0	0.0	0.0	3.6	0.0	0.0	2.2	34.5	1.7	0.6	64.
20.GOATS MOB. MEAT 1B	0.0	11.3	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.
21.GOATS MOB. MEAT 3B	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.
22.DONKEY SED. 2	3.3	5.2	7.4	7.3	0.8	0.5	2.4	0.6	4.6	0.3	0.1	32.
23.CAMELS 1B	0.0	0.0	0.0	0.0	0.0	15.5	0.0	0.0	0.0	0.0	0.0	16.
24.VACANT												
TOTAL	180.	55.	146.	698.	51.	91.	68.	22.	144.	12.	23.	1491.

B15. Livestock production and livestock inputs

LIVESTOCK PRODUCTION

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
MEAT [TON]	8492.	2115.	5743.	45995.	2936.	3201.	3745.	1691.	10349.	1178.	1410.	86854.
MILK [TON]	9130.	1127.	4839.	157936.	5065.	2555.	1255.	700.	18859.	838.	1696.	204000.
WOOL [TON]	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EGGS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OXEN [NUMBER]	36823.	13078.	34399.	24202.	5838.	3955.	9234.	0.	13177.	0.	0.	140707.
DONKEYS [NUMBER]	6500.	10450.	14800.	14550.	1500.	1050.	4750.	1100.	9250.	600.	200.	64750.
CAMELS [NUMBER]	0.	0.	0.	0.	0.	12950.	0.	0.	0.	0.	0.	12950.
MANURE [1000 TON]	110.	28.	80.	171.	26.	24.	44.	16.	87.	8.	11.	603.

LIVESTOCK INPUTS

	SOUROU	SENO B.	PLATEAU	DELTA C.	MEMA D.	SENO M.	GOURMA	BODARA	ZONE LAC	HODD	MEMA S.	5E REGION +C.de NIAF.
FORAGE W.S.,Q''≥1 [TON]	125840.	21567.	72853.	28594.	32492.	38580.	49664.	18219.	105831.	10393.	14230.	518263.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000)	
FORAGE W.S.,Q''≥2 [TON]	125840.	21567.	72853.	28594.	32492.	38580.	49664.	18219.	105831.	10393.	14230.	518263.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000)	
FORAGE W.S.,Q''≥3 [TON]	125840.	21567.	72853.	28594.	32492.	38580.	49664.	18219.	105831.	10393.	14230.	518263.
SHADOW PRICES (	0.00000	0.00000	0.03120	0.00000	0.00000	0.00000	0.00816	0.00000	0.00000	0.00000	0.00000)	
FORAGE W.S.,Q''≤4 [TON]	66590.	10784.	36426.	14297.	17811.	19633.	24832.	10360.	71194.	7185.	7355.	286467.
SHADOW PRICES (	0.00783	0.17807	0.00000	0.30898	0.00000	0.00083	0.01132	0.00000	0.00000	0.00000	0.00000)	
FORAGE D.S.,Q''≥1 [TON]	343568.	103341.	273795.	1104086.	94754.	133088.	144493.	52993.	291128.	29889.	42230.	2613366.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000)	
FORAGE D.S.,Q''≥2 [TON]	210129.	65570.	165452.	941836.	68619.	89952.	93188.	37926.	229668.	25195.	30664.	1958199.
SHADOW PRICES (	0.01670	0.07501	0.03041	0.00000	0.00000	0.00000	0.01828	0.00000	0.00000	0.00000	0.00000)	
FORAGE D.S.,Q''≥3 [TON]	7449.	2414.	3419.	378498.	12664.	9783.	3300.	5625.	78140.	10250.	6157.	517698.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.01372	0.01573	0.00000	0.01158	0.00000	0.00000	0.01501)	
FORAGE D.S.,Q''≤4 [TON]	960.	0.	0.	624.	825.	826.	1370.	43.	0.	197.	98.	4941.
SHADOW PRICES (	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02329	0.00000	0.00000)	
FORAGE WOODY [TON]	34128.	4124.	17711.	6819.	2752.	3063.	4592.	1694.	26364.	1290.	477.	103013.
SHADOW PRICES (	0.01962	0.11843	0.04227	0.00000	0.00000	0.00000	0.02481	0.00000	0.00000	0.00000	0.00000)	
FORAGE W.S-PAST. [TON]	0.	14237.	24265.	342133.	0.	6809.	0.	0.	0.	0.	0.	387444.
SHADOW PRICE											(	0.00000)
FORAGE CONCENTR. [TON]	0.	0.	0.	1276.	0.	0.	0.	0.	0.	0.	0.	1276.
LABOUR WET SEAS. [MAN]	20832.	4924.	14190.	29698.	4249.	2503.	7990.	3478.	19674.	2175.	1840.	111553.
LABOUR DRY SEAS. [MAN]	19042.	4405.	12720.	24536.	4045.	2438.	7582.	3378.	18294.	2107.	1768.	100314.
MONEY [MILLION FCFA]	84.	16.	44.	1078.	48.	53.	27.	16.	183.	19.	24.	1591.
BOURGOU CULT. [KM2]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

B16. Fisheries

FISHERIES (PRIMARY MIGRANT = 1; PRIMARY SEDENTARY = 2; SECONDARY SED. = 3

NORMAL YEARS

	PRODUCTION [TON]	LABOUR INPUT [HOUSEHOLDS]	[MAN-YEARS]	DEPRECIATION [MILL.CFA]	OTHER COSTS [MILL.CFA]	PRODUCTIVITY [TON/HOUSEHOLD]
FISHING ACTIVITY 1	8763.	1872.	6778.	341.	311.	4.680
FISHING ACTIVITY 2	62003.	16578.	60014.	2570.	2056.	3.740
FISHING ACTIVITY 3	22729.	29906.	54130.	927.	778.	0.760
TOTAL	93495. (0.20160)	48357.	120922.	3838.	3144.	

DRY YEARS

	PRODUCTION [TON]	LABOUR INPUT [HOUSEHOLDS]	[MAN-YEARS]	DEPRECIATION [MILL.CFA]	OTHER COSTS [MILL.CFA]	PRODUCTIVITY [TON/HOUSEHOLD]
FISHING ACTIVITY 1	5018.	1872.	6778.	341.	311.	2.680
FISHING ACTIVITY 2	35478.	16578.	60014.	2570.	2056.	2.140
FISHING ACTIVITY 3	12860.	29906.	54130.	927.	778.	0.430
TOTAL	53355. (0.00000)	48357.	120922.	3838.	3144.	

AUTO-CONSUMPTION FISH [TON] 15764.

ANNEX C. LIST OF ACRONYMS AND ABBREVIATIONS

ADRAO = Association pour le Développement de la Riziculture en Afrique de l'Ouest (synonym WARDA = West Africa Rice Development Association)
AEZ = agro-ecological zone
At = working day of oxen-team
CABO = Centre for Agrobiological Research
CIPEA = ILCA
CRD = Comité Régional de Développement
CMDT = Compagnie Malienne pour le Développement des Fibres Textiles
d = day
DM = dry matter
DAE = days after emergence
DANIDA = Danish International Development Agency
DRA = Direction Régionale de l'Agriculture (Mopti)
DRSPR = Division de Recherches sur les Systèmes de Production Rurale, IER
ESPR = Equipe chargée de l'Etude sur les Systèmes de Productions Rurales en 5ème Région et Cercle de Niafunké
FAO = Food and Agricultural Organisation of the United Nations
h = hour
ha = hectare
HI = harvest index
IER = Institut d'Economie Rurale
ILCA = International Livestock Centre for Africa
mnd = man-day in adult-equivalent
myr = man-year
ODEM = Opération de Développement de l'Elevage de la région de Mopti
OMBEVI = Office Malien du Bétail et de la Viande
ORM = Opération Mil Mopti
ORM = Opération Riz Mopti
ox = oxen
PIRT = Projet Inventaire des Ressources Terrestres - Mali
PPIV = small village irrigation scheme
RFMC = République Francaise, Ministère de la Coopération
RIM = Resource Inventory and Management Ltd.
RZ = rainfall zone (I-IV)
SRCVO = Section des Recherches sur les Cultures Vivrières et Oléagineuses, IER
t = metric ton or tonne (1000 kg)
TAC = Technical Advisory Comittee to the Consultative Group of International Agricultural Research
WIP = Wirtschaft und Infrastructur GMBH & Co. Planungs
yr = year