

## Article

# Analysis and Diagnosis of the Agrarian System in the Niayes Region, Northwest Senegal (West Africa)

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**Abstract:** The agrarian system Analysis and Diagnosis is used for this study, the goal of which was to provide a corpus of basic knowledge and elements of reflection necessary for the understanding the *Niayes* farming systems dynamics in Senegal, West Africa. Such holistic work has never been done before for this small region that provides the majority of vegetables in the area, thanks to its microclimate and access to fresh water in an arid country. Reading of the landscape and historical interviews coupled with fine-tuned household surveys were used to build a typology of agricultural production units (each type being represented by a production system). The main phases within the region's history were distinguished. Before colonization, agriculture was based on gathering and shifting agriculture (millet and peanut) in the southern region and transhumant stockbreeding in the North. During colonization, market gardening became a source of income as a response to cities' increasing demand. Two major droughts (in the 1970s and 1980s) have accelerated this movement. Extension of market gardening areas and intensification of activities were made possible by Sahelian migrants' influx and the creation of *mbeye seddo*, a contract that allows for sharing added value between the employer and seasonal workers, named *sourghas*. Over the past 20 years, the "race for motorization" has created important social gaps (added value sharing deserves review) and a risk of overexploitation of groundwater.

**Keywords:** comparative agriculture; survey on farming; socioeconomic differentiation; Senegal

## 1. Introduction

From 3.3 million inhabitants in 1961, Senegal will count its population at about 17 million in 2020. Feeding an unceasingly growing population and supplying towns with fresh and quality vegetables as well as fruits are challenges for the country, which has mainly Sahelian conditions. Due to urban growth, competition for foreign products and devaluation of West African FCFA (Franc de la Communauté financière en Afrique, the currency of eight independent states in West Africa), Senegal saw an increase in imports of onions, potatoes, rutabagas and carrots. Production from the Niayes agricultural region seems to play a non-negligible role in importation to satisfy national needs. In fact, Niayes farmers provide anywhere from half to two-thirds of the national production of fresh vegetables (tomatoes, onions, rutabagas, cabbages, carrots, etc.) [1]. Despite the dynamism of the

Niayes production systems, there has never been any holistic work to prepare Senegalese policy makers to face the challenges of feeding the cities that are growing with Niayes production. Our research was conducted within agricultural development projects, led by a non-governmental organization (NGO) named SOS SAHEL, and aims at:

- Understanding conditions of market gardening development in the Niayes (environmental parameters: Soil fertility, water resources, etc.) and the diversity of production units in this region to fine-tune forthcoming projects.
- Determining the conditions necessary for the Niayes to better contribute to the country's agricultural production. Beyond technological choices, we had to understand the economic rationality of Niayes' production units. Understanding their rationality will help this project to better suggest social, economic and political actions that would be able to boost production and create jobs while respecting the environment.

To address these objectives, this study has adopted as a theoretical reference the concept of the "Agrarian System" developed at the French Agricultural Research National Institute, Agrarians Systems and Development Department (INRA-SAD) [2–4]. This holistic methodology has been used to describe many situations in world agriculture but not in the Niayes [5]. The extension of this approach to Niayes would enrich our knowledge of the world's agriculture, in addition to providing answers to the abovementioned questions.

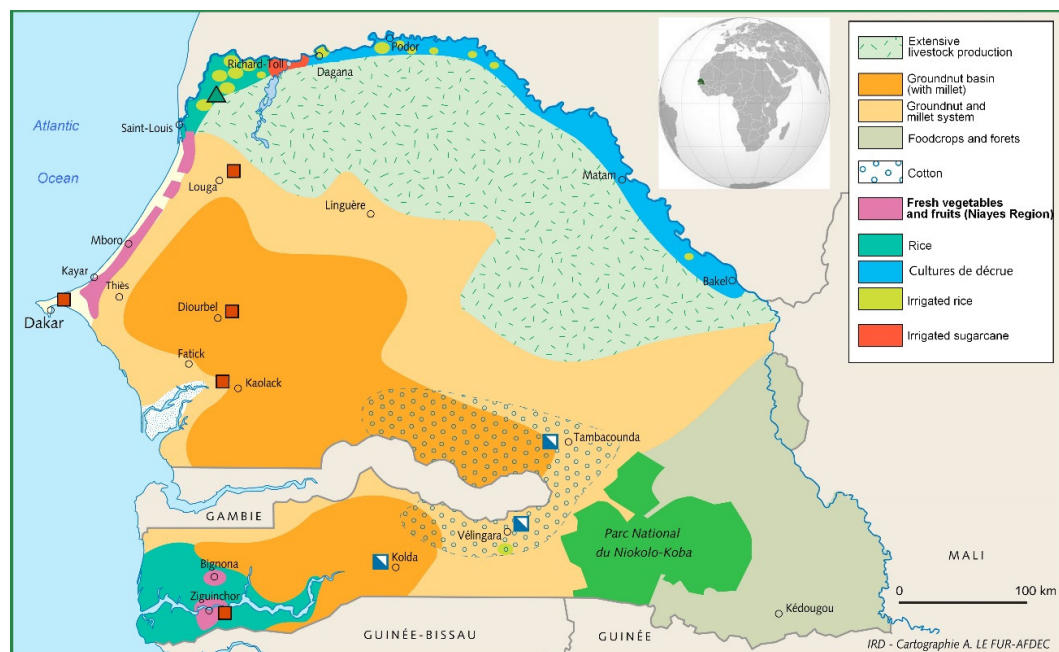
Originating from comparative agriculture studies and systems research applied to agriculture, the concept is defined as "a mode of exploitation of a given agro-system, historically constituted and long-lasting, adapted to the bioclimatic conditions of a given space, and meeting the requirements and social needs of the time" [2]. "Agrarian System analysis and diagnosis" is the survey method related to the concept of an agrarian system [3,4]. It is an all-encompassing methodology, combining different levels of analysis and therefore capable of making sense of agricultural activities operated by farmers within a given agricultural district, in a way that accounts for both ecological and socioeconomic dimensions. This holistic approach aims at describing farmers' social and economic practices and techniques and at understanding the phenomena that influence them [4,6]. It also allows for evaluating the sustainability of a region's agriculture and collecting all elements for future transformations and forecasting, with or without any project-like intervention.

For this research project, data have been collected through observation as well as questionnaires and a literature review. The data collection has been organized at different scales from the general level (national situation) to the particular (region, then farms, plots and/or herds) following an iterative analysis–synthesis process. This process obeys the methodology of comparative agriculture, which "favours the usage of a telescopic change of scale, particularly between the three levels of analysis privileged by us, i.e., that of the plot or herd for examining practices, that of the production unit or farm for integrating different cropping and livestock systems, and that of the (more or less vast) region or country for the pertinent application of the agrarian system concept" [3,4]. Understanding the differentiation of previous agrarian systems is an essential step to understanding the dynamics of the production system currently under survey. Within this current agricultural system, farms have either always used the same techniques or implemented similar "strategies" due to different access to production means (land, work, capital) and the heterogeneity of regional conditions [3]. The technical–economic evaluation of the farms surveyed allows for a better understanding of the differences between them [7]. Finally, an analysis of current projects and agricultural policies helps with developing future perspectives and possibly generates some corrective measures to implement from the general interest point of view.

## 2. Materials and Methods

The survey area is the Niayes, a small agricultural region of Senegal specialising in market gardening. The boundaries of our study area are set based on geomorphology, climate and main

agricultural trends as an important market gardening area. The main boundaries of our study area were set as follows: in the West, the Atlantic Ocean; in the East, the main rain-fed agricultural areas (millet–peanuts system); in the North, the Senegal River; and in the South, the Cape Verde Peninsula (Figure 1). This general delimitation was enhanced on site by observations that allowed the project to determine zones, as relatively homogenous sub-units of our survey area.



**Figure 1.** Location of the Niayes within the main agricultural regions of Senegal.

On-site data collection was conducted from 2010 to 2013 with the support of SOS Sahel International teams, a non-governmental organization (NGO). These surveys were completed by five of the authors, sometimes accompanied by local interpreters. Intermediate results have been presented in four Master's theses, supervised by the main author [1,8–10]. Citizens' and farmer organizations' acceptance was facilitated by one of the authors' work with the market gardening union association of Niayes.

First, the study aimed at interviewing groups of elderly farmers who were witnesses to the recent evolution of Niayes agriculture. The topic chosen for discussion during the interviews was Niayes' agricultural history. Souvenirs that we collected directly dated from the 1940s. The participant groups were sometimes associated with people in charge of the farmers' organizations, retired people from technical services who stayed and lived in their former working place. Such information was required in order to understand the rationale for their installation. With the purpose of dividing the long historical period into sequences and locating the souvenirs in time, we used some outstanding events as references: the Second World War; the Leopold Sedar Senghor, Abdou Diouf and Abdoulaye Wade presidential terms; the 1995 CFA franc devaluation; and the 2008 price surges. Thirty historical interviews coupled with 100 related to farms' life cycles were coordinated by the main author, who also took part in many of them. About 80 fine-tuned surveys were used to help establish economic results at the household level. The objective was to obtain the number of workers in each household and those external to the households, the number of people to feed, the technical details for each cultural and production system, locating them in time in landscapes, yearly and inter-yearly rotations, crop shifts, income, inputs and manpower, produce destinations (for self-consumption, sales, transformation), and access to credit. The choice of farms type for the surveys was guided by the farmers' organizations, based on rather general typology standards, but the list of farms was validated based on their gardening

techniques and practices related to their means of irrigation and their location in the landscape, and therefore gardening soil types. Each investigation was led by an investigator accompanied by an interpreter, as open or half-open survey type using a survey guide. During the study, we found that sometimes it was necessary to come back several times to have more accurate information and be more precise about different periods of the year. Investigations at the market and within the Senegalese National Agency on statistics and demography provided price evolution related to different productions in the survey area. Finally, we met some managers of NGO projects, national projects, and microfinance institutions, as well as officers of technical services in the area. Those people know more about the past and current projects operating on the agrarian system. They also offered some assistance during surveys; they helped during the selection of relevant villages, shared contacts of rural leaders and sometimes introduced us to villagers.

## 2.1. The Survey Area

### 2.1.1. Boundaries

The Niayes area, a small and unique region in Western Senegal, covers approximately 2759 km<sup>2</sup> [11,12], less than two percent of the whole country's surface. Niayes covers the area situated between Dakar in the south and Saint-Louis in the north, along the country's northern coast and 5–30 km in width.

The Niayes belongs to a particular ecosystem of the Sahelian strip. Although located at latitude 14°30' and 16° North, this area is nevertheless characterized by a tropical climate of Sub-Canarian type and an original Sub-Guinean vegetation [13]. Such an exception is produced by a marine tradewind, relatively fresh and humid, generated by the Azores anticyclone (Northern Atlantic), which protects the northern coast of Senegal from warm and dry harmattan winds [14]. The Niayes agricultural region's relief is a succession of sand dunes and inter-dune basins. These quaternary-aged dunes are established in a marly and limy substratum dating from the Eocene and Paleocene [15,16]. Rainfall is relatively low, between 350 and 450 mm rain per year, but water availability is important in inter-dune basins. This profusion is tied to the "Nappe des Sables Quaternaires"—NSQ—groundwater, circulating in sandy and sandy-clayey deposits, relatively permeable, on a marly and marly-limy substratum of the Eocene, which is impermeable [17,18]. In current landscapes, from the continent to coastal area, four types of dunes succeed each other:

- Long red and levelled dunes, oriented from northeast to southwest, running parallel with the shore line, witnessing the regressive and dry phase (Ogolian) of the last ice age (18,000 years ago). These dunes are steady and indicate the borders of the Niayes and the Dieri (the local name for the ancient peanut basin).
- Shorter and higher red dunes, sheltering much more than anywhere else humus-bearing soils and peat bogs. These dunes would be resulting from Ogolian dunes alteration by a marine tradewind [16]. They are in general permanent but revive in some places.
- Semi-permanent yellow dunes, forming a coastal dune stretch with variable width from one to four kilometres. Of 20 to 30 m high, they end with an abrupt front in the windy part. They would have been settled in the regressive phase after 5500 BCE. The depressions between dunes bear less humus [16].
- White coastal dunes, sharp, forming a large band ranging from some dozens of meters to 300 m from the beach. The sand was brought by recent coastal accumulation (by 1800 years ago). They are partly maintained of filao trees (*Casuarina equisetifolia*) [14,19,20].

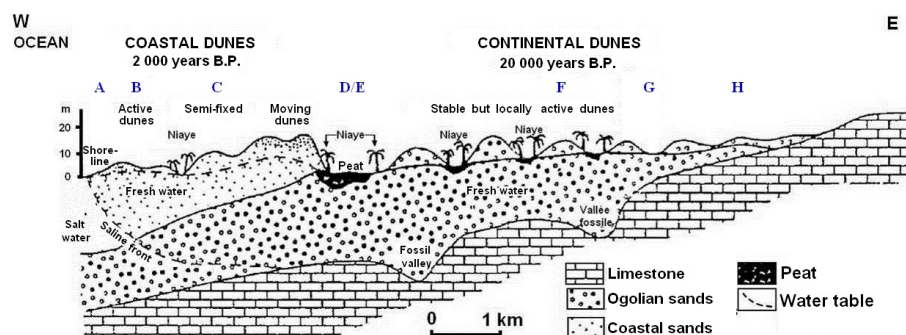
The Niayes area is highly populated and characterized by a dynamic agriculture dominated by market gardening activities (more than half of the national production). The Niayes make an important contribution to the fresh vegetable supply in Dakar. More than two million people lived in Dakar in

2006, more than 20% of Senegal's whole population, and more than two-thirds of Senegal's population live less than 60 km from coastal areas [21].

### 2.1.2. Zoning Elements

Tied in with geomorphology, proximity with NSQ groundwater and soil types, and dune and basin succession can be divided into different zones (Figures 2–4 and Table 1):

- A coastal dune string (A), composed of raw mineral soils. On these dunes, which can be potentially mobilized by wind, colonial forestry administration by the Senegalese government established in successive stages a filao trees strip (*Casuarina equisetifolia* L.), a vegetal barrier protecting against the sand-silting risk to the basins between dunes.
- Small-sized depressions, between levelled and scarcely collected dunes (B). On this area, which stretches a few hundreds of meters behind the filao trees strip, the groundwater level is not very deep (two to five meters). For that reason, undoubtedly, depressions are named “Ndioukis,” meaning “drawing water with a bucket using a pulley.” Soils are of a siliceous type, poor in organic materials and sometimes salinated. Ndioukis are much more numerous in the North of the Niayes (Northern zone: from the South of Saint Louis to the Lompoul s/mer-Kebemer axis; Central zone: between Lompoul-Kebemer axis and Kayar-Thies axis (corresponding to the Eastern boundary and Cape Verde Peninsula: Southern zone: East of the Cape Verde Peninsula, Keur Moussa, Sébikotane, Bayakh, Diender).
- A dune area partly fixed by scarce shrubby and wooded vegetation, with sandy-soiled inter-dune depressions, slightly moist and of ochre colour. This area (C) covers the intermediate part of Niayes (from 300 to 2000 m towards lands, to the west). Depressions are of varied sizes and forms.
- The ancient riverbed or lake zones (D and E) resulting in large depressions; the NSQ is at grounds' level. Depressions are embanked, clayey or even peaty (local name: *xour*; we classify them under subzone D) or clayey and muddy soils (called *ban* in Wolof) (subzone E). The relics of Guinean vegetation can be seen in this area. As we can see in the literature, the term “Niayes” was first associated with this well knows and early populated area. We call this part the “peaty Niayes zone.” The width of that area is much more important in the south and centre than it is in the north (Figure 3).
- The last dunes area, where access to water allows market gardening with adapted drainage means. Soils are of dior type in height and of deck dior in the bottom (F). This constitutes the boundary with the Dieri.
- In the Dieri eastern boundary (G and H), which marks the start of the Senegalese peanut basin, the first subzone (G) is not cultivated but reserved as a livestock way and for forestry produce collection. The ‘H’ area in the diagram (Figure 2) is cultivated with a millet/peanut system under cover of *Acacia albida* Del.



**Figure 2.** Geological section of the Niayes and location of agro-ecological zones (adapted from Pezeril et al. [22]).



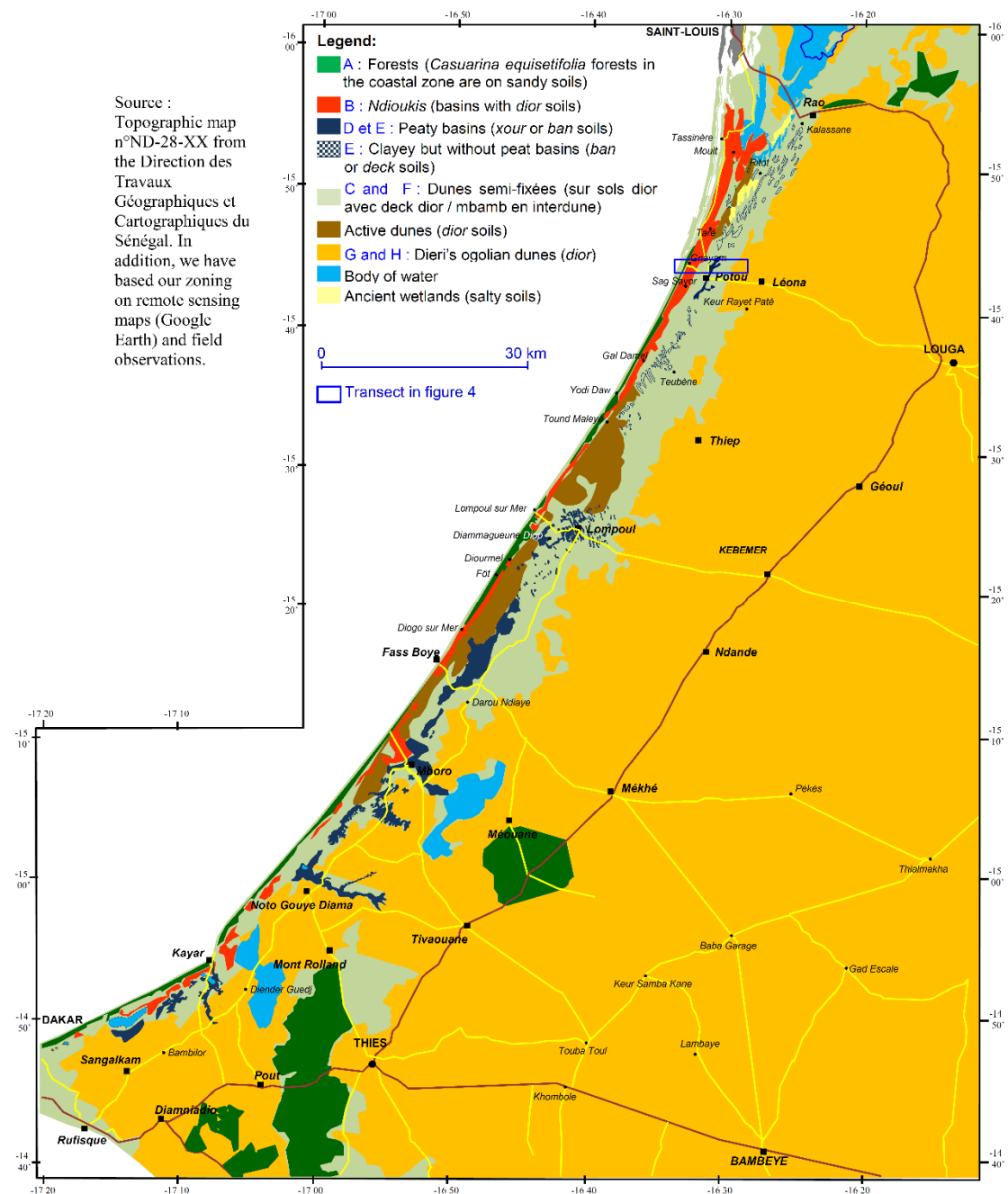
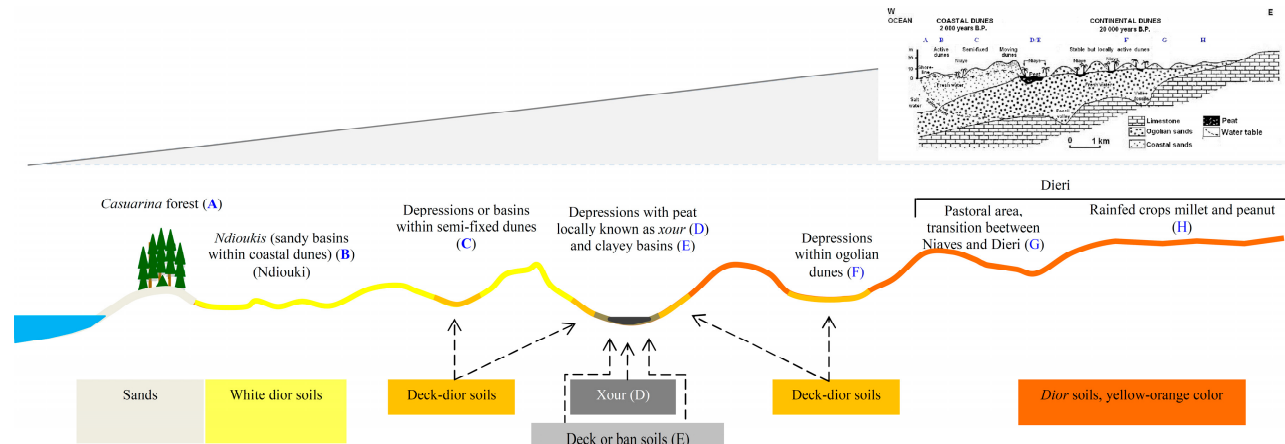


Figure 3. Zoning of the survey region.



**Figure 4.** Diversity of depressions and soils, according to topography (and therefore proximity of the water table).

**Table 1.** Diversity of depressions and soils, according to topography (and therefore proximity of the water table).

Zones	Ndioukis (B)	Semi-Fixed Dunes (C)	Peaty Niaves (D and E)	High Basins of Continental Dunes (F)	Dieri	
					Pastoral Transition Area and Dieri Area (G)	Rainy Cultivating Area (H)
<b>Altitude (≈level difference between thalweg bottom and dune top)</b>	Five to ten meters (m)	10–20 m	10–15 m (more important level difference towards Fass Boye with about 20 m summits)	15–25 m	25 to 30 m	30 to 45 m
<b>Access to water</b>	Water ground is in average two to five meters.	Relatively easy access (water ground is at seven to fifteen meters)	Water is almost flushing in the basin bottom.	Difficult access (15–20 m)	Very deep water ground (>25 m), for annual plants, available water is rain).	
<b>Soils</b>	Sandy and very poor in organic material.	Sandy ( <i>dior</i> ) in height and sandy and muddy or <i>deck-dior</i> in basin bottom.	Clayey and peaty ( <i>xour</i> ) in basin bottom, clayey and sandy in mid-slope ( <i>ban</i> )	Sandy ( <i>Dior</i> )	Sandy <i>dior</i> type, with very slight textural variation on the top of dunes (weak textural stability) in slope bottom (with few silts accumulated by colluviation).	
<b>Spontaneous and woody vegetation</b>	Steppe, with scarce <i>Casuarina equisetifolia</i> , due to close presence of filao trees strip.	Various acacias and combretacea. Cactacea and euphorbiacea disseminated by humans.	Guinean-type vegetation with palm trees ( <i>Elaeis guineensis</i> and <i>Cocos nucifera</i> ) With aquaphyle plants ( <i>Nymphaea lotus</i> , <i>Phragmites vulgaris</i> , <i>Typha australis</i> )	Various acacias and combretacea. Cactacea and euphorbiacea disseminated by humans.	Shrubby savanna with <i>Detarium senegalensis</i> , <i>Cassia sieberiana</i> , <i>Celtis integrifolia</i> , <i>Prosopis africana</i> and <i>Securidaca longipediculata</i>	Wooded parks with <i>Acacia albida</i> and <i>Adansonia digitata</i> .

## 2.2. Definition of the Agricultural Surface

Farmers were generally able to provide us with information on the surface of plots they cultivated in hectares. When that was not the case, we sometimes had to measure the surface or estimate the total sown surface (e.g., sum of all disseminated plots owned by the same farmer). The land reserve of each farmer has also been estimated.

## 2.3. Economic Analysis

### 2.3.1. Evaluation of Performances of Cropping Systems and Livestock Farming System

Gross average product (GP) of a cropping system or livestock:

$$GP = Q \times P, \quad (1)$$

where  $Q$  is the quantity harvested and  $P$  is the price/unit.

Food prices are subject to change year-round. For market gardening produce, we used the average price at the peak period of sales. This was easy enough to set up due to the perishable quality of market gardening produce. The price of livestock produce is more stable, except for sheep sold for yearly festivities (end-of-year festivities, “Tabaski” and “Eid,” which is the name of the end of the Ramadan fast).

Net value added (NVA): Evaluation of value added allows for assessing the creation of wealth from the perspective of the community. In order to compare the performances of the different cropping systems, the economic results were modelled according to a linear model:


$$\begin{aligned} NVA/\text{worker} &= a \cdot S/\text{worker} - b, \\ a &= (GP - IC_p - Amt_p)/\text{hectare} \\ b &= (IC_{np} + Amt_{np}), \end{aligned} \quad (2)$$

where  $S$  is the area farmed (in hectares),  $GP$  is the gross average product per farmed hectare,  $IC$  is the cost of variable inputs, i.e., value of goods and services that have been transformed or fully consumed during the production process (fertilizers, manure, pesticides, etc.) proportional (p) or non-proportional (np) to the farmed area;  $Amt$ : is the average cost per hectare of the amortization and maintenance of equipment and fixed assets, proportional (p) or non-proportional (np) to the farmed area; and  $NVA$  is the net production of wealth per worker, i.e., the net productivity of labour.

### 2.3.2. Typology of Production Systems

To construct the typology, we used structural variables (length of the farm, type of irrigation equipment—manual, motorized, intermediate, number of family workers) and functional variables. In comparative agriculture studies, there are three main groups of farm types: family, family business, and capitalist. In Table 2, we give some criteria related to these three models of farms.

**Table 2.** Types of models of agricultural production units [23,24].

	Entrepreneurial Agricultures		Family Agricultures
<b>Types of production units</b>	Enterprise farm	Family business farm	Family farm
<b>Labour</b>	Specialize in supervision of hired labour	Work on farm and supervise hired labour	Family labour; no permanent hired labour

### 2.3.3. Evaluation of Performance of Each Type of Production System

To refine the interpretation of results of farms’ typology, and really measure the net family’s revenue (RA), it is recommended to withdraw the part of income redistributed to working persons outside of the family (salary or benefit sharing) [3]; we have built a second linear model as follows:



$$\begin{aligned}
 RA/\text{family worker} &= A \cdot S/\text{family worker} - B, \\
 A &= (GP - IC_p - Amt_p - \text{land property taxes} - \text{rents})/\text{hectare} \\
 B &= (IC_{np} + Amt_{np} + \text{taxes} + \text{salaries} - \text{subsidies})/\text{family worker}.
 \end{aligned}
 \tag{3}$$

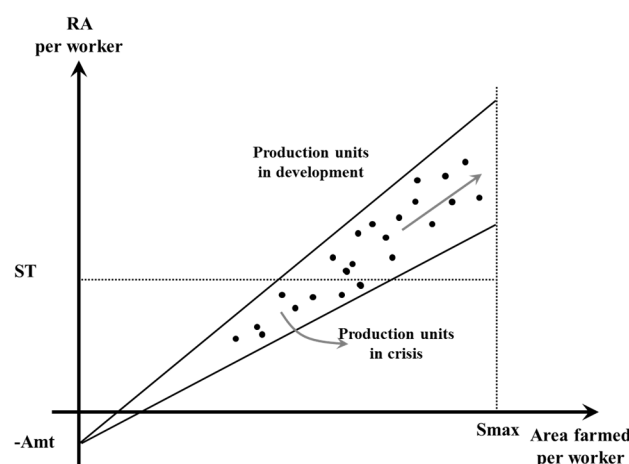
Evaluation of the farm's income allowed the study to assess the profitability of the activity from the farmer's point of view (versus net value added, which represents the creation of wealth from the perspective of the community). While value added and productivity measure the intrinsic economic efficiency of the production system as a value creation process, it is the farm income that is in a position to express the share of value added (potentially increased by the subsidies received), enabling the farmer to support his family and, if possible, to invest so as to increase his capital and, ultimately, the productivity of his farm [1–3].

For each production system-type we have evaluated the average annual income. We then constructed a representation of economic performance per family worker according to the available area per family worker. Finally, we have compared this annual income/family worker to:

- A survival threshold (ST): such a comparison informs us about the future of the farm and its capacity to develop (Figure 5).
  - If  $RA > ST$ , then the production unit is increasing in wealth, which enables the farmer to make some additional net investments.
  - If  $RA < ST$ , then the production unit is even less able to make any additional net investments, and cannot even entirely renew its means of production and remunerate its labour power at the market price. Such a farm is in crisis, losing assets and facing basic needs; in the end, it may disappear, shift to another activity (labourers moving to wealthy neighbouring farms), or the owner may choose to migrate.

In the evaluation of this “survival threshold” (per working person and per person to feed within the family) we asked family members what their basic needs were for a given year.

- The regional opportunity cost of labour: informs about the economic interest farmers may have in dedicating their work to current production system or a possible shift to another competing activity (e.g., urban migration).



**Figure 5.** Production units in development and production units in crisis within the same agrarian system (adapted from [2]).

### 3. Results

#### 3.1. History and Main Features of the Agrarian System

##### 3.1.1. Original Ecosystem

Before agriculture, the vegetation of the coastline between Dakar and Saint-Louis was a relic of Guinean vegetation, also existing in the south of the country [13,25]. This distinguishes the Niayes vegetation from that of the same latitude in Senegal. Archaeological work, being rare, does not allow researchers to get precise data on the origins of agriculture in this area [26]. Using as a basis Arabic and Portuguese travellers' narratives, it can be said that the Niayes was unoccupied in the 15th century, but was visited by *Serer* populations extracting palm wine, oils and ointments from *Elaeis guineensis* Jacq. palm trees [27].

##### 3.1.2. Settling Processes and Pre-Colonial Agriculture

The first most important settlements started in the 13th century. This settling process would be subject to successive migration [28–30]:

- In the Southern part, a temporary *Manding* occupation before the 13th century and undoubtedly following the Ghana Empire dislocation. In their raid to the south, they settled around Mont Rolland in the 13th century, where they practiced shifting agriculture and palm tree exploitation in coast. *Lebous* practiced coastal fishing.
- In the north and centre, towards 1680, *Fula* from Senegal River (*Waalowaalbes*) and from the edge of the current Louga (*Jeerinkkobes*). Hamlets were established along the coast by populations who already know the area due to transhumance: the Niayes provides pasture in the dry season.
- All along the area, *Wolofs*, after a temporary presence regulated by seasons, were installed in the 18th century to escape instability in the *Joloof* kingdom and slave raids in the *Walo*, *Cayor* and *Baol*. They occupied the region without established rules and practiced shifting agriculture (millet, peanut with 15 years of fallow lands).

##### 3.1.3. Pre-Colonial Agriculture (Before 1885)

Oil palm exploitation in the xour basin (area D in the Figure 2) is undoubtedly the most ancient method of agricultural land use in the Niayes. The people practiced an economy of gathering, which provided in small quantities fruit, wine and produce for basket-making [31]. In the central and southern Niayes areas, the first emigration waves of *Lebou* and *Serer* brought sedentary agriculture to the area. This was an itinerant slash-and-burn agricultural system with exploitation of the dry *Acacia seyal* forest in the Dieri area (H) between Dakar and Thies [31,32]. With this self-subsistence agriculture, priority was given to food and textile fibres' supply. Until the early 19th century, the main crops were: the vouandzou (*Voandzeia subterranean* L.), rich in proteins; sesame (*Sesamum indicum* L.), which were grains rich in calcium and grilled for consumption; sweet melon (*Colocynthis citrullus* L.), rustic, of large size called *béref* in *Serer* and *Wolof*; cassava (*Manihot esculenta* Crantz), of an American species; and a few shrubby cotton plants (*Gossypium hirsutum* L.). It cannot be excluded that around humid basins flood-recession kitchen gardens have existed and planted with sweet potatoes (which is also American), African rice and gombo). *Fula* transhumant travelled regularly to the northern area, where some *Fula* hamlets were established.

##### 3.1.4. Introduction of New Cultures by Colonial Administration

The creation, in the 17th century, of the Saint-Louis trading post and, in the 19th century of Richard Toll's experiment gardens marked a determination to develop colonial agriculture. Numerous fruits and vegetables were experimented with at Richard Toll's and Gorée. In Senegal, peanut cultivation organised by agricultural services started in the Cape Verde Peninsula in the 19th century. The Dieri

production development is concomitant with the Cayor Kingdom annexation by France and railway establishment from Dakar to Saint-Louis in 1885.

### 3.1.5. Fruit and Vegetable Market Development during the Colonial Period (1885–1960)

The Niayes' potential to supply Dakar with fruits and vegetables was recognized in the early 20th century. Political and economic decision-making, accompanied by agricultural research and a real climatic advantage, were decisive motivators of the first vegetable producers. Three elements drove market gardening development. The first element was clearing the concerned area of malaria and trypanosomiasis. By 1906, experts were sent to have oversight of area conditions. Clearing and prophylaxis measures were taken afterwards. The second is cities' growth. For Dakar and its surroundings, French installation outside Gorée being negotiated in 1867, the population increased from 8937 inhabitants in 1891 to 18,447 in 1909, including 2000 Europeans [31]. In the North, there was Saint-Louis' influence; along the railway were established markets that helped sell off horticultural production. In the 1910s, various vegetables from Europe were subject to more advanced experimentation. For that, a training support document has been published. After the First World War, the need to produce more locally was evident: during the War, the need for fruits and vegetables from temperate countries and from the West Indies was hardly satisfied by importation. Military forts were also among the vegetable requesters. The third and last element regards the limitation on the peanut policy as much. The area was not adapted to peanut seeds envisaged for the Peanut Basin. Appropriate deforestation would threaten the Niayes area. In 1908, another agricultural orientation was considered: reforest and protect forest to restore ecosystem, and settle dunes and develop market gardening. In order to allow the growth of fruits and vegetables on the northern coast, the forestry administration initiated a dunes settlement operations with a dense population of filao trees (area A in Figure 2).

A proactive policy was developed. In 1920, Governor Ponzio, aiming to motivate market gardening, decided to reduce the related business taxes. This decision had an impact on market gardening in the Southern Niayes Area and, to a lesser extent, in the Central Area (Mboro). In 1937, a policy was elaborated to organize migration from the peanut basin (where demographic pressure was strong) to the Niayes. An agricultural station was also installed in Mboro in 1937. With regards to the northern area, the French introduced potatoes and some other vegetable species to facilitate supply to the forts (Saint-Louis, etc.). These new species are cultivated counter-season, which allowed for easy mobilization of manpower. Rain-fed crops (millet, peanut, niebe) were maintained on ledges to insure cereal and oleaginous ration for family and produce fodder for animals (dead leaves of peanuts, millet and cowpea). The introduction of vegetal species requiring regular watering (potatoes, chili peppers, cabbage, bitter eggplant) modified agricultural and food systems. New species were consequently planted near water points in *xour* and *ban* area (zones D and E). Cabbage was only produced in zones D and E. As its root is not deep enough, this plant is much more sensitive to drought and being planted in soils that are flooded in rainy seasons, next to rivers or lakes. So, in zones D and E, cabbage was cultivated in small quantities, as a single crop or associated with maize.

In the Ndioukis area (zone B), producers had to dig *céanes* in depressions, and basic wells were reinforced with straws and wood. Potatoes gradually replaced sweet potatoes, in shifts with cassava and maize. Women cultivated shrubby species (chili peppers, bitter eggplant) in small and fenced vegetable gardens not exceeding 300 m<sup>2</sup>. Each year, producers in the northern Niayes area left half of their cultivation area fallow. During dry seasons, they cultivated cassava, maize and cowpea. Apart from potatoes, each cultivated species was entirely destined for family consumption. Surplus potatoes were transported by donkey to be sold in Saint-Louis. The revenues allowed producers to have new production tools (cast-iron buckets, hoes, *iler* which is a long-handled scuffle *hoehilaire*, cans, rakes, axes and machetes).

With the 1942 Plan bearing his name, Robert Sagot, an Agricultural General Inspector of the AOF and Director of the Agronomic Centre of Bambey from 1928 to 1942, designed the region's supply program on a local basis. Among his supporting measures was the objective to increase the production

of Dakar's vegetable gardening belt from 12,000 tons in 1938 to 17,000 tons in 1944. This encouragement was furthermore seen as decisive for the development of market gardening, already existing in Cape Verde Peninsula and the Niayes territory. Soil saturation near Dakar encouraged improvement of the northern area, which was of poor quality. In fact, in 1945, to better rationalize production and improve quality, farmers in Dakar formed a syndicate named le Syndicat des Jardiniers et Maraîchers du Cap-Vert (SYNJARMAR). This syndicate initiative provided inspiration and market gardening extended little by little all along the Niayes. Training increased, coupled with campaign planning.

### 3.1.6. Impacts of the Drought in the 1970s–1980s

Drought in the 1970s caused considerable changes in the Niayes' agricultural activities and population density. For example, in the Southern Niayes, dune slopes with loamy sandy soils (*dior*), still less cultivated in cereals and peanuts, became unproductive and were finally abandoned. These fallow areas were subject to sale to civil servants on land close to Dakar's suburbs. These citizens had already invested in fruit arboriculture. This had been greatly developed, mainly along the "Niayes' route" (the Thiaroye–Malika–Rufisque axis) which was opened on the national highway situated next to the main market for horticultural produce selling in Thiaroye. Aviculture developed in Dakar's periphery, but in the 1980s drought persisted; NSQ groundwater carried on decreasing. In basins where ponds formerly existed, market gardening occupied the lowest lands where it was possible to access water because of farmers digging basic wells. Peaty soils (*xour*) on which rice was cultivated became dewatered (except in wintering). People cultivated potatoes on these soils henceforth and cabbage on the silty–clayey slopes where sweet potatoes were cultivated before. To combat drought and satisfy constantly increasing demand, some wealthy farmers started to buy motor-pumps, pre-built cemented wells, and basins interconnected by PVC (polyvinyl chloride) plastic piping. This allowed for cultivating its wide surface and multiplying campaigns as it was possible to cultivate even late in the dry season. The first established families (*Lebous* in the South and Centre, and the *Wolof* or *Fula* in the North), who had access to best soils and other sources of income (fishing, cattle breeding), could obtain such materials. Traders also had the means to buy land (without originating from the villages) and to invest in drainage materials and water distribution. Despite motorization, some activities required manual work (picking, weeding, harvesting); this slowly encouraged the family to seek manpower outside of their household.

The Niayes absorbed part of a rural exodus, with migrants seeking income-generating activities throughout the year. Much of the land had not been turned to profit; accordingly, the chiefs of the villages granted ownership rights to each newcomer. The Ndioukis were by preference saturated because of easy water access (manual watering was easier) and the availability of organic materials (litter from *filao* trees). This beneficial ownership was from time to time transformed into real ownership due to alliances (mainly marriages). After Ndioukis' saturation, the migration waves were oriented to semi-fixed dunes, but access to water was more difficult.

A 5–6-month seasonal contract was negotiated between the already established cultivators and job hunters. These seasonal workers, who are present mainly during dry seasons, are called *sourghas*. The worker is fed and accommodated on the farm. He works by himself on a dedicated plot (e.g., from 800 to 1200 m<sup>2</sup> in manual culture; 2500 m<sup>2</sup> in the connected basin system). The farm owner provides inputs (seeds, animal excrements, and eventually synthesis fertilizers) and production tools. The worker must manage all the production activities (nursery preparation, picking out, fertilization, watering, weeding, harvesting), and sell the produce at the market (the farmer provides the bags and the transportation). He gets half of the production's added value. A new type of agricultural venture, the family business, thereby emerged. A cultivator–employer, by getting 50% of the added value generated by *sourghas*, increases his income considerably. This sharing method, which is called *mbeye seddo*, has created a gap with regards to unequal access to drainage means, and has led to an unequal ability to make profit in the available basins. Remarkably, access to heavy equipment was not enough. It was also necessary, in order to secure production campaigns, to have a treasury: fuel to

ensure motor-pumps operations 70 to 90 days per campaign based on cultivated species, fertilizers, organic manuring, daily costs related to *sourghas* (rice, meat, tea, soap, etc.).

### 3.1.7. Since 1995, an Increasing Level of Equipment and Production

Among the objectives of the 1995 CFA Franc devaluation was “the agricultural income enhancement by (1) encouraging exportations and internal demand for local agricultural produces, (2) increasing price paid to cultivators for these produces and creating new opportunities for activities upstream and downstream production. Analysts forecast a rise of market gardening channels due to the competitiveness and profits within European markets (French bean) as well as African markets for basic market gardening produce (onion, tomatoes)”. For instance, in Senegal, the national production of onions has experienced intense growth, but this was mainly the case after the CFA Franc devaluation. This growth significantly increased prices among producers.

The drought between the 1970s and 1980s was conducive to the settlement of numerous rural migrants in the Niayes, and allowed ancient farmers of the peanut basins or ancient transhumant breeder of the Ferlo to find alternative income in this trading agriculture; moreover, farms could develop activities requiring manpower, by leaning on *sourghas*. The phenomenon intensified with the CFA Franc devaluation (in 1994), which encouraged cultivators to produce trading cultures (mostly onions, but also tomatoes, carrots, and cabbages), more intensely (two cycles per year in the northern area; three to four cycles in the central and southern areas), and in larger quantities. Family business farms, which were able to make much more savings than family farms, could reinvest in materials, recruit more *sourghas*, and extend their surface area. Some farmers have limited their responsibilities to supervision, entrusting almost all land to the *sourghas* by providing them a monthly salary instead of benefit-sharing. Capitalist arrangements became more and more numerous in the 2000s.

By the end of the 2000s, the following coexisted in the Niayes’:

- Capitalist arrangements (all workers are employees), which little by little concentrated peat bog land in the southern and central zones. They were equipped with powerful motor-pumps and irrigation networks. Watering was done using a hose. Workers receive monthly wages.
- Family businesses (farms with both family workers and employees) in the entire region, of variable size depending on equipment (simple wells using pulley for drainage; small motor-pumps feeding a concrete basin network; big motor-pumps associated with spraying hoses). Workers, *sourghas*, are fed and accommodated and receive by the end of the year half of the added value.
- Family businesses (all workers are family members), mostly of humble size, with equipment varying from wells to basin networks. They are situated mostly in the central and northern Niayes zones.

## 3.2. Contemporary Agrarian System Analysis

### 3.2.1. Determining the Economic Thresholds

The survival threshold (meaning the minimal level of necessary resources, Table 3) was estimated for an average family at CFA 149,000 per working person and per year (227 Euros). The evaluation of the “survival threshold” (per working person and per person to feed within the family) was possible by asking family members (including working and non-working members) what were their basic needs for a given year (i.e., the goods needed to ensure maintenance and reproduction in decent conditions). This threshold includes food and non-food expenses as well as self-consumption. This indicator was set for a family with an average of 12 persons including seven working persons (three men and four women), two retired persons (a man and a woman of more than 65 years old) and three young children (Table 3). This average family was considered based on data collected during surveys. The survival threshold per working person shows what each of them should own at the minimum to support their family. In Senegal, the work situation is extremely unstable: Dakar hosts more and more migrants from the countryside, for which the unemployment rate is very important. In such a condition, using the minimum legal salary as the farm survival threshold would be irrational.



**Table 3.** Model of the survival threshold for a family composed of seven working people, two retired persons, and three children.

Item	Qty	Unit	Unit Price (FCFA)	Expense (FCFA)	Frequency	Ratio	Yearly Expenses (FCFA)
<b>Food</b>							
Rice	3	kg/day	300	328,500	every day	1.00	328,500
Millet	3.7	kg/day	150	202,575	every day	1.00	202,575
Fresh mill	3.7	kg/day	30	40,515	every day	1.00	40,515
Peanut paste	0.4	kg/day	240	23,360	2 days over 3	1.00	23,360
Crushed peanut	0.4	kg/day	480	23,360	1 day over 3	1.00	23,360
Charge in water	1	Daily rate	150	54,750	every day	1.00	54,750
Condiments	1	Daily rate	400	146,000	every day	1.00	146,000
<b>Total</b>							<b>819,060</b>
<b>Clothes</b>							
Uniform for children	9	set	2500	22,500	3 times per year (start of academic year, tabaski and other)	1.00	22,500
Sandals for women	6	pair	750	4500	2 times a year	1.00	4500
Uniforms for women	16	Set of 3 pagnes	4000	64,000	3 times	1.00	64,000
Sandals for men	8	pair	750	6000	2 times a year	1.00	6000
Uniforms for men	12	uniform	4000	48,000	2 times	1.00	48,000
Sandals	8	pair	750	6000	2 times a year	1.00	6000
<b>Total</b>							<b>151,000</b>
<b>Consumable</b>							
Soap	12	month	1500	18,000	pm	1.00	18,000
Battery or oil	1	Monthly rate	1500	1500	pm	1.00	1500
Health care	12	month	3000	36,000	pm	1.00	36,000
<b>Total</b>							<b>55,500</b>
<b>Utensils</b>							
Torch	8	Unit	1000	8000	1 year over 4	0.25	2000
Cooking pot	4	Unit	4000	16,000	1 year over 2	0.50	8000
Basin	2	Unit	3000	6000	1 year over 4	0.25	1500
Bucket	2	Unit	3000	6000	1 year over 4	0.25	1500
Spoon	4	Unit	500	2000	1 year over 5	0.20	400
Cup	10	Unit	300	3000	1 year over 5	0.20	600
Tray	4	Unit	2000	8000	1 year over 5	0.20	1600
Plate	10	Unit	300	3000	1 year over 5	0.20	600
Mortar	2	Unit	2500	5000	1 year over 5	0.20	1000
Pestle	2	Unit	250	500	1 year over 5	0.20	100
<b>Total</b>							<b>17,300</b>
<b>Survival threshold</b>							<b>1,042,860 (≈1,590 €)</b>
<b>Per working person</b>							<b>148,980 (≈227 €)</b>

Acronyms: Qty = quantity.

Another threshold, the opportunity cost of labour, was estimated based on the salary obtained by a non-qualified worker. In the survey area, the labour force is remunerated at 1000 FCFA a day (about one euro and fifty cents) for basic activities (as a farm labour for instance). We considered that a labourer works 300 days a year.

### 3.2.2. Typology of Production Systems

Three criteria have brought social differentiation among the Niayes' households: access to land, importance of livestock, and access to capital and/or treasury (with market gardening requiring an important pre-financing level). The typical trajectories were as follows:

- Main *Lebou* owners. Installed very close to southern peat bogs' surrounding, they had access to most fertile lands in Southern Niayes and could develop a more diversified culture and access to motorization by converting a part of land inheritance into money and/or making savings from fish sales.
- Wealthy families descended from *Fulani* or *Toucouleur's* stockbreeders. Established very early in the pasture area (G), they could start market gardening and were at once able to finance campaigns (treasury from stock sales), get materials (transportation of manure, crops, pumps, and hoses), and fertilize fields: these families have important land reserves, both in *Niayes* and *Dieri*; herds are parked in the *Dieri* in rainy season and dried manure from stockyards are transferred to the *Niayes* progressively with culture installation.
- Wealthy *Wolof* families also settled very early. They started off with combined rain-fed agriculture in the *Dieri* and market gardening in the *Niayes* during the dry season. Little by little, with the peanut channel crisis and drought, they became established in the *Niayes*. Those who saved capital in the form of herds could later get enough materials.

Nowadays, these three groups implement production systems that largely call for *sourghas* (seasonal workers).

Here are the two most frequent settlement processes for new farmers in the *Niayes*:

- They are cultivators arriving in a place with no other means than their ability to work. They started as *sourghas*, moving between the peanut basin and the *Niayes*. Then, they progressively made alliances (marriages) and became autonomous, but very slowly (free land lending).
- They are cultivators and tradespeople (*bana bana*). They were either in charge of peanut cooperatives, or peanut collectors in the *Dieri*, or hawkers of various goods. They knew the *Niayes* from their trading activity, or from associative movements (agricultural syndicates). Owning some capital, they could get land in the peat bogs, and became rapidly equipped with motor-pumps. Today, *bana bana* merchants still buy land to cultivate that is on the way to decapitalization; *bana bana* can also open new fields in area where watering is more difficult. Their heavy equipment allows them to resolve drainage issues. The *bana bana* group generally calls for paid manpower (Table 4).

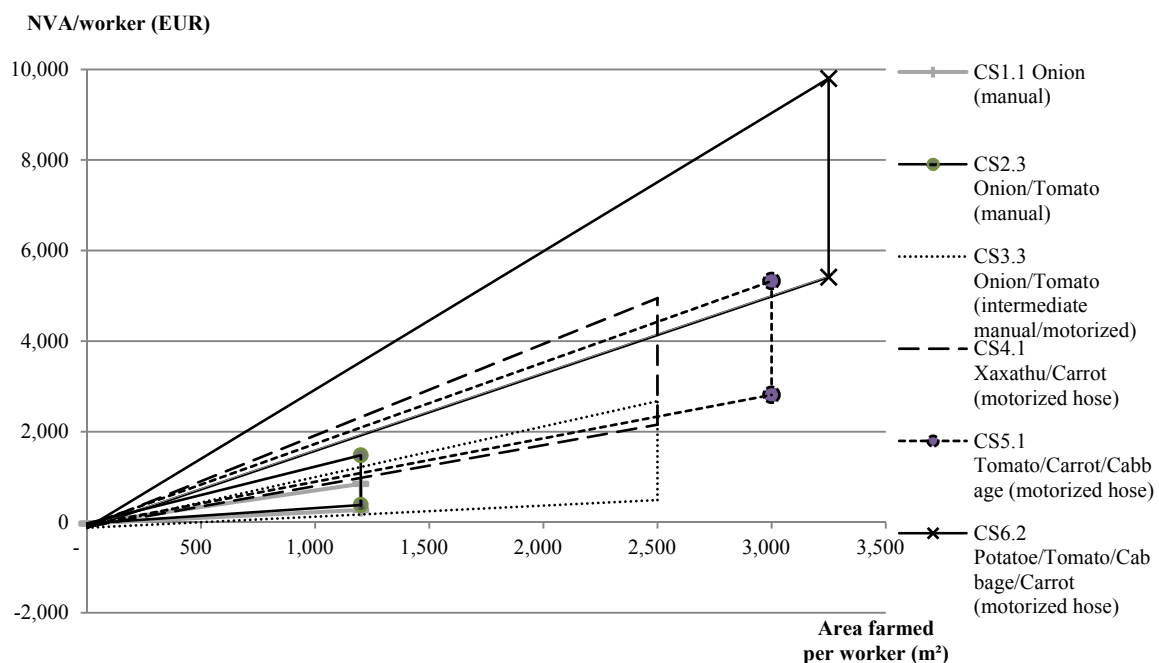
In terms of farms' organization, there are three main methods:

- Direct control, in which all activities are accomplished by family members. During heavy periods, they manage the work with assistance from villagers. In comparative agriculture, this is called "a family farm".
- The *mbey seddo*, in which the gross added value is split fifty-fifty between the employer and the *sourgha*. The *sourghas* are foreigners—Guinean, Malian, Gambian—or Senegalese from poor villages of the *Dieri*. These groups are generally present in the *Niayes* for about six months a year. In comparative agriculture, this is called "a family business farm".

- The use of employees (with a monthly salary and not a share of added value). The head of the business hires labour on a monthly basis. In comparative agriculture, this is called “a capitalist farm”. During heavy periods, the head also calls for workers, who are paid on a daily basis, with money or in kind. The labourer often comes from a nearby village or are manual farmers who devote a quarter of their time to such employment and the rest to his family’s vegetable garden.

Also, there are three levels of equipment that give evidence of unequal productivity (Table 5 and Figure 6), regardless of the type of farm organization (family farm, family business or capitalist):

- Manual: water drawing and distribution are manual (with a bucket-pulley and a bucket, respectively);
- Combined: water drawing is motorized (motor-pump) but water is distributed manually (bucket);
- Almost entirely motorized: use of a motor-pump, then water is distributed via a network of vinyl tubing (PVC) and sprayed through a hose.



**Figure 6.** Comparative labour productivity of manual (CS1.1), semi-motorized (CS2.3), and motorized (CS 4.1, 5.1 and 6.1) cultivation systems. NVA: net value added; CS: cropping system.

### 3.2.3. Land Owners’ Accumulation of Wealth

To describe this process of social distinction, let us consider the case of a family cultivator initially doing manual work (CS 1.1). Alone, doing manual work, the farmer cannot cultivate more than 1200 m<sup>2</sup> of onions. If the farmer gets associated with a *sourgha* (CS 2.1), he doubles the surface and increases his income by 50% for the surface unit (Figure 6). This “fruit-part or benefit-sharing contract” is named *mbeeye seddo*. As the employer is committed to his plot and does not provide more than a few days of supervision, the *mbeeye seddo* is advantageous for him. In fact, the income difference is more and more important if considering the man/day ratio (a ratio of one to four or one to five following obtained income, in Table 6 and Figure 7).

**Table 4.** Niayes agricultural ventures' historical trajectories and current production systems (PS).

Main Types Based on Social Organization of the Farm	Sub-Types Based on Irrigation Capacities of the Farm	Basin Types	Origins/Social Trajectories of the Farmers
PS1: Familial	PS1.1: Familial Manual	B	Recent migrants in zone B, coming in the 1980's–1990's from zone H, with no other means but their labour force. <i>Fulani</i> shepherds starting agriculture (treasury brought by cattle selling)
PS2: Familial with employees	PS2.1: Employer Manual	B, C	Idem, but with some amount as economy brought from the <i>Dieri</i> . Thanks to success in livestock farming, they were gradually able to employ <i>sourghas</i> .
PS3: Capitalist	PS3.1: Capitalist manual	B, C, D	<i>Bana-bana</i> traders from <i>Dieri</i> knowing the <i>Niayes</i> from their work.
PS1: Familial	PS1.2: Familial semi-motorized (pumps and basins)	C, F	Recent migrants with consistent means. <i>Fulani</i> shepherds from zones C, F and B, with few cattle in the beginning.
PS2: Familial with employees	PS2.2: Employer semi-motorized (motor-pumps and basins)	C, D	<i>Fulani</i> shepherds from C, F and B zones, with access to larger surfaces and integration agriculture-breeding.
PS1: Familial	PS1.3: Familial motorized (hoses, drop-by-drop)	D, E	Young people from large families. Recent comers, former employees in cities or traders having invested little by little in the area through harvesting campaigns.
PS2: Familial with employees	PS2.3: Employer motorized (hoses, drop-by-drop)	D, E	Descendants of wealthy families; marabout notables; <i>bana bana</i> traders; former employees in cities (early retired or in reorientation, former immigrant). Systems maximizing peat bog valuing.
PS3: Capitalist	PS3.3: Capitalist motorized (hoses, drop-by-drop)	D, E, F	Wealthy <i>bana bana</i> traders; <i>marabout</i> notables or their relatives.

PS: Production system.

**Table 5.** Comparative performance of the various irrigation methods used in the Niayes.

	Strictly Manual	Manual + Basins	Motor-Pumps + Basins	Motor-Pumps + Hoses	Drop-by-Drop
Volume of water (l/m <sup>2</sup> /j)	9	9	9	7	4
Maximal watered surface $S_{\max}$ /working person/campaign	800 m <sup>2</sup> /working person (cabbage) to 1200 m <sup>2</sup> /working person (onion) (1 ha p. 10 working persons)	1200–1500 m <sup>2</sup> (1 ha p. 8 working persons)	2000–2500 m <sup>2</sup> / working person	2 ha p. 2 working person + 2 trainees (sometimes 4 working persons + 4 trainees), so 5000 m <sup>2</sup> /working person (sometimes 2500)	1 ha p. 1 working person, even more
Cultivation ability ratio (basis1 = $S_{\max}$ in manual)	1	1.2–1.5	2–2.5 (+40% of basins)	3.5	10
Number of campaigns maximum/year/working person	2	2	2	3–4	2–3
Investment (annual depreciation per ha)	230 €	380 €	300 €	160 €	4000 €

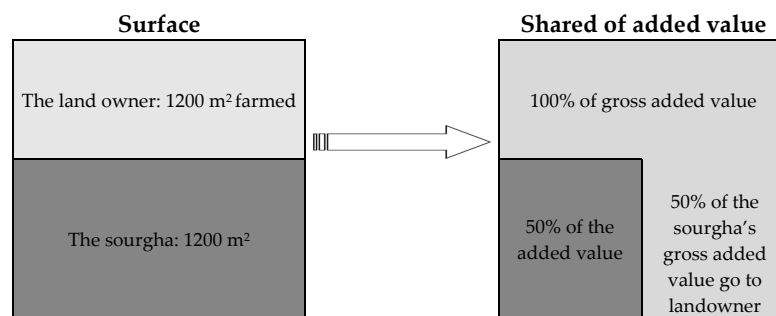
$S_{\max}$ : maximum surface; ha: hectare.

**Table 6.** Added value partition between employer and *sourgha* within an onion manual cultivation system using a *mbeye seddo* (benefit sharing contract).

Plot of 1200 m <sup>2</sup>	GAV (€)	GAV Sourgha (€)	GAV Employer (€)	Workload (Man Days)				Labour Productivity GAV/md (before Sharing)	Income/md Sourgha	Income/md Employer and Family
				Total	Employee (Sourgha)	Employer	Punctual Labourers			
Low yields	301	151	151	183	138	26	20	1.6 €	1.1 €	6 €
Average yields	684	342	342	196	138	32	27	3.5 €	2.5 €	11 €
High yields	875 €	438	438	203	138	35	31	4.3 €	3.2 €	13 €

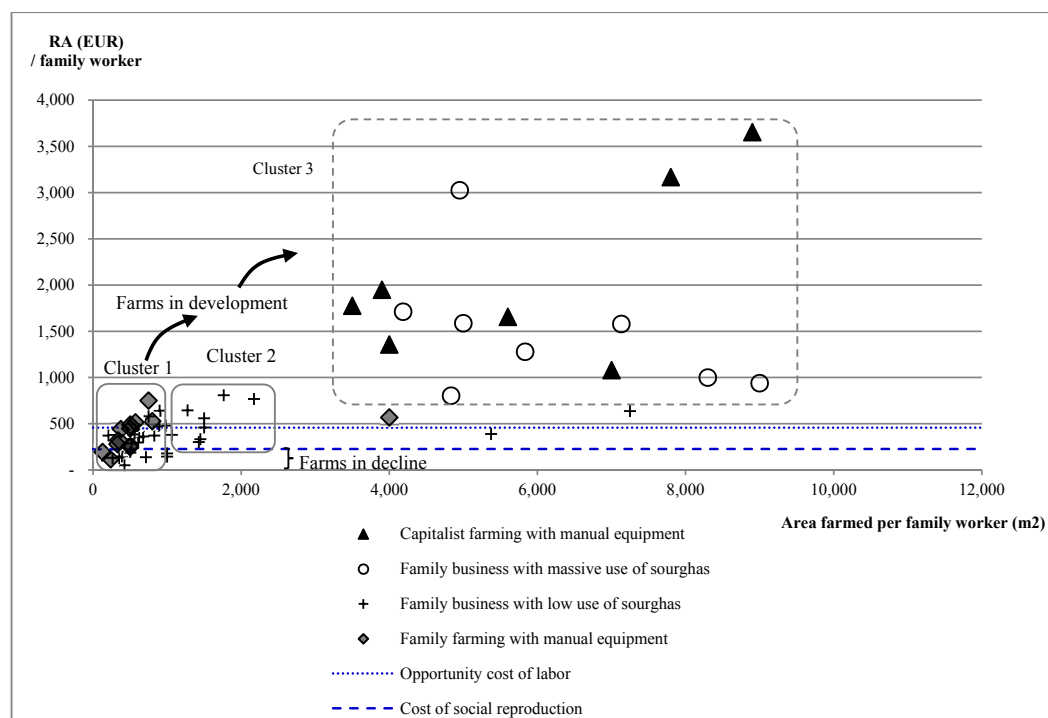
GAV: Gross Added Value = Gross Product – Intermediate consumptions. md: man-day.





**Figure 7.** Representation of unequal development due to income partition between land owners and *sourghas*—Example of 1200 m<sup>2</sup>, which is the maximum surface in manual agriculture—The land owner accomplish his own farming on 1200 m<sup>2</sup> farmed (that is the maximum surface for one person with manual equipment) and keeps 100% of the added value he has generated. The *sourgha* who borrows 1200 m<sup>2</sup> to the landowner reassign 50% of the added value he has generated to the landowner. The two persons had the same level of effort but one (landowner) earns three times the income of the second (*sourgha*).

In Figure 8, we present results from surveys over 57 manual farms. Family manual farms (PS1.1) and some of the family businesses that have low use of *sourghas* (PS2.1) can hardly manage to reproduce their business from year to year (cluster 1). A lot of them fall under the survival threshold and almost all are tempted to sell their labour force in cities (with little hope) or in capitalist-type farms that hire experimented workers at 30,000 FCFA (45 euros) a month. Hiring *sourghas* is a solution adopted by wealthier farms (with important herds and, therefore, able to provide campaign costs and *sourghas*' living expenses in advance), if they have available land reserves. Such collaboration allows the heads of employers' manual farms (PS2.1) to sensitively increase surfaces per family member by entrusting a part to *sourghas* and thereby make more profit (cluster 2). Access to land coupled with the ability to save money and then hiring employees is a major shift in the history of farming in the Niayes region.



**Figure 8.** Comparative performance of manual production systems.

### 3.2.4. Motorization Allows an Acceleration of Enrichment

Intermediate motorization (motor-pump + basin network) or complete motorization (motor-pump + sprinkling) allows cultivators who are able to afford it to dramatically exceed the survival threshold. That applies to family, family business, or capitalist-type farms (Figure 9). Fruit-part contracts remain valid in combined systems. Yet, for many farms, purchasing a motor-pump would be an opportunity to “liberate themselves” from *sourghas* and keep the whole generated wealth within the family. Otherwise, fruit-sharing brings income to a level that is far from that of a system employing many *sourghas*. This reorientation allows them to make savings again, to invest in pumps and basins in other plots within the family reserve, and to entrust them to a *sourgha* using a fruit-part contract. The third accumulation phase most of the time results in almost total motorization: motor-pump + sprinkler. In such systems, remuneration is the rule. Within motorized farms, the most profitable are the capitalist-type farms of the Niayes’ southern peat bogs: these are able to undertake three and even four campaigns a year (PS 3.3.3).

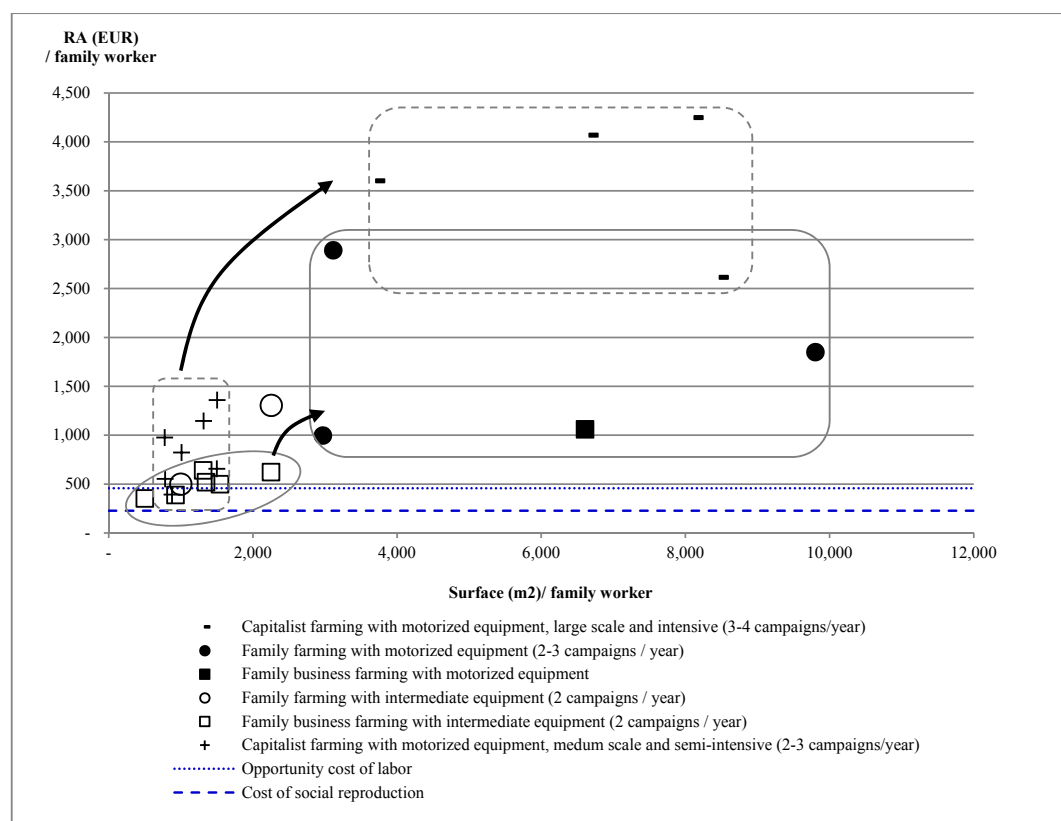


Figure 9. Comparative performance of semi-motorized and motorized production systems.

## 4. Discussion

In the present agrarian system, we distinguished three main production systems categories (family farming, family business and capitalist agriculture; see Table 7). Within these groups, farms use manual, semi-motorized or motorized cultivating systems. With manual cultivating systems, it is possible for a working person to develop 800 to 1200 m<sup>2</sup> of Niaye (a piece of fertile land located in depressions between dunes), with at best two yields of vegetables per year. The income varies from 500 to 1500 Euros/working person/year. Systems that combine motorized pumping and manual watering increase that to 2500 m<sup>2</sup>/working person/year with two plantings per year and an income of 500 to 2600 Euros/working person/year. Complete motorization (pumping and water distribution, using hoses) allows two to four plantings per year and 3000 to 3500 m<sup>2</sup>/working person. In such a case, income varies between 2000 and 10,000 Euros/working person/year.

**Table 7.** Synthesis of the main features of the five main production systems identified ( $N = 79$ ).

	Manual Production System (Number of Farms Surveyed)											
	Family-Type Farms with Manual Equipment SP1.1 (13)			Family Business/Manual Equipment SP2.1 (37)			Capitalist-Type Farms with Manual Equipment SP3.1 (7)					
	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.			
Number of family members	8	17	2	8	25	2	2	3	2			
Number of family workers	5	12	1	5	13	1	1	2	1			
Number of employees or sharecropper	-	-	-	4	10	1	9	16	5			
Arable land (m <sup>2</sup> /family worker)	733	4000	129	2329	9000	208	5814	8900	3500			
Total cultivated area (m <sup>2</sup> /family worker)	440	750	129	1140	4186	169	4750	8300	3000			
Livestock (Tropical Livestock Unit/ha cultivated)	25	125	-	16	146	-	6	13	-			
Net annual income (EUR/family worker)												
Average	397			620			2091					
Maximum	751			3025			3653					
Minimum	116			51			1079					
	Intermediate and Fully Motorized Irrigation Systems (Number of Farms Surveyed)											
	Family-Type Farms/Intermediate Motorizationsp1.2 (2)			Family Business Intermediate Motorization SP2.2 (6)			Family-Type Farms with Machines SP1.3 (3)			Capitalist-Type Farms with Machines SP3.3 (11)		
	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
Number of family members	15	19	11	10	17	3	31	79	6	12	23	5
Number of family workers	10	12	7	7	11	2	20	51	5	8	13	5
Number of employees or sharecropper	4	8	-	5	11	1	1	3	-	6	16	2
Arable land (m <sup>2</sup> /family worker)	1627	2254	1000	1313	2250	500	5296	9804	2970	3158	8475	777
Total cultivated area (m <sup>2</sup> /family worker)	1484	2254	714	1118	2000	500	2152	3113	1431	2358	5556	777
Livestock (Tropical Livestock Unit/ha cultivated)	1	2	1	2	6	-	5	14	-	10	39	1
Net annual income (EUR/family worker)												
Average	902			504			1913			1858		
Maximum	1304			640			2892			4248		
Minimum	499			353			996			393		

Manual family farms (i.e., without employees) or family businesses, which hire few *sourghas*, face difficulties because the income is barely above the survival threshold (an average of 260 to 300 Euros/working person/year, sometimes 100 Euros) on less than 2000 m<sup>2</sup>/family working person. When they depend heavily on *sourghas*, farms with manual equipment earn between 1000 and 1800 Euros/working person/year on 4000 m<sup>2</sup> to one ha/family working person. Semi- or completely motorized farms can use between 1000 m<sup>2</sup> (semi-) and 1 ha/family working person (complete), with incomes varying from 1500 Euros/working person/year (family system with motorized pumping and manual watering) to 3500 Euros/working person/year (intensive and motorized capitalist agriculture with four plantings/year).

## 5. Conclusions

To conclude, we insist that access to capital is one of the main obstacles to market gardening development in the Niayes. Troubled farms are those that have not yet opted for the *mbeye seddo* system due to their inability to cover *sourghas*' salaries and cultivation expenses in advance. Market gardening is very high-value-added production, but requires starting capital, mainly to purchase seeds, organic fertiliser (for those who do not have enough cattle), chemical fertiliser, packing and transportation. Besides, to provide *sourghas*' cost all through the campaign in advance, would weigh on farmers' capital. The main obstacle to family farms' development is access to capital. Family farms are mostly of humble size, and the work is demanding. To increase income, it would be sensible to intensify the cultivation system in a "reasonable way" by optimizing inputs (with respect to fertilisers' quality and doses and those of phytosanitary products), with the introduction of leguminous plants in shifts, using compost from filao trees litter (filao compost is proven to provide nitrogen) and eventually using mulching techniques. This will allow for mobilizing larger surfaces with a good productivity level in the long term. These farms support local employment, which is an essential lever to economic development in the region and to strengthening the social fabric (vs. capitalist ventures that tend to lay off the labour force).

The motorization of drainage would be a first, useful step in these farms' development. Nevertheless, does it lead to sustainable development? Drainage motorization requires use of fossil fuels, of which the price is uncertain. Moreover, if everyone is equipped with motor-pumps, cultivated surfaces will extend and groundwater use will be increasingly required. Risk of salinization will be all the greater, and there will also be the risk of air and water pollution. From the general interest point of view, with these risks taken into account, it would be more efficient to maintain a labor intensive activity. If work conditions in the Niayes region are too harsh, *sourghas* choose to take their chances somewhere else, even if the unemployment rate is very high. It would be more reasonable, in general, to support employment in the Niayes. In doing so, intermediate solutions improving water pumping (mainly in areas where water ground is deep) without going to extremes would be useful. To mitigate the impacts of motorized farms on the water table, two techniques are being tested by NGOs: sprinklers and drip irrigation. The first technique's objective is to control the flow of water by replacing the irrigation hoses with more professional sprinklers: this seems to be one of the best first steps towards sustainability improvement within motorized farms and increase the productivity of manual farms step by step. The second solution's efficiency is proven in terms of low water consumption (diminution by half) and labour productivity (800 to 1200 m<sup>2</sup> for manual farmers versus 10,000 for drip irrigation) [33]; however, the NGO's field teams have faced many failures due to a lack of training given to farmers and high investment costs. These two difficulties need to be addressed in the future [34,35].

The history of the Niayes shows a progressive enhancement of the cultivation of vegetable gardening basins per farmer in the Niayes, which has led, mainly since FCFA devaluation (1994), to a huge transformation in farms' social organization. Today, however, most agricultural enterprises have remained manual, with a cultivation ability of one to two plantings per year. The accumulation process is based on an income differential inherent to the added value sharing method: related to the

production obtained with the *sourgha* labour force, the employer got 50% of the added value. Due to the accommodation of migrants escaping from drought, *mbeye seddo* indeed fostered remarkable job creation, but also increased income inequality. The salaries for *sourghas* is quite unattractive and they have to wait until the end of harvesting to receive their income. However, the system urges them to terminate their contract as quickly as possible, at the risk of selling the product for a rather low price (vegetables are not yet mature, therefore weighing less and sold cheaper). Would it not be possible to think of a system where the *sourgha* receives monthly salaries (which would be superior to the labour opportunity cost)? If *sourghas* have better conditions, work would also be improved, and adapted practices (fertilization, pesticide, harvesting calendar) would also be respected. A new system of value-added sharing should be negotiated between the two concerned parties, farmers and *sourghas*, on whom the sustainability of the system depends.

Employers often talk about high living expenses. Yet, it is not the expenses related to *sourghas'* food that gives farmers an incentive to get rid of *sourghas* and replace them with hoses. The price of inputs has risen for some years, mainly that of seeds and imported fertilisers (those containing nitrogen and potassium). Production costs have increased to a greater extent, with decreasing returns (due to unsuitable practices): this places farmers under the obligation to dismiss their labour. Apart from improving workers' conditions, it is also important to improve production quality in order to maintain high returns, and therefore preserve a high employment level in the Niayes area.

All this requires a new approach coupled with "tailor-made" technical monitoring, seeking as much sustainability as possible, and a new pre-financing method for campaigns. Savings and loans may also play a key role.

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