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AGRICULTURAL DEVELOPMENT AND NUTRITION AMONG RURAL POPULATIONS: A CASE STUDY OF THE MIDDLE VALLEY IN SENEGAL

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Food production in Sahelian countries is very dependent on erratic rainfall. To eliminate this climatic risk, modern irrigated agriculture was introduced and spread into the Senegal Valley in the course of the last thirty years. In such a context of changes in farming systems and food consumption patterns, a nutritional and dietary study was conducted three different times at six month intervals among 37 families of a village community which farmed a recently established irrigated area. Women played an important part in agricultural tasks. Average food consumption met the recommended intake for energy but deficiencies persist for certain nutrients. The prevalence of malnutrition was high, with 16% stunting and 13% wasting among children between the ages of 0 and 10 years; a third of the older children and 20% of the adults presented an emaciated appearance. Rice production has increased food security but, in comparison with the situation in the valley 35 years ago, nutritional gains were slight and there were no differences in the malnutrition rate of preschool children from that observed nine years earlier in a non-irrigated neighboring area. The findings suggest increase in food production following introduction of irrigation without improvement of hygienic conditions is not sufficient to ameliorate the nutritional status of the community. Consequences of added work load in habitual physical activity need to be considered, particularly when, as is the case here, food production is in part the result of efforts of women.

KEY WORDS: Food consumption, malnutrition, nutritional status, physical activity, irrigated agriculture, Senegal, Sahel, women's roles

INTRODUCTION

Increasing agricultural production is a critical objective for Sahelian countries experiencing accelerated demographic growth rates, in which agriculture is confronted with extremely difficult climatic conditions. The Senegal River Valley, however, holds great potential for irrigation. The flood waters of the Senegal River annually inundate a vast alluvial plain downstream from Bakel, of which between 100,000 and 150,000 hectares can be cultivated after the flood waters have receded (Figure 1). In reality, the flooded surface area is subject to extreme variations, from 180,000 hectares during a good year such as 1950 to less than 10,000 hectares during a drought year as was the case in 1972 (Ba and Crousse, 1985). As a response to these conditions, an effort was made to control water by building irrigation structures, with the coming on stream in 1989 of two large dams: an antisalinization dam in the Diama delta and a reservoir at Manantali

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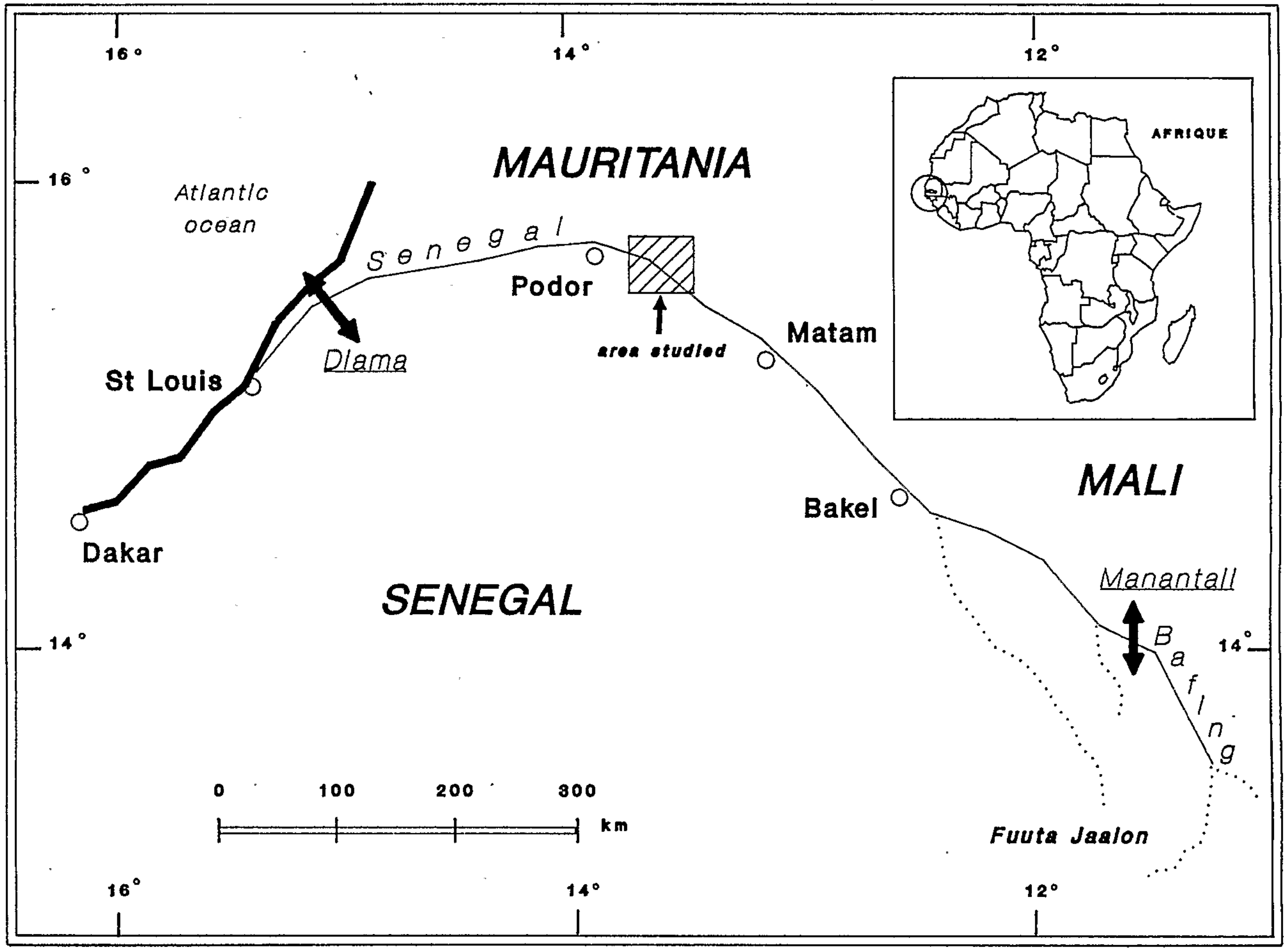

FIGURE 1 Map of the Senegal River Valley.

on the Bafing tributary of the Senegal River in Mali. The aim of the dams is to ensure complete control of water supply for agriculture and human requirements. However all the necessary irrigation structures are far from finished and as a consequence it was decided to maintain artificial flooding during a transitional period (10 to 20 years or perhaps more). This will allow the running of traditional flood recession agriculture. It is possible now to regulate a constant flow and level of water. This is done by periodic water releasing from the upstream dam of Manantali. The decision to release the water is taken by a committee integrating technical experts and political representatives of the three member countries integrating the OMVS (Organisation de Mise en Valeur du Sénégal), Mauritanie, Mali and Sénégal. The volume to be released is determined by examining technical data and requirements for human services. The committee tries to release water sparingly because the reservoir of Manantali has not been filled until now. Reverse outflow of water to sea could occur by opening the antisalt dam of Diama in order to level the peak of the flood which occurs generally in mid-September (B. Ouattara, personal communication). The goal is to irrigate 250,000 hectares in the valley (Flavigny and Cousin, 1982; Afrique-Agriculture, 1990). Most of the irrigated area is allocated to rice production; a small part is targeted for vegetable production. Consequently, three different agricultural systems now coexist: a traditional rain-related cultivation, a traditional flood recession agriculture by artificial flooding, and cultivation by completely controlled flooding.

These irrigation dams and related structures lead to decrease in the importance of the traditional subsistence systems, based on the successive and complementary activities of fishing, livestock production and agriculture, that will gradually be replaced by a rice-based monoculture. Substantial changes in food consumption patterns and nutritional status of affected populations are anticipated. An examination of these consequences is provoking increased interest on the part of development agencies (Pinstrup-Andersen, 1984).

The present study was conducted in the Middle Valley of Senegal from February 1990 through July 1991. Its goal is to describe the current food consumption patterns and nutritional status of a population recently benefiting from a modern irrigated agricultural system and to compare the findings with the previously existing situation in order to better understand the effects of the subsequent changes from a nutritional standpoint. Because the study was conducted at the time of the outset of a rice-production project, it can be considered a reference point for future monitoring.

STUDY CONTEXT

Traditional and Modern Irrigation in the Senegal River Valley

Subsistence activities in the Middle Valley are regulated by floodwaters and rains, which in combination permit the cultivation of sorghum (*Sorghum spp.*) and cowpeas (*Vigna unguiculata*) in the dry season in alluvial basins after the waters have receded, as well as fast-maturing varieties of rainfed millet (*Pennisetum nigritarum*) in those areas which remain unflooded. Figure 2 diagrams successive agricultural activities during an annual cycle. There are three main seasons: the cold dry season from November through February allowing fishing in the ponds and flooded recession agriculture in the bottoms of the valley, or *Waalo*; the hot dry season from March to June allowing gardening on the banks of the river, or

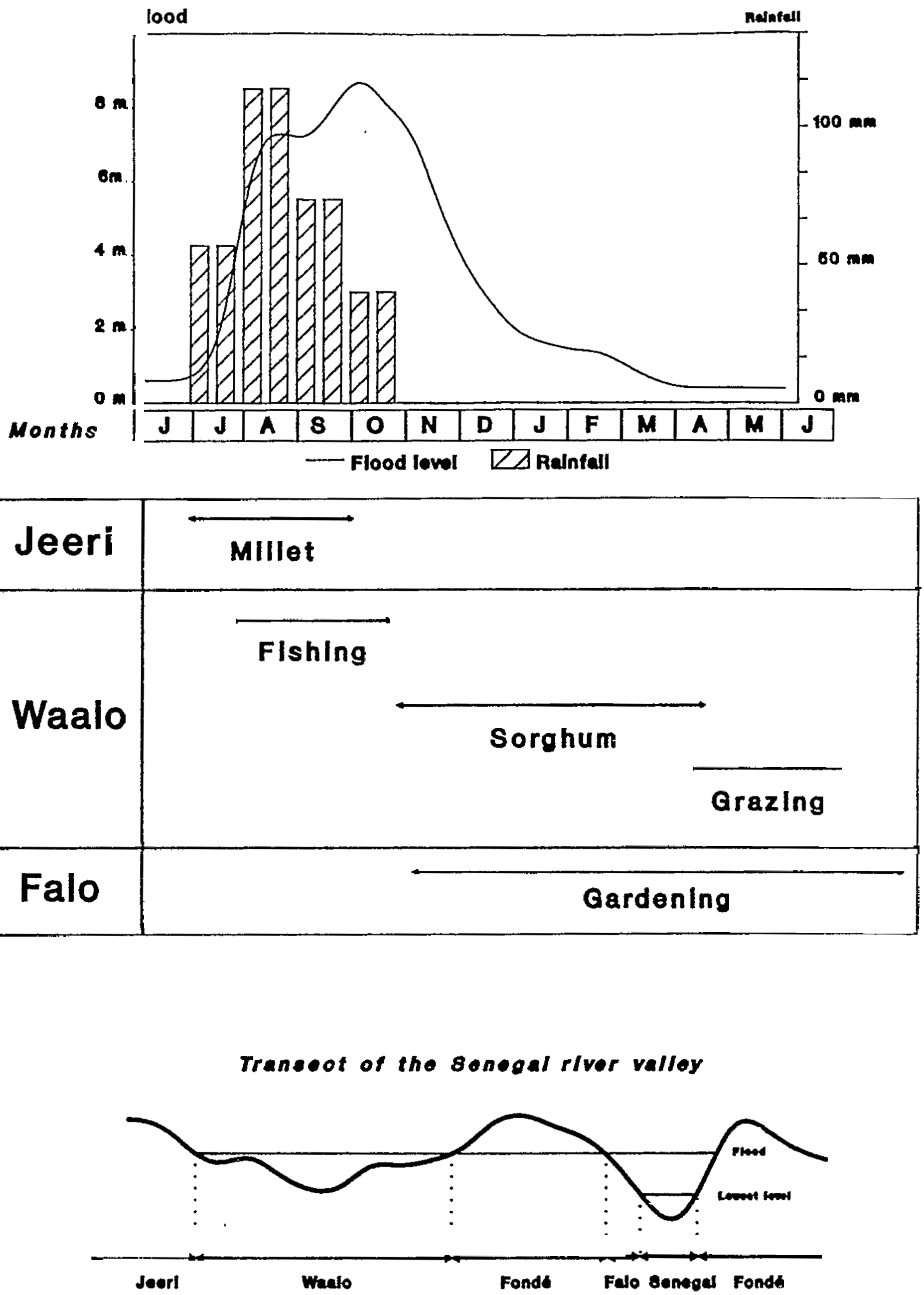

FIGURE 2 Land use according to rainfalls and flood level in the Senegal River Valley. (*jeeri*: land outside the flooded area; *waalo*: flooded area; *falo*: bank of the river).

Falo; and, finally, the rainy season from July to October which permits millet cultivation on the lands outside the flooded area, or *Jeeri*. The rainy season is also the preferred period for irrigated agriculture because of reduced water requirements. Use of different ecosystems in the valley is regulated by precise rules which are strictly followed and constitute a unique feature of the Haalpulaar society. The Haalpulaaren comprise two distinct ethnic groups: the Fulani who are pastoralists and still practise a seasonal nomadism on a small scale (Benefice, Chevassus-Agnès and Barral, 1984), and the Tokolors who are sedentary agriculturalists and fishers. These two groups share the same language. The total Haalpulaar population in the Senegal valley is estimated at 470,000 inhabitants (370,000 in the two districts of Podor and Matam constituting the Middle valley). The organization of production activities is accompanied by a network of symbiotic relationships, permitting each group to procure by barter the products which they are lacking (Schmitz, 1986). The weak point of this system is the low yields which are, on average, 450 kg of cereal/ha for flood recession agriculture (Boutillier *et al.*, 1962) and the great variability of cultivated area due to dependence on the capricious rains and floods.

Modern irrigation seeks to control plain submersion by the construction of dikes and by watershed management on plots called "irrigated perimeters." The type of scheme now becoming prevalent is the "medium perimeter" in which the construction of dikes and submersion techniques are sophisticated but the surface areas remain modest, permitting some degree of villager control. The financial break-evenpoint of these perimeters would be reached with a production of 6 to 7 tons of paddy/ha (Afrique-Agriculture, 1990). In the newly built irrigated perimeters the villagers contribute to the payment of fuel for pumping, of fertilizers and seeds. Maintenance of dikes and pumps, commercialization and processing of the harvest are the responsibility of the "Société d'Aménagement et d'Exploitation des Terres du Delta et de la vallée du fleuve Sénégal et de la Falémé" (SAED). A part of the paddy harvested is kept by the villagers for their personal consumption.

Migration and Labour Organization

Emigration is an old phenomenon in the valley but has increased considerably over the last decades. As it is young, able-bodied men who emigrate, it is estimated that this reduces the work force by 45% to 65%. (Minvielle, 1985). Ivory Coast and Gabon in Africa and France in Europe are the main destinations of emigrants. Emigration was the only possible response to very strong demographic pressure and to the lack of improvement in agricultural techniques and yields (the population has nearly doubled since the 1960s). Normally, in Haalpuular culture, agricultural labor is strenuous men's work and women participate only to help with sowing and harvesting. However, emigration of males, on the one hand, and the introduction of irrigated crops on the other, have favored a new division of labor: women have become responsible for cereal production and men for securing monetary revenues (Diemer and Van der Laan, 1987).

Dietary Practices

The villagers customarily eat three meals a day, often reduced to two at the end of the dry season. The traditional staple is a steamed sorghum semolina (couscous) served with milk, cowpeas, fish and various sauces. At present, rice increasingly replaces sorghum and the mid-day meal is generally a plate of rice with sea fish (*Sardinella spp.*), vegetables (tomato, cabbage, pumpkin) and sweet potato. Meat consumption is scarce except during the religious feast days, marriage or baptism. Foods are consumed around communal dishes, the men and older boys eat together apart from the women and children.

METHODS

Study Conditions

The site was selected to permit study of a recently improved perimeter, typical of those planned for the zone. The perimeter which was studied is farmed by members of three villages and two hamlets in the district of Dodel, located in the Department of Podor. The initial flooding took place in July of 1989. The surface area is 582 irrigated hectares, devoted essentially to rice production. A part is set aside for dry season (March to June) vegetable production (tomatoes and onions); these products are produced for sale but distribution problems result in a portion being consumed on farms. Practice of flood recession agriculture has been reduced, as most of the land is now utilized by the irrigated area. The villagers did not practice rainfed agriculture, due to insufficient rains, in 1990 (142.8 mm) and 1991 (97 mm).

Sample Frame

An exhaustive census of the perimeter's members was conducted in 1989. The total population is 4,434 divided into 397 family groups or *foyré* (Handschumacher, 1989). The foyré is the extended family unit which can comprise one to several households. Of the 282 foyrés in the three principal villages, 110 were randomly selected. All of the members who were present in February and April of 1990 (1,105 persons) were examined in a clinical and anthropometric survey (Simondon and Bénéfice, 1990). Among these 110 foyrés, 37 (comprising 573 individuals of whom 315 were children and 258 were adults) were chosen to participate in a nutritional survey. These persons were recruited on a voluntary basis by selecting medium-sized families (8 to 20 persons) which also had a large number of young children. These families were visited three times at six-month intervals (July 1990: outset of rainy season, January 1991: cold dry season, June 1991: end of the hot dry season), dates chosen because they correspond to the "abundance period" in January during or immediately after the harvest in the perimeter, to a relative food shortage at the end of the dry season to the beginning of rainy season. All of the families were seen at each visit except for two families which had separated into several groups and one which joined the neighbor's group with whom it shared meals.

Field Work Methodology

Our study comprised three types of surveys: a nutritional study of family members; a family food consumption survey; a study of adult physical activity.

Health and nutritional status. All family members underwent a clinical examination and were examined for anthropometric measurements in January and June of 1991 by the authors; data used for July 1990 were those obtained in April 1990

(Simondon and Bénéfice, 1990). Weight (W) was measured using a baby scale for unclothed children younger than 2 years of age (precise to 20 g). Older subjects were lightly clothed and wore no jewelry or other adornment. Weight was measured with a Tefal® electronic scale, precise to 200 g. Height (H) was measured using a measuring board on subjects younger than 2 years; older subjects were measured in an upright position using a Harpenden® anthropometer. The W and H measurements permitted calculation of nutritional indices, based on a comparison with the NCHS (National Center for Health Statistics) child population, used as a reference point, as recommended by the WHO (1983). The threshold for malnutrition was chosen as two standard deviations from the NCHS reference.

For older children and adults, body mass index ($BMI = W/H^2$) was chosen as a nutritional index. For adolescents, the thresholds for emaciation and overweight were fixed at 14.5 kg/m^2 and 17.5 kg/m^2 respectively; for adults the values were 18.5 kg/m^2 and 25 kg/m^2. The values correspond to about the fifth and fiftieth percentiles of scores registered by the Americans of African origin sample population of the NCHS survey for the 10–12 and 30–40 age groups (Cronk and Roche, 1982).

Food consumption. Family food consumption was studied by measuring weight of the dishes prepared. Six specially trained investigators lived for five consecutive days with a family and recorded food products which were used in meal preparation, their origin (produced in traditional fields, produced in the irrigated perimeter, bought, bartered, originating from food aid) and how they were prepared. The food was weighed to an accuracy of 5 g before preparation and after cooking, as were the leftovers at the end of the meal. The presence of all people at each meal was recorded. The activities of family members older than 14 years were recorded in order to permit an evaluation of energy requirements (see below). Surveys were done during normal days: periods of religious feasts or ceremonies were avoided. The habitual recommended length for a food consumption survey is 7 days (Ferro-Luzzi, 1982); but because there were no significant variations between households in the nature of food consumed for a given season and because the day-to-day consumption patterns within households were quite monotonous, the length of the survey was reduced to 5 days. The main factors of variation were due to food availability that is linked to the yield harvested and cash incomes. To take into account this effect, we chose to repeat the observations in the same families.

Dietary analysis was done using a computer program specially developed for this type of household survey (Chevassus-Agnès and Ndiaye, 1981). The program uses a categorized list of foodstuffs for Senegal containing 360 different entries. This table was developed by compiling the food composition tables of the Organisme de Recherche sur l'Alimentation et la Nutrition Africaine (ORANA) (Toury *et al.*, 1967), FAO food composition tables for Africa (1968) and Asia (1972) completed by measurements of certain food products such as millet (Favier, 1977) and fishes (Dupin and Wane, 1963; Savina, 1965). The recommended intakes to meet protein and caloric requirements were calculated according to recommendations of the FAO/WHO/UNU committee (FAO/WHO/UNU, 1985). Expenditure of energy is expressed in multiples of basal metabolic rate. In the case of children, the values chosen were those proposed by the committee (FAO/WHO/UNU, 1985; p. 109); for the adults, the activities were classified according to 17 different types (see below). The basal metabolic rate was calculated using equations proposed by the FAO/WHO/UNU committee. The suggested intakes to meet vitamin and nutrient requirements were calculated as per recommendations of several joint FAO/WHO committees (FAO/WHO, 1962; 1967; 1970), taking into account clarifications made by the last committee to consider some of these nutrients (FAO/WHO, 1989). The total family recommended intakes were compared to the observed intake to obtain a per capita percentage of coverage:

$$\text{Coverage (\%)} = (\text{intake observed/WHO-FAO requirement}) \times 100.$$

Physical activity. In July 1990 physical activity of subjects over 14 years was recorded and characterized (agricultural, artisanal, domestic tasks, social activities, rest) using a simplified questionnaire technique. In January 1991, corresponding to rice harvesting and threshing activities, and June 1991, preparations for the rice campaign, this information was obtained by direct observation of one active man and one active woman in each family. The six food investigators were trained to note the principal activity of the subjects each 15 minutes during 12 hours of a day. When the subjects were far from the house or in the fields, the investigators used a questionnaire. This timed monitoring was done during each of the five-day stints. The same persons were observed in January and June 1991. Statistical analysis did not show any significant difference in the rating of the collectors. In a certain number of cases there were no able-bodied men in the families because of work-related migrations; these were replaced by the woman responsible for the man's functions. This explains both the preponderance of women in the sample and the greater age of men (47 years for the men versus 31 years for the women, $p < 0.001$), as it is the young men who migrate outside the country.

Eighteen different types of activities, corresponding to increasing levels of effort were identified. The values for expended energy were borrowed from studies conducted in tropical countries (Bleiberg *et al.*, 1980; Brun, Bleiberg and Goihman, 1981; Torun, McGuire and Mendoza, 1982) and summarized in Table I. For the night-time period, expenditure was fixed at one multiple of the basal metabolic

TABLE I
Energetic cost of activities ($Cal.min^{-1}$) according to published values[a]

Moderate housework	*Farming*
—washing, dressing (3.3[b]; 3.4[c])	—planting, harvesting, thinning out (3.6[b], 3.8[c])
—care for children, cooking meals (3.0[b])	—sowing (3.9[b]; 3.9[c])
—washing clothes, cleaning (3.6[b])	—hoeing (4.3[b]; 5.1[c])
—stirring sorghum porridge (3.7[b])	—breeding sheep (2.8[c])
Heavy housework	—carrying load (3.4[b])
—pounding (4.5[b])	—cutting wood (4.6[c])
—fetching water (4.1[b])	*Handicraft*
—gathering wood (3.4[b])	—wood, jewel handicraft (2.0[c])
Walking (3.0[b]; 3.6[c])	*Social activities* (2.8[d])
Sitting (1.3[b]; 1.38[c])	
Lying (1.2[b]; 1.39[c])	

[a]Bleiberg *et al.* (1981); Brun, Bleiberg and Goihman (1981); Torun, McGuire and Mendoza (1982).
[b]women.
[c]Men.
[d]Both.

rate (MET) during eight hours and at 1.2 METs for four hours. To conduct the adult energy evaluation, food intakes were recalculated individually by a weighed distribution of the total intakes recorded at the family level by sex and age, postulating that each person ate a quantity proportional to his needs.

Statistical analysis. Statistical analysis was conducted using the Biomedical Computer Package-BMDP (Dixon *et al.*, 1985). For the comparisons, nonparametric, Chi-square and Kruskal-Wallis tests were used when a normal distribution could not be assumed (Schwartz, 1977).

RESULTS

The Current Status of Nutrition and Food Consumption

Nutritional status of the community. Approximately 1% of the village children between the ages of 0 and 5 years presented clinical signs of severe marasmus such as wasting in muscle and subcutaneous fat mass. There were no signs of oedema. However, using anthropometric criteria, the prevalence rate of malnutrition was higher. No variation in the prevalence of malnutrition was observed from one visit to another, thus values recorded during visits in January and June of 1991 were combined. Table II summarizes the data for children less than 10 years old. The over-all prevalences of stunting (16.9%, confidence interval of 95% CI = 12.5 to 19.7) and wasting (13.3%; CI = 9.7 to 6.4) are high. There is a significant increase in prevalence as a function of age.

According to the selected thresholds, the number of emaciated older children represents one third of the sample, with no difference in the distribution between sexes. Among men, the prevalence of emaciation decreases significantly with age; this trend exists among women, without, however, attaining a statistically significant level (Table III).

Food consumption of families. One hundred thirty six food items were found. The most frequently eaten foods were millet, sorghum, rice, sweet potatoes,

TABLE II
Prevalence of malnutrition as measured by W/age, H/age and W/H indices of 0–120-month-old children in the Senegal River Valley

Age group (months)	No.	Stunting (HAZ <-2)[a]	Wasting (WHZ <-2)[b]	Underweight (WAZ <-2)[c]
			%	
0–12	55	3.6	1.8	9.1
12.1–60	177	12.4	13.0	29.4
60.1–120	166	24.7	17.5	30.7
All	398	16.3	13.3	27.1
Chi² (df = 2)		16.9 $p < 0.00$	8.8 $p < 0.01$	10.6 $p < 0.00$

[a]HAZ = H/age Z-score.
[b]WHZ = W-for-H Z/score.
[c]WAZ = W/age Z-score.

TABLE III
Prevalence of malnutrition according to Body Mass Index (BMI, kg/m²) in children over 10 years and adults in the Senegal River Valley

Children (10.1–16 years)			
BMI	Boys (n = 76)	Girls (n = 100)	All (n = 176)
		%	
<14.5	34.2	31.0	32.4
14.5–18	57.9	57.0	57.4
>18	7.9	12.0	10.2
Total	100.0	100.0	100.0
Chi² = 0.8, df = 2, p = 0.65.			
Men			
	<40 years (n = 116)	>40 years (n = 88)	All (n = 204)
		%	
<18.5	23.3	6.8	16.2
18.5–25	74.1	70.5	72.5
>25	2.6	22.7	11.3
Total	100.0	100.0	100.0
Chi² = 26.4, df = 2, p < 0.00			
Women			
	<40 years (n = 225)	>40 years (n = 97)	All (n = 322)
		%	
<18.5	20.0	17.5	19.3
18.5–25	70.2	63.9	68.3
>25	9.8	18.6	12.4
Total	100.0	100.0	100.0

Chi² = 4.8, df = 2, p = 0.09.

cowpeas, pumpkins, onions, pimento, tomatoes, peanut oil, fish, sugar and cow milk (powder).

Table IV summarizes the contribution of the major food groups to nutritional intake. One notes that cereals provide 60.7% of the calories and 49.6% of the proteins. The contribution of fats to energy intake is low (15.9%) compared with other surveys done in Senegal: 20% in rural areas and 30 to 35% in urban areas (Chevassus-Agnès and Ndiaye, 1981). Foodstuffs consumed in small quantities such as tubers, fruits and vegetables play an important role in intake of calcium, iron, vitamin A and vitamin C. The same is true with fish for protein and riboflavin intakes and milk for riboflavin and calcium. There are variations in the nature and origin of the foodstuffs depending on the survey period. It is thus logical that the rice produced in the perimeter contributes the most to caloric intake in January during the harvest when it constitutes 48% of the total energy intake, but the villagers must purchase 50% of their energy requirements in January and 61% in June. Flood recession agriculture only made a significant contribution to the food supply during the first survey (Figure 3).

TABLE IV
Relative % per capita contribution of food groups to energy and nutrient intakes in the Senegal River Valley
(n = 106 households; 5586 daily allowances)

Nutrient	Food										
	Cereals	Roots	Legumes	Fruits and vegetables	Oil	Sugar	Meat	Fish	Dairy products	Other	Total (%)
				% contribution							
Energy	60.7	1.6	4.2	1.8	15.9	6.9	1.0	4.2	2.7	1.0	100
Protein	49.6	0.8	7.2	3.6	—	—	2.9	28.9	5.7	1.3	100
Fat	23.6	0.4	21.1	1.7	19.2	—	8.7	10.9	14.4	—	100
Carbohydrate	81.0	2.4	1.2	2.5	—	10.8	—	—	0.8	1.3	100
Calcium	22.8	2.4	2.4	29.0	—	—	—	11.4	27.5	4.5	100
Iron	60.4	4.3	4.3	13.5	—	—	1.2	11.7	0.6	3.9	100
Vitamin A	0.3	9.9	0.8	76.6	2.2	—	0.3	3.2	4.8	1.9	100
Thiamin	80.0	—	6.6	6.6	—	—	1.3	—	4.0	1.5	100
Riboflavin	20.3	—	5.5	12.9	—	—	5.5	24.0	31.4	—	100
Vitamin C	—	27.0	—	60.0	—	—	—	—	2.0	11.0	100
Folates	55.2	11.3	12.2	16.6	—	—	0.5	1.4	0.2	0.6	100
Zinc	70.0	2.0	2.0	5.1	—	—	3.0	12.3	5.1	0.5	100

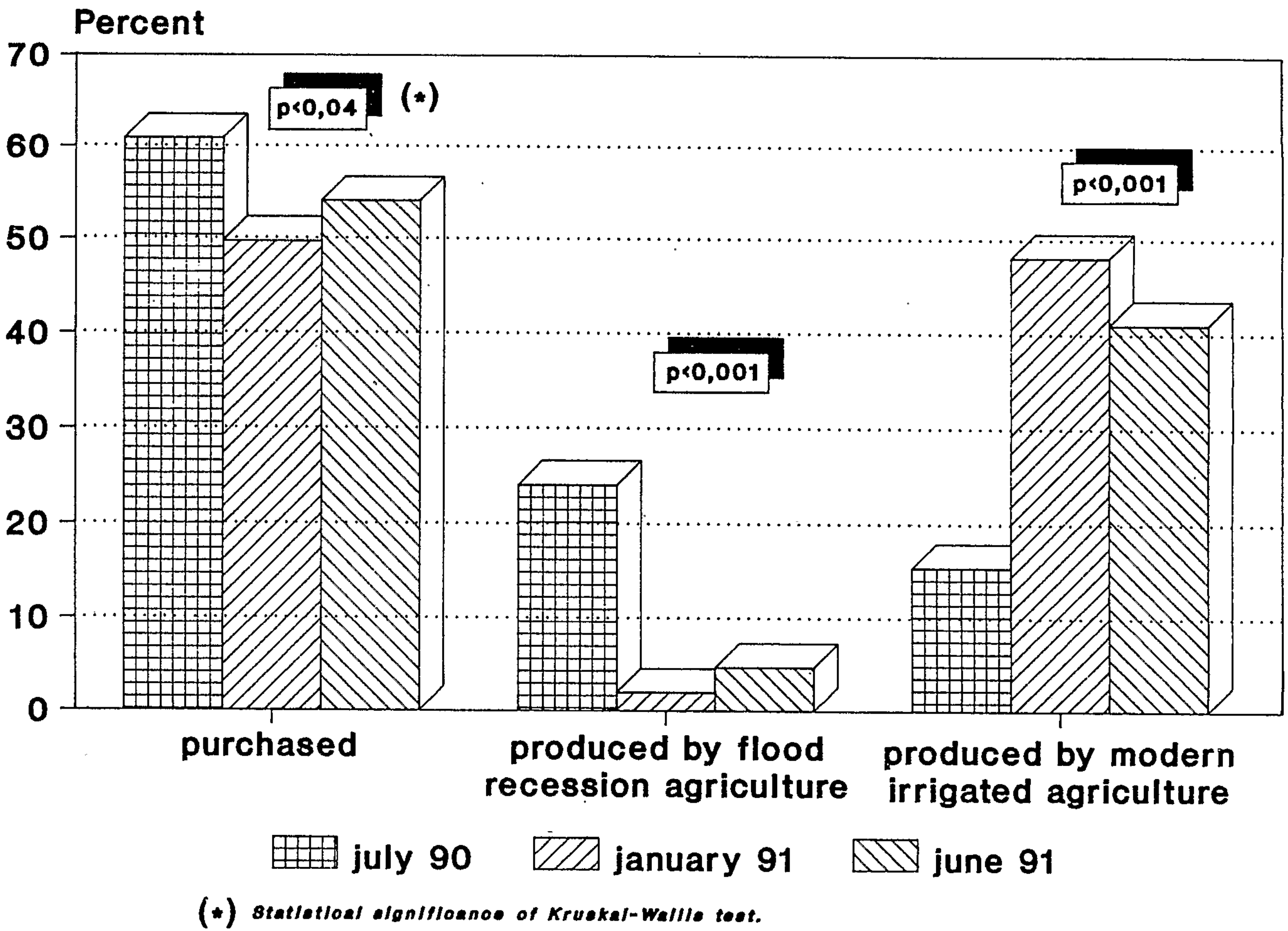

FIGURE 3 Change in food provenance expressed as a percentage of total energy intakes, according to month of survey.

The nutritional value of the villagers' rations is indicated in Table V. All of the nutritional requirements are covered with the exception of four nutrients: calcium, riboflavin, folic acid and zinc. There were slight variations around this mean during the different visits, but, with the exception of calcium, requirements for which were met during the first visit, the other values remained steady. Protein requirements were completely met; the regular availability of cowpeas, fish, or milk, even in small quantities, contributes to increasing protein quality; nevertheless, among two thirds of the families, the chemical score for amino acids as the limiting factor was below 90 (Block and Mitchell, 1946); the limiting amino acid most frequently found is lysine, which is to be expected in a cereal-based diet.

The mean energy intakes of the families are good but the range of values is wide. The distribution is slightly asymmetric and skewed to the right (skewness

TABLE V
Daily per capita intakes of energy and nutrients in the Senegal River Valley compared with WHO/FAO requirements[a]
(n = 106 households; 5586 daily allowances)

Nutrient	Intake noted	WHO/FAO requirement	% coverage
Energy (Cal)	2459.3[b]	2213.4	111.1
	487.0[c]	438.4	9.1
(MJ)	9.5	9.2	
	2.0	1.8	
Protein (g)	64.8	33.4	197.8
	16.0	3.9	58.8
Fat (g)	23.4	—	—
	10.7		
Carbohydrate (g)	393.2	—	—
	81.6		
Fiber (g)	5.29	—	—
	2.4		
Calcium (mg)	495.0	541.2	92.3
	252.3	43.9	47.9
Iron (mg)	16.8	13.9	123.9
	5.7	1.9	49.9
Vitamin A (μg RE)[d]	652.4	610.7	111.7
	446.0	80.9	85.8
Thiamin (mg)	0.76	0.66	115.0
	0.24	0.16	28.0
Riboflavin (mg)	0.48	1.10	52.4
	0.23	1.36	26.6
Niacin (mg)	71.7	21.6	311.4
	394.4	109.4	62.4
Vitamin C (mg)	46.2	27.1	178.2
	27.3	3.5	118.0
Folates (μg)	130.2	344.1	38.2
	38.7	33.8	11.7
Zinc (mg)	12.6	26.4	54.4
	17.4	34.6	29.4

[a]FAO/WHO, 1962; 1967; 1970.
[b]Mean.
[c]SD.
[d]μg of retinol equivalent (FAO/WHO, 1989).

TABLE VI
Comparison of prevalence of malnutrition in children from households meeting and not meeting the energy requirements in the Senegal River Valley[a]

Age group	Energy intakes < requirements	Energy intakes > requirements	Chi[2b]	p
0–60 months	(n = 87)	(n = 140)		
	%			
HAZ <−2[c]	12.6[d]	9.4	0.58	ns
WAZ <−2	26.4	22.5	0.46	ns
61–120 months	(n = 62)	(=100)		
	%			
HAZ <−2	36.1	15.3	9.0	<0.002
WAX <−2	42.6	22.4	7.3	<0.007
121–192 months	(n = 71)	(=103)		
	%			
BMI <14.5 kg/m²	40.8	27.2	3.6	<0.05

[a]FAO/WHO/UNU (1985).
[b]Chi² distribution with 1 df.
[c]HAZ = H/age Z-score; WAZ = W/age Z-score.
[d]Prevalence (%).

value = 0.43). However, of the total of 106 families studied, 37 or 35% do not meet their energy requirements. This situation worsens in June 1991 when 16 of the 34 families (47%) do not meet their requirements as compared to 23% in January after the crops are harvested ($chi^2 = 14$, df = 2, $p < 0.02$).

Table VI illustrates the prevalence of malnutrition in subjects by nutritional indicators according to the relative coverage of energy requirements of the subjects' families. Among children younger than five years, there is no significant difference in the prevalence of malnutrition, although there is a tendency for children from calorie-deficient families to show stunting compared to others. In contrast, there is a significant difference in the prevalence of malnutrition for W/age and H/age of children between 5 and 10 years of age and the BMI of older children: more subjects register lower values among families not meeting their energy requirements than others.

Physical activity and the energy equilibrium of adults. In July 1990, when the activities were not timed but merely listed, it was estimated that energy expenditure for men was 1.55 METS (light activity) and 1.80 METS for women (moderate to heavy activity) (FAO/WHO/UNU, 1985). Table VII summarizes the evaluation of energy intake and expenditure under the aforementioned conditions. Energy intakes and expenditures were higher in January 1991 than during the other surveys, but the relative rate of coverage did not change. Expressed in multiples of basal metabolism, the energy expenditure of women is classified by the FAO/WHO/UNU committee as "heavy," whereas that of the men is classified

TABLE VII
Daily energy intake and expenditure of adults according by time of survey in the Senegal River Valley

Month, year	July 90	January 91	June 91	H[a]	p[a]
		Energy intake			
Men (MJ)	11.47[b]	12.25	10.56	10.0	0.00
	1.76[c]	2.02	2.23		
(Cal)	2745.0	2933.0	2528.0	10.0	0.00
	421.7	484.5	535.4		
n	(26)	(30)	(28)		
Women (MJ)	11.23	12.04	11.05	4.64	0.09
	2.05	1.88	2.69		
(Cal)	2687.1	2882.0	2645.0	4.64	0.09
	492.3	450.9	644.8		
n	(43)	(38)	(42)		
		Energy expenditure			
Men (MJ)	10.49	11.13	10.09	15.2	0.00
	0.81	1.04	0.89		
(Cal)	2511.4	2663.0	2415.4	15.2	0.00
	195.1	249.7	213.3		
Women (MJ)	10.11	11.49	10.00	39.9	0.00
	0.70	0.88	1.26		
(Cal)	2420.6	2750.8	2394.0	39.9	0.00
	168.4	212.4	302.4		
		% of adequacy			
Men	109.4	110.9	106.5	3.4	ns
	15.1	19.9	30.4		
Women	111.0	105.4	112.0	1.9	ns
	19.7	18.5	31.1		
		Multiples of BMR (METs)			
Men	1.55	1.61	1.48	9.4	0.09
	—	0.18	0.19		
Women	1.80	2.08	1.79	45.2	0.00
	—	0.23	0.28		

[a]Kruskal-Wallis test statistic; level of significance for a chi^2 distribution with 2 df.
[b]Mean.
[c]1 sd.

as "moderate to light." The difference between sexes is significant ($p < 0.001$). Table VIII indicates the amount of time adults were engaged in the different types of activities in June and July. Farming activities are greater for men than for women, nevertheless women participate extensively in agricultural activities in January even though their level of domestic activities remains the same as in June. Men's level of participation in field activities does not vary. Agricultural tasks are generally of short duration, but there are substantial variations between individuals (more than 7 hours).

Evolution of Food Consumption in the Valley

It is possible to evaluate the changes in consumption by comparing results with surveys conducted throughout the Middle Valley in 1957–58 (Boutillier *et al.*,

TABLE VIII
Mean daily duration (hours) of various types of activities of adults in the Senegal River Valley[a]

Type of activity	Women January (n = 38)	Women June (n = 42)	h[b]	p[c]	Men January (n = 30)	Men June (n = 28)	h	p
Moderate	3.4[d]	2.8	3.5	0.06	0.4	0.42	0.47	ns
housework	1.6[e]	1.4			0.8	0.36		
Heavy	1.5	1.38	0.37	ns	0.18	0.25	0.40	ns
housework	1.1	1.0			0.32	0.53		
Farming	1.19	0.67	3.6	0.05	2.38	1.83	1.6	ns
	1.3	1.1			1.7	1.8		
Handicraft	0.63	0.53	3.2	0.07	1.75	1.51	0.13	ns
	0.8	1.4			1.93	1.8		
Walking	1.16	0.70	3.1	0.07	1.9	1.1	5.9	0.01
	1.0	0.8			1.4	1.1		
Social activities	0.53	0.56	0.0		0.83	1.79	5.7	0.01
	1.0	0.9			1.08	1.74		
Sitting/resting	2.98	4.43	16.8	0.00	3.87	3.76	0.11	ns
	1.0	1.7			1.65	1.40		
Lying/sleeping	0.48	0.81	3.4	0.06	0.59	1.20	8.0	0.00
	0.4	0.8			0.50	0.95		

[a]See Table I for energy costs of activities cited.
[b]Kruskall-Wallis test statistics.
[c]Level of significance using Chi^2 distribution with 1 df.
[d]Mean.
[e]1 sd.

1962) thus well before the irrigation works, and in 1983 (Bénéfice *et al.*, 1985a). For the 1958 survey, we used data concerning a large area between Podor and Matam collected during the dry season (January to March 1958). In February to March 1983 one of us performed a food and nutrition survey in 5 villages located near the site of the present study, 30 km to the east, and having similar ecological and cultural characteristics. Thus comparisons were done during the same period at the beginning of the dry season when food availabilities are supposed to be optimal. In all cases, the survey method was the same precise weighing technic. Table IX shows the amount of food consumed by families by food group during the same period at the beginning of the dry season. One may note a small decrease in the consumption of cereals from 1957–58 to 1983, specifically traditional cereals, while the consumption of rice increased dramatically. The contribution of fats and sweets increased between 1958 and 1983. The consumption of fish has been greatly reduced and that of vegetables increased; the consumption of other food groups scarcely varied. It is not only the quantities consumed which have changed but also the origin of the products: in 1957–58 the fish that was consumed came from the river, whereas from 1983 onwards, it was from the ocean; in 1957–58, milk was from local production but it has been replaced by purchase of powdered milk.

Table X illustrates the change in daily intakes of the families. There is little difference in the intake of energy between 1957 and 1991 whereas intakes of vitamin A and C and niacin have clearly improved. Intakes of calcium, riboflavin and iron remained low and indeed have decreased.

TABLE IX

Change in daily per capita consumption of food groups in the Senegal River Valley at the outset of the dry season: 1958, 1983 and 1991[a]

Food group	Year 1958	Year 1983	Year 1991
		g	
Total cereal	531.6	420.6	478.6
Rice	29.8	188.3	388.4
Millet and sorghum	444.3	164.1	16.2
Maïze	53.6	19.7	6.0
Bread	3.9	48.5	68.0
Roots[b]	12.0	4.8	6.9
Legumes[c]	19.2	26.3	18.5
Vegetable and leaves	39.7	91.3	146.4
Fruits	1.4	2.0	2.6
Oil[d]	4.3	52.8	42.9
Sugar	23.0	32.4	45.7
Meat	18.1	25.7	11.0
Fish	172.6	47.4	88.0
Dairy products	38.4	46.2	30.0
Total energy intake (MJ)	9.8	9.4	10.7
(Cal)	2344.5	2248.8	2559.8
% supplied by cereals	70.2	61.0	63.4

[a]Villages and populations are not drawn from the same sample.
[b]Mainly sweet potatoes.
[c]Mainly cowpeas also including seeds of peanut.
[d]Peanut oil.

TABLE X

Change in daily per capita intakes of energy and nutrients during dry season in the Senegal River Valley, 1958, 1983 and 1991[a]

Nutrient	Year 1958	Year 1983	Year 1991
Energy (MJ)	9.8	9.3	10.7
(Cal)	2344.5	2224.8	2559.8
Protein (g)	94.2	58.7	65.1
Calcium (mg)	764.9	406.0	418.0
Iron (mg)	21.6	19.7	15.3
Vitamin A (μg of RE)[b]	319.3	391.0	602.0
Thiamin (mg)	2.00	0.94	0.76
Riboflavin (mg)	1.30	0.40	0.49
Niacin (mg)	18.1	28.2	35.6
Vitamin C (mg)	19.2	44.0	51.0
Folates (μg)	—	142.5	25.7
Zinc (mg)	—	8.8	10.7

[a]Villages and populations are not drawn from the same sample.
[b]μg of retinol equivalent (FAO/WHO, 1989).

TABLE XI
Prevalence of observed malnutrition in 1983 compared with 1991, outset of the dry season, Senegal River Valley

	1983	1991	Chi²[a]	p
WHZ < −2[b]	%			
0–5 years	15.8[c]	9.9	1.8	ns
n	(139)	(101)		
5.1–10 years	31.5	13.8	7.8	<0.00
n	(89)	(87)		
BMI <14.5 kg/m²	%			
10.1–16 years	28.0	29.0	0.0	ns
n	(100)	(88)		
BMI <18.5 kg/m²				
Women	39.3	19.2	15.1	<0.00
n	(168)	(146)		
Men	43.6	16.7	15.7	<0.00
n	(78)	(102)		

[a]Chi² distribution with 1 df.
[b]WHZ = W-for-H Z-score.
[c]Prevalence (%).

Anthropometric data from the 1983 survey (Bénéfice *et al.*, 1985b) may be compared with those from the 1991 survey conducted under the same conditions. Age, however, was less precisely estimated in 1983 than in 1991. Thus comparisons have been made with factors which were independent of age (Table XI). It may be seen that there is no significant difference in the prevalence of wasting among children between the ages of 0–5 years. On the other hand, there was greater emaciation among children between the ages of 5 to 10 in 1983 than was seen in 1991. Similarly, the prevalence of thinness among adults of both sexes was less in 1991 than in 1983.

DISCUSSION

The community which was studied has a diet which meets, on average, most of its nutritional requirements. However there is an unequal distribution of food among families of which between one-quarter and one-third, depending on the season, have insufficient dietary intakes. The level of malnutrition among children is high, as well as the frequency of thinness among older children and adults.

An important limiting factor of household consumption surveys is the neglect of study of individual intakes. The hypothesis that each person eats according to his needs is not always validated (Bull, 1991). The degree of error introduced is not known. Otherwise the custom of consuming food around a "common bowl" does not permit individual measurement without greatly interfering with meal etiquette and could have been excessively expensive in relation to the objectives of this study. The subsample of households surveyed was drawn from 110 randomly selected families (40% of the total families' number). The coefficient of variation of energy intakes between families was equaled to 0.19 and did not change in the course of visits. This variation corresponds to that reported in other Senegalese surveys (Chevassus-Agnès and Ndiaye, 1981). For this reason we believe that this sample gives an acceptable representation of the food eating patterns in this district. The collected data allow for a better understanding of the villagers' situation and the evolution of their dietary patterns.

The introduction of irrigated crops added a measure of security to food production: rainfall and thus harvests vary greatly in this region. It may be noted that 1957–58 were climatically good years; 279 mm of rain fell in 1957 and 375 mm in 1958. In contrast, only 169 mm fell in 1982 and 76.3 mm in 1983 (Le Borgne, 1988). For the present period, in 1989, the first year of perimeter flooding, 323.6 mm of rain fell but the following years there was a substantial shortfall: 142.8 mm in 1990 and 97.1 mm in 1991. In addition in 1990, the level of flood was low because the reservoir of the Manantali dam was not filled and the rising of the two other tributaries of the Senegal river, Falémé and Bakoy, which contribute 50% of the flow, occurred late owing to the scarcity of the rains on their source in the Fuuta Jaalon mountains (see map, Figure 1). Consequently, the produce of traditional flood recession agriculture (sorghum and niébé) was insignificant. Despite this constraint, modern irrigation allowed for a satisfactory rice harvest. This point should be emphasized.

However, in spite of these efforts, success of the agricultural project is mitigated and current harvests do not cover the families' consumption needs: 50% of foodstuffs must be bought with money sent by family members who have emigrated from the region. During this survey it was noted that women's participation in field work was substantial, even though data collectors were not present at the high point of agricultural labor during the rainy season.

The availability of women's time is not limitless, as the time they spend on agricultural tasks is taken from other household activities (McGuire and Popkin, 1988). This could ultimately have negative effects on nutrition and care of the younger children. This situation has been the focus of recent studies (Rubin, 1990; Vaughan and Moore, 1988; Brun, Reynaud and Chevassus-Agnès, 1989) showing that the increase in income from women's employment does not necessarily result in an improvement in family nutritional status. Nutritional status, particularly among small children, is also a function of non-nutritional factors such as infections (Martorell, 1985) and parasitism (Taren *et al.*, 1987; Egger *et al.*, 1990), which are themselves linked to hygienic conditions of the surroundings. In the Senegal Valley hygienic improvement and water supply have not evolved as rapidly as progress in food production. This could explain why, in our sample, one does not observe a better nutritional status among children less than five years of age from families which have a quantitatively elevated nutritional intake, in contrast to that observed among older children. It would seem that these older children are better protected from repeated infections and are thus more influenced by purely nutritional factors. As a matter of fact, it must be stressed that health status may be threatened with water-based parasites in connection with the development of irrigation on a large-scale (Audibert *et al.*, 1990). Risk of schistosomiasis outbreak was especially investigated and until now no infected subjects have been detected in our villages (Diallo *et al.*, 1990).

The prior studies of 1958–59 and 1983 were not conducted on the same family groups. Thus one cannot affirm that these data strictly represent the evolution of the studied community; nevertheless, the similar living conditions and the common culture in the three cases permits certain reflections. The diet has changed from one based on sorghum, millet and cowpeas to one based on rice in which peanut oil plays an important role, but the nutritional improvement in today's villagers from those studied in 1957–58 and 1983 is modest. The most interesting evolution concerns intake of vitamins A and C; the improvement is due to the introduction of vegetable production which permits a regular consumption of fresh vegetables and tomatoes during a large part of the year. Deficiencies in intakes of calcium, riboflavin, zinc and folates remain. Intake of animal products, in particular dairy products, is insufficient. In 1957–58, the rotation of fishing and livestock production in the basin made animal protein available practically year-round (Boutillier *et al.*, 1962). When one compares the results of the anthropometric surveys from 1991 and 1983, which were conducted under the same conditions, one does not note a significant difference in the prevalence of emaciation among the younger children, but there are fewer cases of emaciation among older children and adults. This shows a favorable evolution of nutritional profiles although young children have not yet been positively affected, probably for the same reasons cited above: the hygienic conditions of the surroundings have not been ameliorated.

If these farmers have safeguarded their harvests, albeit going from an "ecological risk to a financial risk" (Flavigny and Cousin, 1982), their diet is not always sufficient to cover their needs and malnutrition persists. This demonstrates the limits of nutritional benefits provided by development projects which are based only on the increase in food production, and confirms results observed elsewhere (Brun, Geissler and Kennedy, 1991; Holmboe-Ottesen, Wandel and Oshaug, 1989). Nutritional status is the result of complex interactions between man and his environment (McElroy and Townsend, 1989): to obtain positive results, other objectives must be integrated within a project, not only those concerning improvement of hygienic conditions and health care, but also consideration of added work loads and the division of tasks within the family.

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