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Water conflict in the Senegal River Valley: Implications of a "no-flood" scenario

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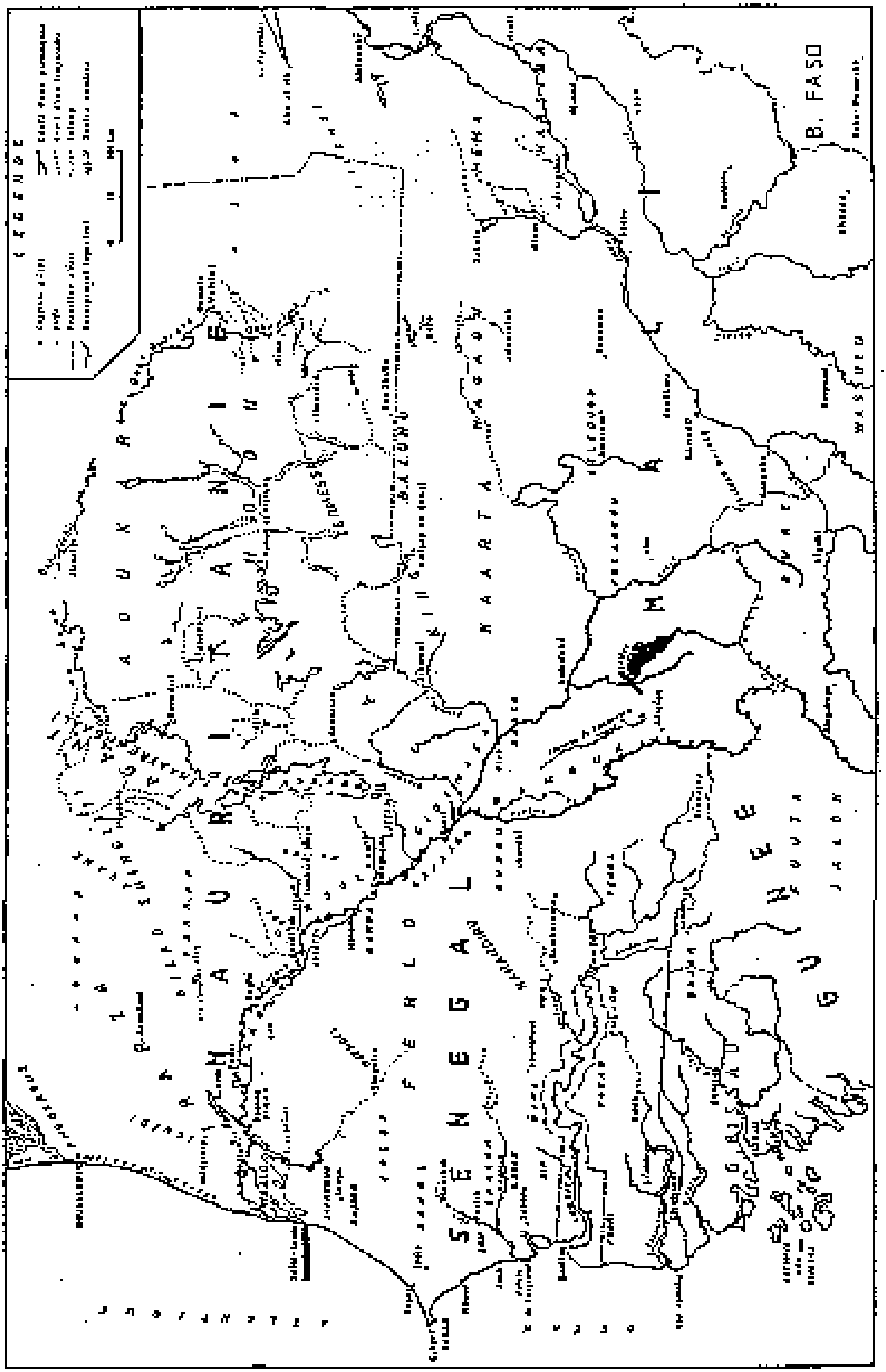
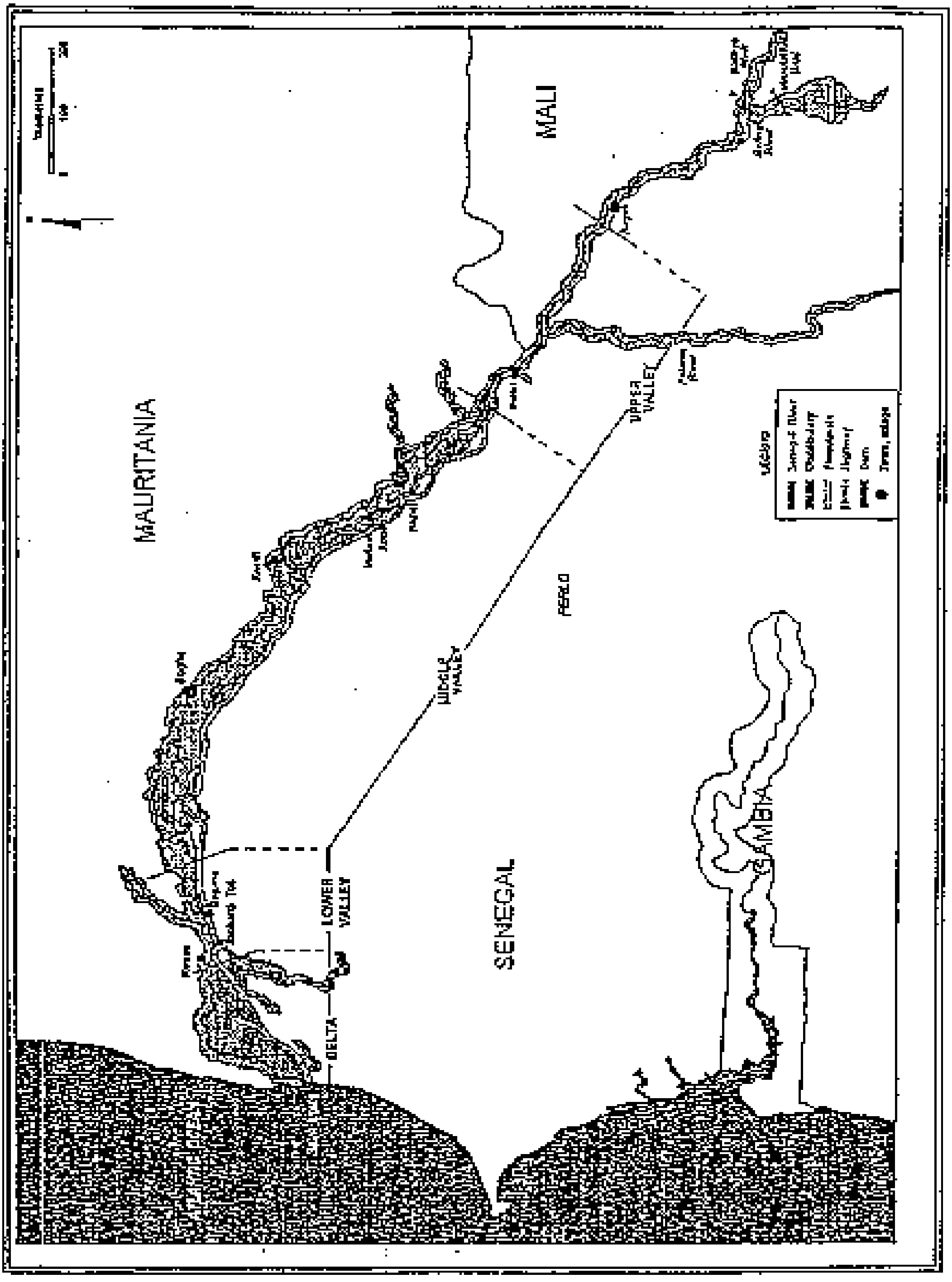
Map 1 The Senegal river basin



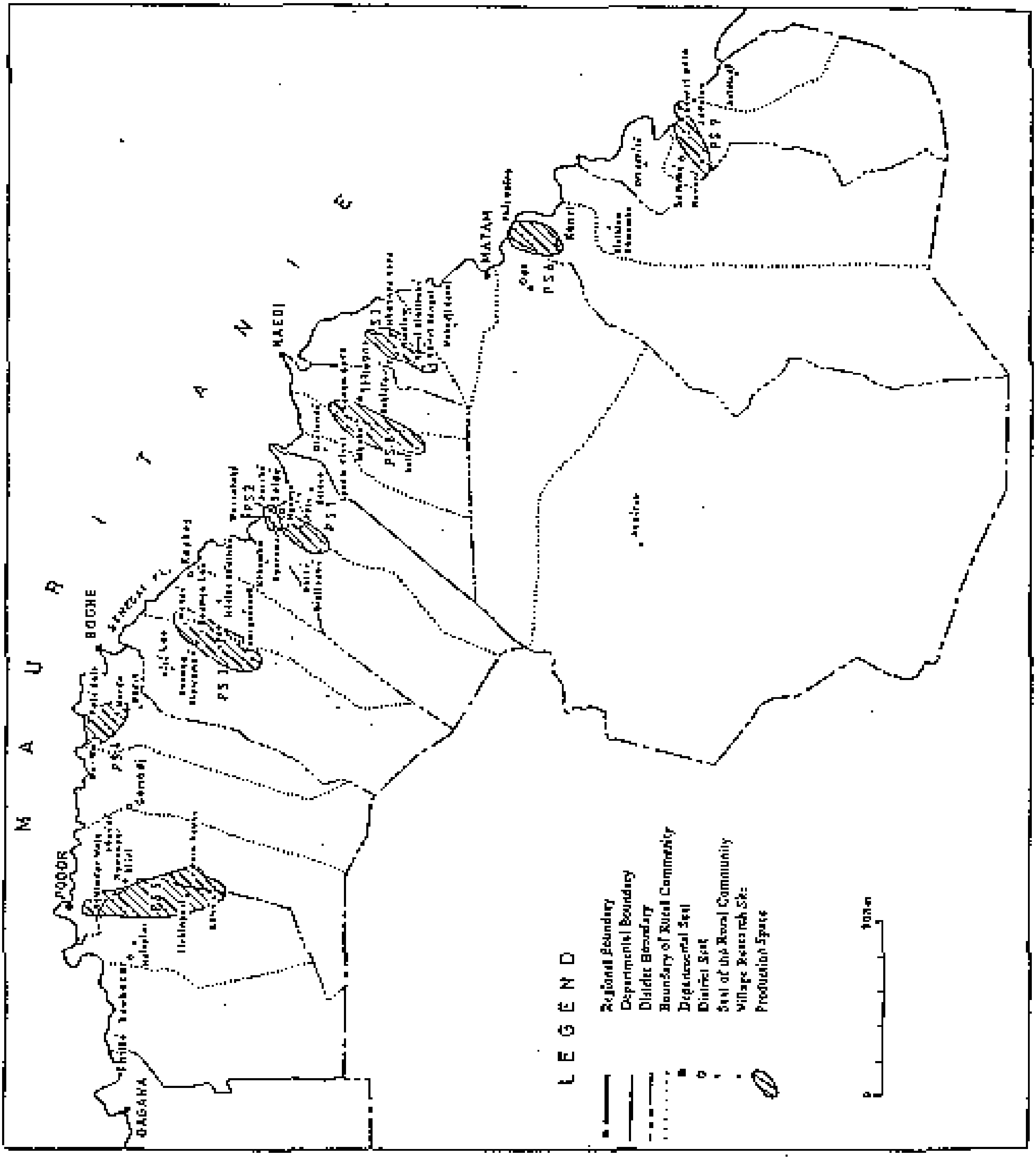
From Horowitz, Salem-Murdock, *et al.* 1990.

Map 2 The Senegal river valley



From Salem-Murdock and Niasse, 1993.

Map 3 SRBMA II research areas



From Salem-Murdock and Niasse 1993.

WATER CONFLICT IN THE SENEGAL RIVER VALLEY: IMPLICATIONS OF A "NO-FLOOD" SCENARIO

INTRODUCTION

The socio-economic and ecological viability of Senegal's floodplain economy is increasingly a cause for concern. On the one hand, the floodplains are currently subject to a variety of development programmes. On the other hand, the commercial demands of hydropower generation, large-scale, capital-intensive irrigation from high mainstream dams and huge reservoirs have created settlement and resettlement issues in the Senegal River Valley which have yet to be resolved (Adams 1990; Hollis, Adams and Aminu-Kano 1993; Horowitz 1994; Horowitz and Salem-Murdock 1993; Horowitz, Salem-Murdock et al 1990; Magistro 1994; Salem-Murdock and Niasse 1993; Scudder 1968, 1985; Scudder and Colson 1982). At best, mainstream dams interfere with the natural flooding of downstream water courses; at worst, they cause the elimination of surrounding rivers and tributaries, with disastrous effects on Senegal's floodplain ecology and demography.

The data presented here was gathered in the Middle Senegal Valley between 1990 and 1992[1]. This paper discusses - in the context of the management of the Manantali dam in Mali - a conflict between power generation and irrigation on the one hand, and the maintenance of the annual flooding of the Senegal River on the other. The data would indicate that, with proper regulation, the Dam could be used for electricity generation and irrigation while at the same time maintaining the productivity of the floodplain at current levels. The Dam could even improve the floodplain by removing some of the uncertainties associated with natural flooding.

BACKGROUND

Large-scale attempts to control the flow of the Senegal River were begun towards the middle of the present century, with the launching in 1945 of the Richard Toll irrigation scheme aimed at irrigating the delta to grow rice. Although created to develop 50,000 hectares over a decade, only 6,000 hectares had been developed by 1957 (Patterson 1984, p.44). Two parastatal

[1] Known as the Senegal River Basin Monitoring Activity (SRBMA) and financed by USAID/Dakar. Phase I of the activity (1988-1990) was codirected by Muneera Salem-Murdock, Michael Horowitz and Thayer Scudder. Phase II (1990-1992) was directed by Salem-Murdock.

organisations, the *Organisation Autonome du Delta* (OAD; replaced by the *Societé d'Aménagement et Exploitation des Terre du Delta* (SAED) in 1965) and the *Organisation Autonome de la Vallée* (OAV) were created in 1960 and 1961 respectively to take charge of irrigation development in the delta area and in the valley at large. Subsequently SAED took over the responsibility for the entire valley.

Up to the early 1970s, state-financed irrigation of the Senegal River Valley was concentrated almost exclusively in the Delta area and on large-scale schemes for the cultivation of export crops, especially sugar-cane and rice. It was an almost complete failure. Productivity per unit of land fell: SAED failed to expand irrigation in the Delta, let alone the entire valley. Plagued by very high production costs and low profits, it became clear that large-scale irrigation could not reach its objectives. With the severe Sahelian drought of the late 1960s and early 1970s, donors were prompted to include food in the repertoire of irrigated crops they were promoting and to explore the viability of village-level irrigated perimeters (PIVs). From zero in 1973, the number of PIVs on both sides of the Senegal River increased to 750 by 1985 (Boutillier and Schmitz 1987, p.534).

The genesis of OMVS and the construction of the Manantali and Diama dams

The Sahelian drought prompted the construction of village-level irrigated perimeters (PIV's), but also the creation, in 1972, of an international agency charged with overseeing the development of the Senegal River Valley. The *Organisation pour la Mise en Valeur du Fleuve Sénégal* (OMVS), with Senegal, Mali and Mauritania as founding members was created. They made a decision to construct two dams: the antisaline intrusion Diama in the lower valley near the mouth of the river and Manantali, on the Bafing tributary of the Senegal River in the southwestern region of Mali (Map 1). Completed in 1985 and 1988 respectively, the dams were constructed with the following objectives:

- to provide the generation of 800 gigawatts of electricity per annum to meet the electric power demands of urban areas and rural hinterland;
- to enable the irrigation year-round (double cropping) of 375,000 hectares of rice fields on both sides of the river (9,000 hectares in Mali, 126,000 in Mauritania and 240,000 in Senegal); and
- to give land-locked Mali an outlet to the sea by regulating river flow to permit year round navigation, from a port at Kayes in Mali, down to Saint Louis and the Atlantic Ocean.

During Phase 1 of the SRBMA activity (1990-1992), research focused on the extent to which pursuit of these objectives would have an impact on the floodplain systems downstream, and we asked 'How many years between 1904 and 1984 would a flood sufficient for the cultivation of 50,000 hectares downstream have occurred without additional release from Manantali?'[2] Analysis and modelling of historical rainfall data showed only in 19 years would a controlled release have been necessary (Hollis 1990a, 1990b; Horowitz, Salem-Murdock *et al* 1990), as explained in a report made in 1990.

Although the simulated peaks for these 19 deficit years were not high enough to assure a 50,000 cultivated hectare flood, the monthly data from the simulation shows that in many of these years the reservoir would have contained sufficient water to reach the requisite flow. In fact, analysis of the 86 megawatt simulation shows that, except for 1913, a year infamous in West African history for the severity of its drought, *for every other year from 1904 to 1977 the reservoir would have been filled to capacity before the end of October, and waters would have poured through the spillways of the dam through most of October and November*. ... In only 8 of 81 simulated years (9.9 percent), did the reservoir not reach its full capacity: 1913, 1977, 1979-1984 (Horowitz, Salem-Murdock *et al* 1990, pp.33-34; italicised in the original).

In the context of the Sahelian environment in which droughts are a recurrent event, there are bound to be years without sufficient water behind the dam to allow for both power generation and an artificial flood. In most years, however, an artificial flood would not conflict with the capacity of the dam to generate power, but would also sustain downstream ecology and biodiversity. It would support production systems, reduce food insecurity, allow the pursuit of irrigation and by increasing the number of economic opportunities in the area, might reduce rural-urban migration.

The extremely high costs of construction and maintenance work needed meant the third goal was never entertained seriously at the scale envisaged. The first two goals could be accomplished, with modest modifications, while still allowing the release of water from the Manantali reservoir to replicate the natural flood and allow the inhabitants of the region to pursue their pre-dam floodplain activities. Despite this, the OMVS decided to terminate this flood

[2] Three principal tributaries—the Bafing, the Falamé, and the Bakoy—make up the flow of the Senegal River and determine the extent of flooding in any particular year as measured at Bakel. Although the contribution of each tributary to the overall flow varies from year to year, it is generally agreed that the Bafing, the tributary upon which the Manantali dam has been erected, contributes 40 to 60 percent of total.

after a transitional period of 10 years to wean farmers from flood retreat agriculture to irrigation. The decision was based on cost-benefit analyses that overestimated losses in electricity from continuing the flood release, and underestimated the value of floodplain farming, because productivity was calculated mainly on the basis of a single crop, sorghum. The analysis ignored the floodplain's contributions to herding, reforestation, fishing and groundwater recharge (Horowitz, Salem-Murdock *et al* 1990). The returns to irrigation were calculated on the basis of double cropping, a feat that has never been realised on any meaningful scale, and on assuring 100 percent power output in every single year.

FLOODPLAIN ECOLOGY

The viability of the floodplain economy is based on diversification of income. Research on household strategies was carried out in the Middle Senegal Valley along the left bank of the Senegal River from the *département* of Matam, westward to the *département* of Podor and, from the River southward to the sandy upland areas *(jeeri)*. Climate and rainfall patterns, production activities and administrative structures of the area are shown in map form (Map 2). Each of the two *départements*, Matam and Podor, is divided into four *arrondissements* and further subdivided into twenty-two *communautés rurales*, twelve of which are in Matam and ten in Podor.

Natural resources

Four main production activities are associated with the Senegal River areas;

(i) dryland farming or *jeeri;* recession cultivation, including *falo* (along the banks of the river) and *waalo* (in the floodplain);

(ii) irrigation, including large, medium and small perimeters, and irrigated vegetable gardens;

(iii) fishing, both in the main channel and in flooded *cuvettes*; and

(iv) herding.

This paper will focus on the contributions made to household income of the first two elements.

Forest areas around villages and camp-sites are combed for firewood, gathered largely by women and children who are also in charge of domestic water supplies.

Labour migration has been an important labour strategy in the Senegal River Valley for some considerable time. Since the early 1970s, drought, declining rural incomes, smallholder debt, unfavourable terms of trade, increased need for cash (for taxes and food purchases) and the growing economic decline in the region have driven many rural households to seek income from non-agricultural activities. The absence of opportunities to generate income in the region has prompted a steady rise in seasonal and long-term labour migration, especially among young men. Our data show an absentee rate of 56 percent among males aged 15 to 45. Among females of the same age group the rate is 15 percent (Salem-Murdock and Niasse 1993). But non-farm work is not well paid and does not allow farmers to invest in labour-saving technology or hire substitute labour in seasonal peaks. Thus the labour strategy that has evolved to compensate for food shortages in the area is becoming increasingly an important contributor to the food crisis itself.

The population

The population of the Middle Senegal Valley is ethnically homogenous. Among 331 households monitored, 227 identified themselves as *Haalpulaar*, a general term that means 'speaker of *Pulaar*'. Gender and age determine access to the means of production.

Broadly, the society is divided into three social categories:

- The *Rimbe*, or Free Men, comprise five categories who have direct access to land and water: the *Fulbe*, also knows as *Peul* or *Fulani*, are semi-nomadic agropastoralists, descended from the first local rulers of the Middle Valley, known as the *Fuuta*; the *Toorobbe*, who often think of themselves and are identified by others as former or sedentarised *Fulbe*, are people of diverse origin who have dominated the religious and political life of the population and have important control over land distribution; the *Sebbe* are descendants of warriors who were used by the *Toorobbe* for defence against the *Maures* to the north, and in their fight with the *Fulbe* for political supremacy the *Fuuta* were rewarded with large tracts of land that had belonged to the *Fulbe*; the *Subalbe* are fishermen whose chief is referred to as the *Jaaltabe*, master of the water spirits; and the *Jaawambe* are courtiers who, in earlier times, served in

Fulbe and *Toorobbe* courts.

- The *Nyeenybe*, is a general term applied to a caste group that is composed of craftsmen. They occupy an inferior position to the *Rimbe* and relate to them in patron-client relationships that are passed from father to son.

- The *Maccube* who occupy the lowest level of the social hierarchy, are descended from former prisoners who often were made into slaves and treated as property.

Local economy and the organisation of production

Data was collected from the *Haalpulaar* of the Middle Valley of the Senegal River between October 1990 and December 1992. For purposes of sample selection, we divided the area into eight strata corresponding to the administrative boundaries of the eight *arrondissements* in the *départements* of Matam and Podor, reflecting the geographic, climatic, socioeconomic and demographic differences in the area.

To capture the historical linkages and exchange relationships among Middle Valley villages at varying distances from the River we selected what we called a *Production Space* (PS) to define the area in which a group of people have specific rights of cultivation, herding, and fishing. Accordingly, one PS was identified in each of seven *arrondissements*: Semme, Kanel, Ogo, Thilogne, Cascas, Gamadji and Thille Boubacar. The production system in the *arrondissement* of Salde, département of Podor, was judged too complex to be represented by one entity. Accordingly, two PSs were selected from that region, resulting in a total of nine PSs that incorporated 32 villages (Salem-Murdock and Niasse 1993; Map 3).

Resource access, resource allocation and division of labour

(i) Dryland farming

Dryland farming is carried out on the sandy soils of the upland (*jeeri*) fields and on the sandy clay soils on the elevated areas of the floodplain known as *fonde*. *Jeeri* lands are the most numerous and most readily available to all groups, irrespective of caste affiliation but because of low and variable rainfall and attacks on crops by predators, it is also the riskiest kind of all farming activities.

The high degree of risk associated with dryland farming is magnified by the high level of labour input when compared with potential crop returns. Before the advent of the first rains in June-July, the season starts with field preparation which involves land clearing, fence construction and burning to remove weeds and stubble from the preceding season; it is a time-consuming process. Planting, using a long-handled hoe, takes place directly after the first rains. Germination is accompanied by a rapid growth of weeds that continues throughout the season and requires several weedings. Thinning and transplanting usually take place along with the first weeding: young plants that have grown too close to each other are separated and replanted in holes made for seeds that did not germinate. Guarding of fields starts as soon as the young plants begin to mature and continues until harvest and threshing of fields.

Our data indicated that labour requirements habitually depend on rainfall. Of 135 households, 88 had to abandon their dryland farms due to lack of rain. It also appeared that extrafamilial labour was only required where rainfall had been good. Men were largely responsible for weeding and maintenance in the *jeeri*.

- *Jeeri* Farm Income

Table 1 shows the relationship between labour hours and farm income from *jeeri* farming, for the combined years 1991 and 1992. The second column represents the number of sample households that farmed, the third, average labour hours per household. The fourth column indicates the number of households that harvested. As harvest data were collected from the entire sample while labour data were collected from the subsample only, the number of households that harvested is larger than the number who worked on *jeeri* plots for all PSs except 2 and 4.

Comparing *jeeri* labour input to the value of the harvest demonstrates the riskiness entailed in dryland farming. An average negative income of 514 FCFA (about $2.00) for PS 5 might not seem dramatic, even in the context of the Middle Valley, but to end up $2.00 short after having expended an average of 119 labour hours (nearly 15 eight-hour days) is to suffer a substantial loss. However, dryland farming remains a very important component of the domestic economy because when the rains are good, returns can be worthwhile, as indicated in PSs 2, 6, and 7. Moreover, *jeeri* crop residues constitute an important component of animal feed.

Table 1 Net farm income per household from *Jeeri* fields compared to labour expended, by production space (PS)[3]

PS	Number of households farming on *Jeeri*	Labour hours per household	Number of households harvesting	Net income per household (FCFA)	Net income per labour hour
1	11	154	24	-1,253	-8.14
2	4	302	4	29,504	97.70
3	15	80	25	656	8.20
4	1	22	0	0	0
5	9	119	22	-514	-4.32
6	10	833	26	31,073	37.30
7	15	175	46	10,957	62.61
8	12	236	27	1,999	8.47
9	11	427	38	9,731	22.79
All	88	269	212	8,131	30.22

The risk associated with *jeeri* cultivation is even more in evidence if we regard each of the agricultural seasons (1991 and 1992) separately. Table 2 compares the number of households that engaged in *jeeri* farming in 1991 and 1992, listing the three most frequently grown crops: watermelons, rainfed sorghum and millet. The total number of households that cultivated in 1992 is always larger than in 1991. Due to poor rains, few farmers were able to cultivate in 1991. Many of those who did plant crops could not harvest them: there was virtually no successful cultivation in PSs 1, 2, and 4; and cultivation was restricted to watermelons in PSs 3 and 5. While PS 8 endured a poor season in 1991, the fact that 1992 was even worse confirms the unevenness of the distribution of rainfall even in a relatively more generous year.

[3] Only those households that participated in *jeeri* farming were counted to calculate an average. The number of households planting is sometimes larger than that harvesting, reflecting the very poor rainfall conditions in 1991-1992, when many households spent time at the beginning of the season but never harvested.

Table 2 Number of households practising *Jeeri* farming: 1991 and 1992

PS	Watermelons		Millet		Sorghum	
	1991	1992	1991	1992	1991	1992
1	0	9	0	5	0	0
2	0	0	0	0	0	4
3	7	3	0	1	0	0
4	0	0	0	0	0	0
5	2	1	0	0	0	0
6	0	0	6	8	10	22
7	0	3	0	26	1	14
8	2	0	2	0	0	0
9	0	0	11	3	15	13
All	11	16	19	43	26	53

Table 3 shows average quantities of harvest in kilogrammes for these three crops. Watermelon is a supplementary crop, grown mostly for its seeds. In 1991, watermelon was harvested in only 3 of the 9 areas; for these, the average harvest per household was 100 kg. In 1992 it was grown in 4 PSs, but the average harvest per household, 32 kg, was much smaller. Although the number of households cultivating sorghum and millet in 1992 was considerably larger than in 1991, total and average production do not always reflect this substantial increase. In PS 6, for example, the number of households cultivating millet increased from 6 to 8 and those cultivating sorghum from 10 to 22. Total production for millet in this PS, however, went down from 3,445 to 2,951 while the average dropped by almost one-third (from 574 kg to 369 kg).

Overall, millet harvested per household fell from 412 kg to 205 kg, the failure of production in PS 8 contributing a substantial share of the decline. The sorghum harvest showed marked improvement on the whole (from an average of 260 kg to 456 kg per household), but five PSs harvested no sorghum at all in 1992.

Table 3 Quantity of harvest per household by PS and produce: 1991 and 1992 (in kilogrammes)

PS	Watermelon		Millet		Sorghum	
	1991	1992	1991	1992	1991	1992
1	0	18	0	51	0	0
2	0	0	0	0	0	1,012
3	139	87	0	1	0	0
4	0	0	0	0	0	0
5	2	12	0	0	0	0
6	0	0	574	369	349	500
7	0	24	0	167	16	357
8	62	0	1,035	0	0	0
9	0	0	211	423	217	319
All	100	32	412	205	260	456

Recession farming

- *Waalo* Farming

A household's land, and *waalo* bottomland in particular, is a clear manifestation of its social status and caste affiliation (Boutillier *et al* 1962; Magistro 1994; Minvielle 1985; Salem-Murdock and Niasse 1993; Schmitz 1986). Our data show that, while ownership or direct control over the very valuable bottomland used in *waalo* cultivation tends to be vested in the *Rimbe*, mechanisms exist that allow for a more equal distribution, which include sharecropping by which one-half (*didabal*) or one-third (*tatabal*) of the harvest is paid to the owner of the land; renting for cash; and loan of the land without charge.

Table 4 shows patterns of tenure for *waalo* land by caste. More than half the sample households had no access to *waalo* land.

Table 4 Types of tenure among householders with access to *Waalo*, by caste: 1991-1992 (percent)

Caste	No. with Access	FLH	RLO	SCR	SCO
Fulbe	24	79.17	20.83	16.67	0
Toorobbe	49	81.63	24.49	12.24	2.04
Jaawambe	5	80.00	20.00	20.00	0
Sebbe	8	75.00	25.00	62.50	0
Subalbe	14	71.43	21.43	28.57	0
Nyeenybe	10	70.00	20.00	30.00	0
Maccube	44	27.27	36.37	56.82	0
Other	2	50.00	0	50.00	0
All	156	63.46	26.28	31.41	0.64

Key: FHL owner/cultivator; RLO rented out for cash or loaned free of charge; SCR rented in for a fraction of harvest; SCO rented out for a fraction of harvest

The agricultural season lasts for about five months, starting with field clearing and culminating in harvesting. Planting starts about two weeks after the retreat of water, usually with sorghum intercropped with cowpeas, in late September to early October. Because the beginning of the *waalo* season overlaps the end of *jeeri* cultivation, skilful management of time and farm resources is required. In the absence of repeated flooding, which would require reseeding, and natural disasters, such as locust or grasshopper invasions, there is little to do in the *waalo* fields until harvest time in late February other than weeding and guarding.

- *Waalo* Farm Income

Table 5 presents the relationship between labour and farm income from *waalo* cultivation. As with the *jeeri* data, harvest information was collected from the entire sample, while labour data were collected from the subsample only. In the areas where *waalo* cultivation was practised, average returns per hour of labour ranged from a low of 29 FCFA (PS 7) to a high of 344 FCFA (PS 6). At an exchange rate of 250 FCFA to the US dollar, the latter seems not a bad rate of return.

Table 5 Net farm income per household from *Waalo* fields compared to labour expended, by production space (PS)[4]

PS	Number of households farming *Waalo*	Average labour hours per household	Number of households harvesting	Net income per household (FCFA)	Net income per labour hour (FCFA)[5]
1	0	0	0	0	0
2[6]	0	0	1	61,875	n.a.
3	12	590	31	42,419	71.90
4	13	353	29	58,095	166.87
5	0	0	0	0	0
6	8	708	20	243,206	343.51
7	9	467		13,546	29.0
8	13	1,038	34	60,004	57.81
9	0	0	7	-2,889	0

- *Falo* Farming

While farming the *waalo* is the most important component of recession cultivation, horticultural gardening on the riverbanks - *falo* - is an important supplement. Access to *falo* fields tends to be limited because fields are very small and their location on riverbanks restricts their number. Naturally, the *Subalbe* fishermen, masters of the water and by extension its banks, have the best access to *falo* lands.

[4] Only those households that participated in *waalo* cultivation were counted to calculate average.

[5] Labour hours are calculated from a subsample, cost of production and value of harvest from the full sample, income per labour hour is thus approximate.

[6] Although there was no flood in PS2, a few bottomlands were submerged long enough to allow some households to attempt to cultivate. Only one household in the full sample actually harvested *waalo* fields in this PS, however. As it was not in the subsample, the number of labour hours and net income per labour hour are not available.

Table 6 Percentage of households that own, farm or rent *falo* fields, by caste: 1991-1992

Caste	Number of households	FLH	RLO	SCR	Access	No access
Fulbe	71	4.23	0	1.41	5.63	94.37
Toorobbe	106	17.92	7.55	1.89	24.53	75.47
Jaawambe	7	0	0	0	0	100.00
Sebbe	10	0	0	0	0	100.00
Subalbe	30	73.33	26.67	3.33	83.33	16.67
Nyeenybe	32	0	0	0	0	100.00
Maccube	71	1.41	11.27	2.82	14.08	85.92
Other	4	25.00	0	0	25.00	75.00

Key: FHL owner/cultivator; RLO rented out for cash or loaned free of charge; SCR rented in for a fraction of harvest; SCO rented out for a fraction of harvest

Falo farming is an important component of the production system, not only because of its proximity to the villages, which permits the active participation of women, but also because of the great variety of crops grown there: maize, aubergines, pumpkin, tomatoes, hibiscus (bissap), gourds, okra, sorghum, rice, watermelons and other local produce, which contribute nutritional variety. Crop residues, including maize stalks and bean vines, provide a valuable source of feed for sheep and goats.

Planting in *falo* fields is staggered to suit the retreat of floodwaters which leave behind useful deposits of sediment for the subsequent crop. The nature of the crop, mainly vegetables, allows for ongoing harvest while the staggering of planting dates, leads to staggered harvests and provides households with a constant supply of food throughout the season. It also complicates the process of calculating crop output. As a result, people tend to report considerably less than they actually harvest, so that our data probably underestimate output and farm income from *falo*. Women are much more involved in *falo* gardening than in *jeeri* and more active than men in this area, with a per-household average of 194 hours for men and 230 hours for women.

- *Falo* Farm Income

Despite problems of trying to estimate total harvest in *falo* gardens, yields per hectare are much higher than the other systems (*waalo, foonde* and *jeeri*) combined. Table 7 compares average hours of labour and net returns (in FCFA) for *falo* among PSs. The area PS 5 is excluded because of absence of *falo* cultivation. Columns two and three show the number of households in our subsample that participated in cultivation, and average number of labour hours per household. The next column gives the number of households in the whole sample that had *falo* harvests. As harvest data were collected from the entire sample and labour data only from the subsample, the number of households that harvested is larger (or equal, in the case of PS 6) than the number that worked on *falo* plots, except in PS 9, where we have two households labouring but only one harvesting. Our data on access to land reveal that only one of these households reported access to *falo* land. The other supplied labour for someone else's *falo* field but did not report any harvest, since they did not have specific rights to a portion of harvest.

Table 7 Net farm income per household from *Falo* fields compared to labour expended, by production space (PS)

PS	No. of households farming *falo*	Average labour hours	No. of households harvesting	Net value of harvest (FCFA)	Av net income per labour hour (FCFA)
1	7	867	9	63,783	73.57
2	8	111	14	18,842	169.75
3	2	375	6	21,145	56.39
4	13	75	20	6,216	82.88
6	4	897	4	142,779	159.17
7	6	693	13	122,238	17.66
8	3	302	7	18,083	59.88
9	2	226	1	49,616	219.54

(ii) Irrigation

Since Village Irrigated Perimeters (PIVs) and women's gardens are the most widespread forms of irrigation in the Senegal River Valley, we will restrict our current discussion to them. The arrival of PIVs in the Senegal Valley was greeted with a great deal of enthusiasm. They were welcomed not only for their anticipated important role in food production but also because they were regarded as a force for democratisation that would pave the way towards more equal access to land. As land was traditionally controlled by rural high-caste elites, some referred to PIVs as 'a small-scale social revolution' (Schmitz 1986, p. 52).

Table 8 Percentage of households that own, cultivate and rent PIV fields excluding PSs 5, 8 and 9 by caste: 1991-1992

Caste	Number of households	Percent					
		FLH	SCR	RLO	SCO	RLR	With no access
Fulbe	31	9.7	16.1	0	0	0	77.4
Toorobbe	78	48.7	7.7	9.0	0	1.3	47.4
Jaawambe	7	0	14.3	14.3	0	0	85.7
Sebbe	2	50.0	0	0	0	0	50.0
Subalbe	30	10.0	23.3	6.7	0	0	53.3
Nyeenybe	18	16.7	16.7	0	22.2	0	55.6
Maccube	43	37.2	7.0	9.3	0	0	58.1
Other	4	50.0	25.0	0	0	0	50.0
All	213	31.0	12.2	6.6	1.9	0.5	56.8

Key: FHL=owner/cultivator; SCR=rented in for a fraction of harvest; RLO=rented out for cash or loaned free of charge; SCO=rented out for a fraction of harvest; RLR=rented in for cash or free of charge

Table 8 shows the percentage of sample households that own, cultivate, or rent PIV parcels by caste, in 1991-1992. A large proportion of households of all castes - 57 percent - do not have access to PIV cultivation whether as owner, sharecropper, or renter. All caste groups show some access to PIV fields, although this varies from group to group.

Despite its high labour and capital demands and its recent emergence in the area, irrigation has become an important component of the agricultural production system in the Middle Senegal Valley. Irrigated parcels are meant to be cultivated three times a year: in the rainy season, cold off-season and the hot off-season, but the reality is otherwise. While 48 of our subsample households cultivated PIV plots in the rainy season, only 18 households cultivated in the cold off-season and 10 in the hot off-season.

Irrigated rice farming is very labour intensive, easily surpassing the labour demands of *jeeri* farming and *walo* recession cultivation. Yet the net returns per unit of labour are low, ranging from -5.97 FCFA for PS 1 to +150 for PS 4 (Table 9).

A season starts with the preparation of fields and nurseries in mid-to-late June. This involves repairing canals, fencing nurseries and preparing beds for planting. Nursery beds are seeded in mid-to-late July, and the first hoeing takes place in August. Young plants are transplanted in August, and the fields are irrigated and fertilised. Irrigation starts soon after planting, first in the nurseries, later in the fields and continues throughout the season. Weeding starts late in August and continues through November. Guarding begins as soon as the young plants start to mature and continues throughout the season. If all operations are more-or-less on time, harvesting, threshing and transportation of the harvest are usually complete by mid-to-late December.

Table 9 Net farm income per household from PIV fields compared to labour expended, by production space

PS	No. of households farming PIVs	Average labour hours	No. of households harvesting	Net value of harvest (FCFA)	Av net income per labour hour (FCFA)
1	8	189	7	-1,128	-5.97
2	3	670	11	70,311	104.94
3	11	581	19	6,054	10.42
4	12	586	26	87,902	150.00
5	0	0	3	-37,350	--
6	6	2,549	7	49,670	19.49
7	14	621	24	19,817	31.91
8	0	0	0	0	0
9	1	125	0	0	0

Floodplain production and diversification

Productivity of land, labour and capital

Tables 10 and 11 compare average yield per hour of labour, average yield per hectare, average expenditure per hectare and average labour hours per hectare for large-scale perimeters (GPI), middle-scale perimeters (CIN), private irrigated perimeters (PIP), village irrigated perimeters (PIV) and irrigated vegetable gardens (MJF); *waalo* (WLO); *falo* (FLO); *jeeri* (JRI); and *foonde* (FND). Table 10 includes a total of 405 parcels: all parcels for which we had parcel size and labour information, including those reporting no harvest. Table 11 excludes parcels that did not report any harvest, leaving a balance of 274 parcels.

Table 10 Land, labour and capital productivity: 1991-1992 (405 parcels)*

Agricultural system	Average yield per hour (FCFA)	Average yield per Ha (FCFA)	Average expenditure per Ha (FCFA)	Average hours of labour per Ha
Irrigation: Mid-Scale Perimeters (CIN)	252	385,436	80,336	1,531
Falo (FLO)	160	220,939	4,512	1,381
Foonde (FND)	24	13,207	1,410	557
Irrigation: Large-Scale Perimeters (GPI)	275	209,508	52,630	761
Jeeri (JRI)	27	5,562	869	209
Irrigated Vegetable Gardens (MJF)	17	27,358	17,656	1,589
Irrigation: Private Irrigated Perimeters (PIP)	5	13,644	37,520	2,849
Irrigation: Village Irrigated Perimeters (PIV)	135	196,581	35,040	1,454
Waalo (WLO)	140	37,772	1,836	271

* All parcels with information on land size and labour, including those with zero harvest

The differences between Table 10, which summarises data on all parcels, including those that reported zero harvest and Table 11, which excludes those that reported zero harvest, are revealing, especially with respect to *jeeri* cultivation. First, among the 405 parcels cultivated by the subsample from which we gathered extensive farm labour data, one-third (131 of the 405) yielded no harvest - a clear example of the risks associated with agriculture, especially dryland farming. Excluding parcels that reported no harvest (Table

11) there are increases in average yields (per hour and per hectare) in all systems. For some systems, yields per hour of labour rise sharply: in irrigated vegetable gardens, by 200 percent; in *jeeri*, by 111 percent; and in *foonde*, by 42 percent (Table 12). We note similar but not parallel types of changes in average yields estimated in FCFA per hectare. For example, while yield per hour of labour in irrigated vegetable gardens is up 200 percent when parcels with no harvests are excluded, per-hectare yield increases by only 14 percent. On *jeeri* parcels, the percent increase measuring the ratio of yield per hectare omitting zero-harvest plots, to yield per hectare including them, is 309 percent.

Table 11 Land, labour and capital productivity: 1991-1992 (274 parcels)*

Agricultural system	Average yield per hour (FCFA)	Average yield per Ha (FCFA)	Average expenditure per Ha (FCFA)	Average hours of labour per Ha
Irrigation: Mid-Scale Perimeters (CIN)	280	447,239	86,384	1,598
Falo (FLO)	181	260,444	4,765	1,439
Foonde (FND)	34	19,903	1,747	581
Irrigation: Large-Scale Perimeters (GPI)	297	212,707	53,434	717
Jeeri (JRI)	57	22,773	961	396
Irrigated Vegetable Gardens (MJF)	51	31,267	18,671	611
Irrigation: Private Irrigated Perimeters (PIP)	5	13,644	37,520	2,849
Irrigation: Village Irrigated Perimeters (PIV)	165	251,981	38,461	1,523
Waalo (WLO)	177	45,455	1,644	257

* All parcels with information on land-size and labour, excluding those with zero harvest

Average expenditure per hectare and average labour per hectare generally show little change when zero-harvest parcels are omitted (Table 12). The decrease in average expenditure per hectare for *waalo* and in labour per hectare for large irrigated perimeters, irrigated vegetable gardens and *waalo*, result from two factors: a decrease in inputs when people realise there will be no harvest and, the likelihood that some of the parcels excluded because of zero harvest had inputs at the beginning of the season that were higher than inputs for some of the successful parcels. The decreases are quite small, however, except for the total labour hours per hectare in irrigated vegetable gardens. The only substantial higher value is for labour per hectare for *jeeri* cultivation, and the largest increase in expenditure per hectare when zero-harvest plots are excluded is for *foonde*.

Since the potential for zero harvest in all agricultural systems in the Middle Valley is a fact of life, it is more revealling to use the data of Table 10 (which includes parcels that reported zero harvest) in our calculation of productivity by units of labour, land and capital. Because of the different values of various crops, we converted the physical weights (in kilogrammes) into monetary values, using average prices received by farmers or average market prices for a given season.

In terms of yields per labour hour in FCFA (Table 10), the larger irrigated parcels, whether large-scale irrigated perimeters (GPI) or middle-scale perimeters (CIN), appear the most rewarding. This is predominantly a function of the much heavier use of machinery in irrigated agriculture, especially in large-scale, middle-scale, private, and village irrigated perimeters, a variable that was not included when we calculated labour. This resulted in over-valuing the labour hour of a man on a tractor, given its heavy cost. In an attempt to resolve this problem, we started by calculating the number of animal and machine hours recorded on the various parcels, as presented in Tables 13 and 14.

Table 12 Percentage changes in key variables when parcels with zero harvest are excluded

Agricultural system	Average yield per hour (FCFA)	Av yield per Ha (FCFA)	Average expenditure per Ha (FCFA)	Average hours of labour per Ha
Irrigation: Mid-Scale Perimeters (CIN)	11	16	8	4
Falo (FLO)	13	18	6	4
Foonde (FND)	42	51	24	4
Irrigation: Large-Scale Perimeters (GPI)	8	2	2	-6
Jeeri (JRI)	111	309	11	89
Irrigated Vegetable Gardens (MJF)	200	14	6	-62
Irrigation: Private Irrigated Perimeters (PIP)	0	0	0	0
Irrigation: Village Irrigated Perimeters (PIV)	22	28	10	5
Waalo (WLO)	26	20	-10	-7

Table 13 Number of animal hours by type and agricultural system: 1991-1992

Agricultural system	Donkey	Horse	Plough	Animal-drawn cart
Falo (FLO)	41	0	0	38
Foonde (FND)	0	0	0	16
Jeeri (JRI)	0	266	543	124
Village Irrigated Perimeter (PIV)	40	8	0	21
Waalo (WLO)	14	22	27	102

Table 13 reveals the widespread use of animals for ploughing and transport of harvests. Examining the use of machinery (Table 14), we notice that only two types of parcels, private irrigated perimeters and village perimeters, reported employing heavy machinery (namely harvester/threshers and tractors) with PIPs reporting 18 hours of harvester/thresher use and PIVs reporting 21 hours of tractor use.

Table 14 Number of machine hours by agricultural system: 1991-1992

Agricultural System	Harvester/Thresher	Tractor
Private Irrigated Perimeter (PIP)	18	0
Village Irrigated Perimeter (PIV)	0	21

As we knew that both tractors and harvester/threshers are used in at least two other types of irrigated parcels, large-scale (GPI) and medium-scale (CIN) perimeters, we looked at production charges to discover the amounts of money that farmers reported spending (Table 15).[7] For hiring tractors, farmers spent

[7] Farm labour and cost data were collected in the fields, cost data on a monthly basis, and labour data every two weeks. Many of the heavier agricultural operations, such as ploughing and harvesting on Government-operated irrigated schemes, be they large-, medium-, or village-level, are coordinated and operated by the Government or a designated agency. Fees for such services are recorded as part of the credit that each farmer/parcel owes and are charged against harvest, if there is any, at the end of the season. Accordingly, farmers (and therefore research assistants) often do not know what these charges are until some time after the season is over and gains and losses are calculated.

FCFA 107,400 on large-scale perimeters (9 instances of use), 105,000 on private perimeters (3 instances of use), 86,000 on middle-scale perimeters (18 instances of use) and 78,000 on village-irrigated perimeters (14 instances of use). Average cost per use varied widely among systems, from the high reported for the three private irrigated perimeter instances to the considerably lower costs per use of the mid-scale and village perimeters.

Table 15 Tractor use by agricultural system, number of uses reported and cost: 1991-1992

Agricultural system	Number of uses reported	Total cost (FCFA)	Cost per use (FCFA)
Large-Scale Perimeters (GPI)	9	107,400	11,933
Mid-Scale Perimeters (CIN)	18	86,000	4,778
Private Irrigated Perimeters (PIP)	3	105,000	35,000
Village Irrigated Perimeters (PIV)	14	78,000	5,571
All	44	376,400	8,555

Leaving aside the complications of returns to labour because of mechanisation in the irrigated systems for the moment, yield per labour hour among the unirrigated systems shows *falo* and *waalo* farming to be the most rewarding, with per-hour yields of 160 FCFA and 140 FCFA respectively (Table 10). The generally low labour returns are a result of the disastrous agricultural year, with out of 405 parcels cultivated, 131 or 32 percent reporting no harvest. Those most affected by natural conditions, in terms of labour returns, were those who irrigated vegetable gardens and *jeeri* farms (Table 12).

In yield per hectare, *falo* exceeds *waalo* by almost sixfold, 220,939 FCFA as opposed to 37,772 FCFA (Table 10). Village irrigated perimeters, at 196,581 FCFA, are closer to *falo* than to *waalo* in per-hectare yield. As expected, on irrigated parcels that rely on heavy machinery, whether large- or middle-scale, yield per hectare is quite high: 385,436 FCFA on middle-scale perimeters and 209,508 FCFA on large perimeters, though *falo* returns per hectare in our sample exceeded those of the large-scale perimeters (Table 10).

Largely because of the use of heavy machinery, fuel, insecticides and herbicides, the [illegible] of production per unit of irrigated land, for middle-scale perimeters (80,330 FCFA), large-scale perimeters (52,630 FCFA), private irrigated perimeters (37,520 FCFA) and village irrigated perimeters (35,040 FCFA) are high (see Table 10). Cost of production for *falo* cultivation, 4,512 FCFA, exceeds those of *waalo* (1,836 FCFA), *foonde* (1,410 FCFA) and *jeeri* (869 FCFA). Compared to the cost of production on irrigated gardens (17,656 FCFA per hectare), however, *falo* production costs seem quite modest.

Despite the use of heavy machinery, which increases the value of labour as we have seen above, larger-scale irrigated farming is still very demanding of labour. Private perimeters reported 2,849 labour hours per hectare, middle-scale perimeters 1,531 hours, village irrigated perimeters 1,454 and large-scale perimeters 761 (Table 10). As we mentioned earlier, *falo* gardening is very labour intensive (1,381 hours), justified by higher returns, especially in terms of units of land and labour. While *falo* gardening demands an average of 173 days per hectare, a little less than what is required on PIVs (182 person/days), *waalo* farming, among the least demanding of the systems, requires 34 person days.

Flood plain cultivation and diversification: necessary choices for survival
The data presented here demonstrate the inability of each component alone to guarantee household survival and the need to exploit each and every element at the household's disposal. It also makes clear that floodplain production is superior to other forms of farming since it assures higher returns to the scarcer factors of production, labour and capital. The significance of the floodplain is magnified even more when its importance for fishing, livestock grazing and forest regeneration is added to its cultivation value.

To maintain a minimum level of food security, households in the Middle River Valley of Senegal learn very quickly not only the value but also the absolute necessity of diversifying sources of food and revenues. This results in a widespread and adaptive production system that can easily incorporate other income-generating opportunities. It also explains both the eagerness of farmers to experiment with other forms of production such as irrigation and their great resistance to replacing floodplain production, with irrigated farming. Farmers understand something that many developers seem slow to comprehend: to abandon flood-related activities will not only deprive them and their families of income opportunities that are tied uniquely with the annual flooding of the Senegal River, it will make it virtually impossible to survive.

Excessive control of the water supply to the Middle Valley Basin of Senegal could, therefore, disrupt the natural rhythms and processes on which its inhabitants depend. To concentrate resources on dam-based irrigated farming too heavily will expose local populations to much higher risks to their incomes and crops, by narrowing the economic opportunities to which they have access.

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