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OFFICE OF MACROECONOMIC ANALYSIS

Socio-economic impact assessment of the tsetse fly eradication campaign in the Niayes area of Senegal

FINAL REPORT

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Contents

Executive Summary

The aim of this study was to assess the socio-economic impact of the tsetse fly eradication campaign on animals, and pastoralist and agro-pastoralist households, in the Niayes area. After 10 years of implementation, the tsetse fly project needed to be evaluated in terms of its socio-economic impact on livestock and livestock farmers in the Niayes area and on the Senegalese population in general.

The methodological approach used combines qualitative and quantitative analyses. The qualitative analysis was based on individual and group interviews with those involved in designing and implementing the eradication campaign, gathering their views on the possible impact of the project. The quantitative analysis was based on household surveys of a random sample in the Niayes area and in a control area (Sine-Saloum). The impact was measured using the propensity score matching (PSM) method. Secondary data was also used to support the analysis.

The results of the socio-economic impact assessment of the tsetse fly eradication campaign in the Niayes area were satisfactory. The main local cattle breeds identified in the control and treatment (beneficiary) groups were N'dama taurine, Gobra zebu and Djakore. The percentage of livestock farmers with N'damas was, however, higher in the control groups than among the beneficiaries (74.7% compared with 53.5%). In both areas, local breeds outnumbered exotic ones. Nevertheless, the percentage of exotic breeds was higher among the beneficiaries than the controls (20% compared with 10%). In terms of mortality, the results show that the rate was 20% in the controls and 15% for the beneficiaries. The eradication of the tsetse fly in the Niayes area has probably contributed somewhat to controlling cattle mortality.

The results on the livestock farmers' income show that most did not exceed 1 000 000 CFA francs per year in 2010. Following the eradication campaign, there was a positive trend in their incomes — both the controls and the beneficiaries saw their incomes rise. Among the controls, 33.68% of livestock farmers had an income of less than 500 000 CFA francs/year — that figure is now 6.74%. Among the beneficiaries, 18.11% of farmers had incomes of between 5 000 000 and 10 000 000 CFA francs, whereas the proportion is now 34.16%. Those with incomes of between 1 and 5 million rose from 55% to 59%.

Between 2010 and 2022, positive changes were noted among the beneficiaries, particularly in terms of reduced pressure from tsetse flies (95% of households), increased livestock productivity (56%) and higher incomes (46%). Changes among the controls were mainly attributable to an increase in livestock numbers (67%), livestock productivity (65%) and an increase in livestock farming income (56%).

In terms of animal health, tsetse-borne trypanosomosis was the most prevalent disease among 92% of cattle herds, followed by lumpy skin disease and foot-and-mouth disease. The beneficiaries had a high incidence of foot-and-mouth disease, followed by ticks and lumpy skin disease. In 2023, trypanosomosis was not reported in other species (sheep, goats, horses and donkeys).

The PSM results show that eradicating tsetse flies in Niayes has a positive effect on income from livestock farming and sales of milk, on the introduction of exotic breeds and the cost of treating trypanosomosis. Indeed, using the kernel method, there is a positive and significant effect of 7 629 405 CFA francs on income from livestock farming and an estimated effect of 7 422 320 CFA francs using the nearest neighbour (NN) method. In other words, eradicating tsetse flies would increase the income of livestock farmers in the Niayes area by 45% using the

kernel approach and 44% according to my NN method. The impact on income from milk sales is also positive and significant. It is estimated to be 581 133 CFA francs using the kernel method and 583 483 CFA francs with the NN method. According to these figures, eradicating tsetse flies would increase the income from sales of milk for livestock farmers in the Niayes area by 60.9% and 61% with the kernel and NN methods, respectively. Eradication also has a positive effect on the composition of livestock farmers' herds, with the introduction of exotic breeds. Eradicating tsetse flies would increase the income of livestock farmers in the Niayes area by 18% using the kernel method and 19% with the NN method. The cost of treating trypanosomosis is estimated to be -7306 CFA francs with the kernel method and -7355 CFA francs with the NN method. Eradicating tsetse flies would reduce the cost of treating trypanosomosis among livestock farmers in the Niayes area by 7306 CFA francs (63.6%) and 7355 CFA francs (63.7%), respectively.

Between 2017 and 2024, 5965 pregnant dairy cows were imported to boost milk production in Senegal. At least 11 930 exotic cattle have therefore been introduced into the country. In 2024, the majority of imported heifers (986 cows, or 72%) were distributed between the regions of Dakar, Thiès, Saint-Louis and Diourbel. Of these 986 exotic cows, 93% (920 cows) were destined for the Niayes area: the regions of Dakar, Thiès and Saint-Louis. This demonstrates that exotic cattle can now live in the Niayes area, compared with the period before the tsetse eradication campaign. One of the main aims of importing pregnant heifers was to improve national milk production. Between 2018 and 2024, milk production from exotic cows rose from 4.3 to 62.5 million litres. Alongside the increase in imports of exotic heifers, the number of beneficiaries also rose between 2017 and 2024, from 64 to 432 intensive livestock farmers and farms. In 2007, three years before the start of the eradication campaign, there were barely 13 intensive livestock farmers and farms with exotic heifers.

Before the eradication campaign, the percentage of trypanotolerant cattle (Djakore) in the extensive system was 98%, whereas in 2023 it was 20%. For intensive systems focused on milk production, this percentage fell from 13% to 0% between 2010 and 2023. By contrast, the Gobra breed increased over the same period in the extensive and intensive milk systems, rising from 0.1% to 21% and from 0.5% to 28.5%, respectively. The percentage of exotic cattle also increased over the period, rising from 1.5% to 15% and from 1.8% to 27% for the extensive and intensive meat systems, respectively. The quantities of milk sold per female rose sharply over the period for the three systems, from 157 L to 1823 L, from 110 L to 864 L and from 339 L to 2120 L, respectively. Sales prices per head also increased on average for the three systems, rising from 174 485 to 279 679 CFA francs, from 288 621 to 340 601 CFA francs and from 152 182 to 679 166 CFA francs, respectively. Meanwhile, the average herd size fell for the extensive and intensive dairy systems, from 52 to 48 and from 31 to 16, respectively, which is positive in terms of environmental impact.

Acronyms and abbreviations

AAT	African animal trypanosomosis
ANIPL	National Association for the Intensification of Dairy Production
BAME	Macroeconomic Research Bureau
CIRAD	International Cooperation Centre of Agricultural Research for Development
DSV	Department of Veterinary Services
FAO	Food and Agriculture Organization of the United Nations
HH	head of household
IAEA	International Atomic Energy Agency
ISRA	Senegalese Institute for Agricultural Research
LNERV	National Laboratory for Livestock and Veterinary Research
NN	nearest neighbour
PCR	polymerase chain reaction
PSM	propensity score matching

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Introduction

Developing and emerging countries need to expand their agriculture and livestock farming to support their populations' economic growth and food security. However, livestock farmers in Africa have to contend with tropical diseases that prevent them from developing their farms' potential, increasing their herds' productivity and investing in improving their results. These diseases are major constraints for livestock farmers and trypanosomosis is one of the biggest health risks. Tsetse flies are vectors of African animal and human trypanosomosis (AAT). They are present in 37 countries across an area of 8.5 million km^2. Forty-six million cattle are at risk of AAT, which directly affects the health of the livestock, agricultural capacity and land use (Swallow, 2000; Itard et al., 2003; Alsan, 2015). Across the continent, direct annual losses for livestock farming have been estimated at US $1.34 billion (Kristjanson et al., 1999) and overall losses for agriculture and livestock farming have been estimated at US $4.75 billion (Vreysen et al., 2013) These losses are all the greater because the tsetse distribution is in the most fertile areas (Alsan, 2015). Scientists, African organizations (in the African Union in particular) and producers in endemic areas describe AAT as the main health constraint to livestock farming in sub-Saharan Africa, particularly in the Niayes area of Senegal. After more than a century of efforts to control trypanosomosis, it remains a subject of socio-technical controversy (Maudlin, 2006).

Trypanosomosis was endemic in the Niayes area and transmitted by a single species of tsetse fly (*Glossina palpalis gambiensis*). In 2007, its seroprevalence was estimated at 28.7%, 4.4% and 0.3% for *Trypanosoma vivax*, *T. congolense* and *T. brucei brucei*, respectively (Seck et al., 2010). The Niayes area is densely populated (150 inhabitants/km^2).

Following an historic decision by African governments at the African Union summit in Lomé, Togo in July 2000, a continent-wide political initiative was introduced in 2001 to eradicate tsetse and human and animal trypanosomosis: the Pan African Tsetse and Trypanosomosis Eradication Campaign (PATTEC). A number of national initiatives are part of the PATTEC framework. Senegal launched its tsetse fly control campaign in 2005, the "Tsetse control project in Niayes", which uses integrated pest management, including the sterile insect technique, to eradicate tsetse fly populations. This eradication campaign was designed and implemented by several institutions, including the IAEA, LNERV, DSV, CIRAD and FAO.

The project to eradicate tsetse flies in the Niayes area should be evaluated on the extent to which it achieved its objectives at the end of its implementation in 2023. The aim of the assessment

was to quantify the socio-economic benefits of the tsetse eradication campaign. Given the food and economic challenges facing Senegal, improving the health situation by controlling tsetse flies is seen as essential to:

(i) enhance and increase livestock production;

(ii) enhance and increase crop production through animal draught power and human health by improving nutrition.

The project partners' assumption on the eradication of tsetse flies in the Niayes area is that wiping out AAT will encourage innovation and progress, particularly in livestock production systems. Eradicating the flies will remove animal trypanosomosis from the study area, leading to a reduction in the cost of treating the animals, increased production and intensified farming systems with the use of exotic breeds and cross-breeds that produce more milk. In addition, eradicating tsetse flies should reduce production losses due to morbidity and mortality, particularly in traditional livestock farming.

The aim of this impact assessment of the tsetse fly eradication campaign in the Niayes area, commissioned from the Macroeconomic Research Bureau of the Senegalese Institute for Agricultural Research (ISRA/BAME), was to analyse changes in a number of socio-economic indicators among pastoral households in the intervention area (Niayes) before and after tsetse fly eradication. In addition, pastoral households in the intervention area were compared with pastoral households in a control zone — in this case the Sine-Saloum area (Foundiougne department in the Fatick region).

More specifically, the assessment has been divided into two parts:

An analysis of stakeholders' perceptions of the project's impact

Qualitative interviews carried out with key players (the project team, veterinary services, local authorities, decentralized services, national and foreign technical and financial partners, etc.) and focus groups held with people living in the intervention areas, in particular cattle farmers and their organizations. This assessment reviews the impressions (strengths and weaknesses) of the various project interventions to better understand perceptions of the eradication campaign. These players were also asked to formulate recommendations to ensure the sustainability of the project's achievements. In this first stage, the data from the socio-economic baseline study, conducted at the start of the project, was mainly collected and used by the research team.

An assessment of the effects of the project on extensive and intensive cattle farms and pastoral households

The effects of the eradication campaign on pastoral households were measured both in terms of animal productivity (herd size, milk production, meat production, reduction in morbidity and mortality, etc.) before and after eradication, and by changes in the income of livestock farmers/producers, particularly from the sale of livestock and livestock products before and after eradication. Expenditure on medicines (in particular the purchase of trypanocides) was also measured, both before and after eradication. We also compared the total cost of eradication with the total post-eradication benefits. This economic cost was then analysed from the point of view of households and compared with the benefits they derived from eradication.

In addition, there was a second level of comparison of indicators in households in the intervention area and those in the control zone (Foundiougne).

I. The intervention area

The study area was the Niayes where the tsetse fly eradication project was implemented over a period of approximately 10 years. The Sine-Saloum area was chosen as the control area for methodological reasons as it has a high density of tsetse flies. The main difference between the two areas was the absence of an eradication campaign in Sine-Saloum. The Niayes area consists of a narrow strip, between 100 and 280 km long, and between 25 and 30 km wide, extending from the Cape Verde peninsula to the Mauritanian border, and from the coastal fringe known as the Grande-Côte approximately to the road leading from Dakar to Saint-Louis. There are four administrative subdivisions in the Niayes area: the regions of Dakar, Thiès, Louga and Saint-Louis. A district in the department of Pikine is named after it, the Niayes arrondissement.

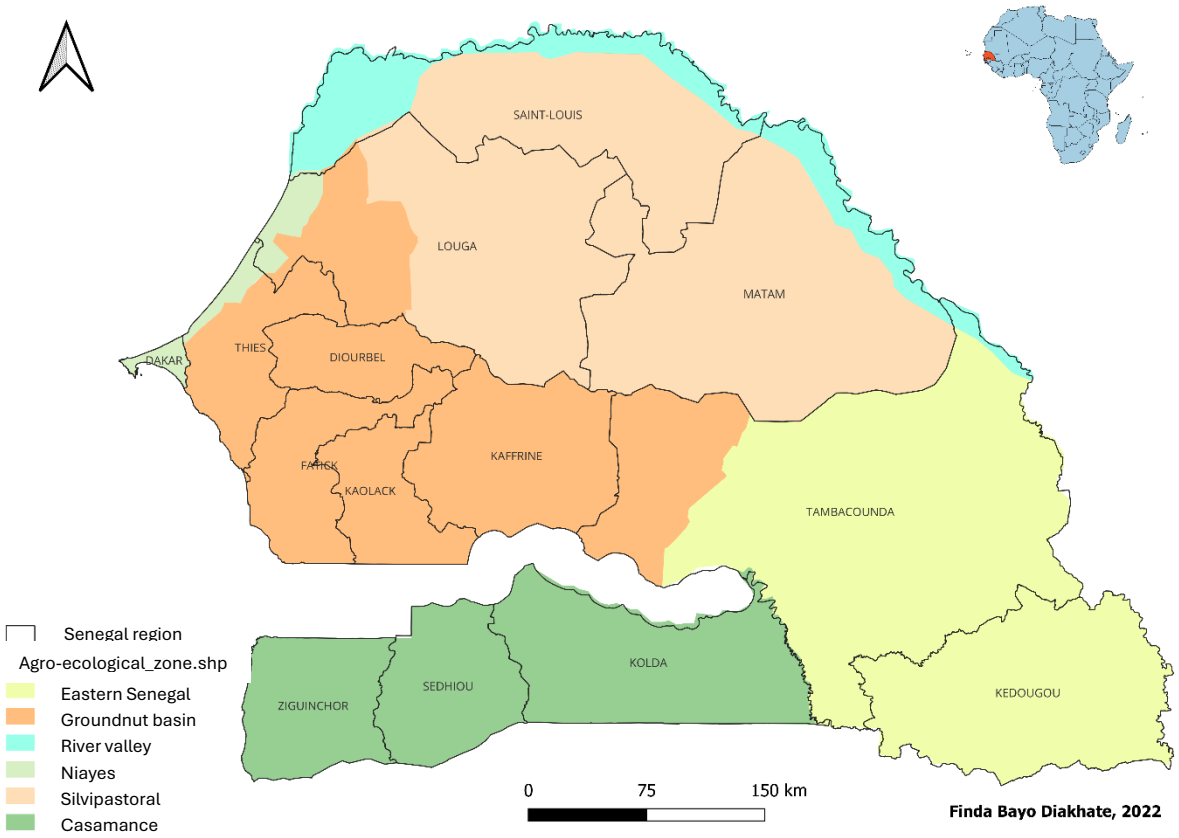

***Figure 1**: Senegal's agro-ecological areas*

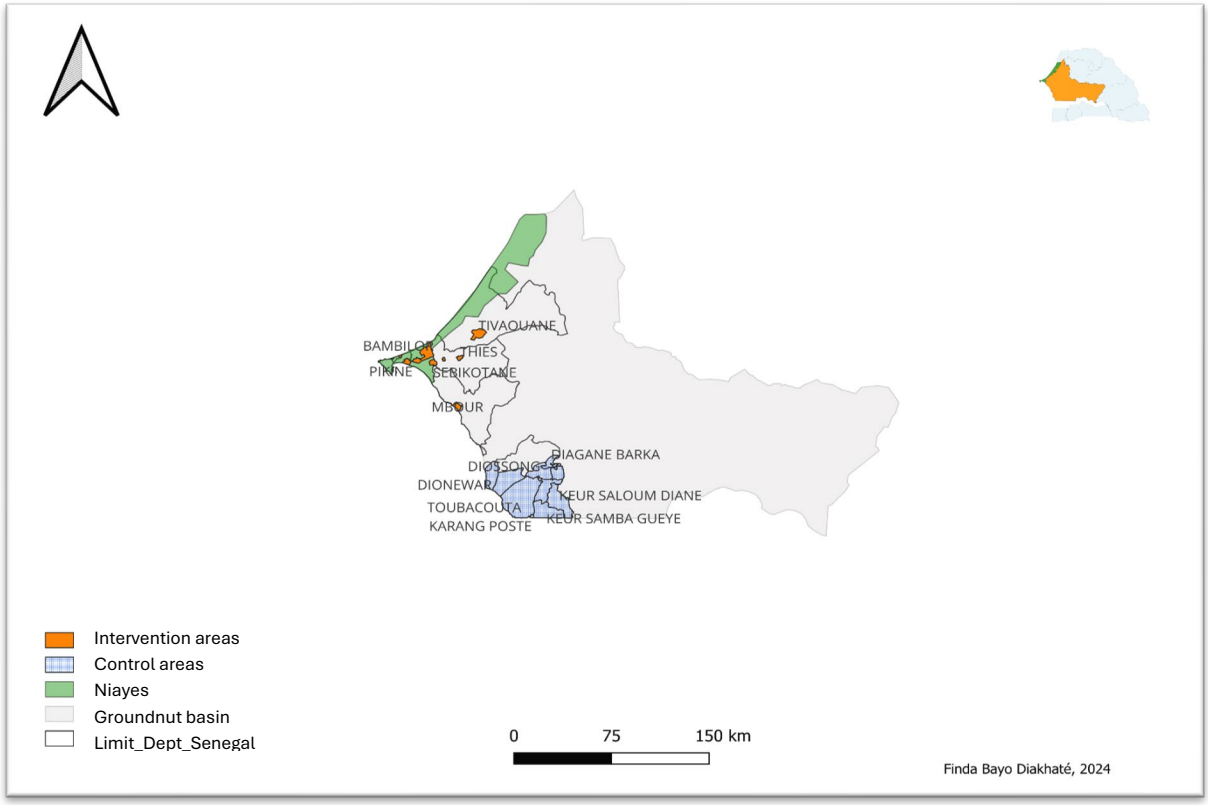

***Figure 2**: Intervention and control areas*

II. Interventions and results of the eradication campaign

In 2005, the Government of Senegal launched a project entitled "Tsetse control project in Niayes" with the aim of creating an area free of tsetse flies. Staff from the Department of Veterinary Services (DSV) of the Ministry of Livestock and Animal Production and the Senegalese Institute for Agricultural Research (ISRA) implemented the project. The project received technical and financial support from the International Atomic Energy Agency (IAEA), the Food and Agriculture Organization of the United Nations (FAO), the International Cooperation Centre of Agricultural Research for Development (CIRAD) and the US Department of State through the Peaceful Uses Initiative (PUI). The International Centre of Research and Development for Livestock in Subhumid Zones (CIRDES) in Burkina Faso, the Slovak Academy of Sciences (SAS) in Slovakia and the Institute of Research for Development (IRD) in France were also full- or part-time project partners.

This project was launched because AAT has been one of the main pathological constraints to the development of intensive livestock farming systems in the Niayes region of Senegal, a 30 km wide strip of land along the coast between Dakar and Saint-Louis. To overcome this constraint, the Government of Senegal launched this area-wide integrated pest management programme, combining chemical control tactics with the sterile insect technique to eradicate a population of the tsetse fly *Glossina palpalis gambiensis* Vanderplank (Diptera: Glossinidae) in this area. The project was implemented using a phased, conditional approach, and the target area was divided into three blocks treated sequentially.

Throughout the implementation period, the project team carried out entomological and epidemiological monitoring to measure changes in tsetse fly density and the prevalence of AAT in Niayes. Between 2009 and 2022, 4359 blood samples were collected from cattle and screened for trypanosomosis using both the buffy coat technique and enzyme-linked immunosorbent assay. Since 2020, samples have also been tested using the polymerase chain reaction (PCR) technique. In block 1, seroprevalence rose from 18.9% (95% CI: 11.2–26.5) in 2009 to 0% in 2017–2022, and from 92.9% (95% CI: 88.2–97) in 2010 to 0% in 2021 in block 2. Parasitological and serological data confirm the results of the entomological monitoring. In other words, there is a strong probability that the *G. p. gambiensis* population will be eradicated from the Niayes and that transmission of AAT will be interrupted in the treated area.

Table 1: Annual serological and parasitological prevalence of animal trypanosomosis in the Niayes area from 2009 to 2022 and number of PCR-positive samples from 2020 to 2022.

Year	Site	Number of samples	Number of seropositive samples	Apparent seroprevalence (%)	Actual seroprevalence (%)	95% CI of actual seroprevalence (%)	Number of positive samples in the buffy coat test	Parasitological prevalence (%)	Number of PCR-positive samples
2009	Pout	126	75	59.5	63.1	54.6–71.6	N/A	N/A	N/A
	Kayar	102	21	20.6	18.9	11.2–26.5	N/A	N/A	N/A
	Tassette	132	7	5.3	1.5	0.0–3.6	N/A	N/A	N/A
2010	Pout	119	102	85.7	92.9	88.2-97.5	N/A	N/A	N/A
	Kayar	101	16	15.8	13.5	6.8–20.2	N/A	N/A	N/A
	Tassette	133	1	0.8	0	0.0–0.0	N/A	N/A	N/A
2011	Pout	114	50	43.9	45.3	36.1–54.5	0	0	N/A
	Kayar	97	3	3.1	0	0.0–0.1	0	0	N/A
	Tassette	94	3	3.2	0	0.0–0.1	5	4.4	N/A
2012	Pout	105	19	18.1	16	9.0–23.1	0	0	N/A
	Kayar	76	3	3.9	0	0.0–0.1	3	3.9	N/A
2013	Pout	111	12	10.8	7.7	2.7–12.8	2	1.8	N/A
	Kayar	89	2	2.3	0	0.0–0.1	3	3.4	N/A
	Thienaba	100	1	1	0	0.0–0.1	0	0	N/A
2014	Pout	112	9	8	4.6	0.7–8.5	2	1.8	N/A
	Kayar	102	1	0.98	0	0.0–0.0	4	3.0	N/A
	Thienaba	100	1	1	0	0.0–0.1	1	1	N/A
2015	Pout	103	17	16.5	14.2	7.4–21.0	0	0	N/A
	Kayar	86	11	12.8	10	3.6–16.4	0	0	N/A
	Thienaba	96	3	3.1	0	0.0–0.1	0	0	N/A
2016	Pout	116	8	6.9	3.3	0.0–6.6	0	0	N/A
	Kayar	100	1	1	0	0.0–0.1	0	0	N/A
	Thienaba	199	9	4.5	0.6	0.0–1.7	0	0	N/A
2017	Pout	129	9	7	3.4	0.2–6.5	0	0	N/A
	Kayar	94	0	0	0	0.0–0.1	0	0	N/A
	Thienaba	100	1	1	0	0.0–0.1	0	0	N/A
2018	Pout	103	9	8.7	5.4	1.0–9.8	0	0	N/A
	Kayar	103	0	0	0	0.0–0.0	2	1.9	N/A
	Thienaba	100	2	2	0	0.0–0.1	0	0	N/A
2019	Pout	99	10	10.1	6.9	1.9–12.0	1	1	N/A
	Kayar	74	0	0	0	0.0–0.1	0	0	N/A
	Thienaba	118	7	5.9	2.2	0.0–4.9	0	0	N/A
2020	Pout	99	15	15.2	12.7	6.1–19.3	0	0	1
	Kayar	102	10	9.8	6.6	1.7–11.5	0	0	0
	Thienaba	100	8	8	4.5	0.4–8.7	0	0	0
2021	Pout	99	1	1	0	0.0–0.1	0	0	0
	Kayar	105	0	0	0	0.0–0.0	0	0	0
	Thienaba	102	1	1	0	0.0–0.0	0	0	0
2022	Pout	121	3	2.5	0	0.0–0.0	0	0	0
	Kayar	96	0	0	0	0.0–0.1	0	0	0
	Thienaba	100	1	1	0	0.0–0.1	0	0	0

III. Impact assessment methodology

The aim of this study was to assess the socio-economic impact of tsetse fly eradication in the Niayes area. The population selected was all livestock-raising households living in the regions of Dakar and Thiès for the Niayes area, and Fatick for the Sine-Saloum area. As the Sine area has not benefited from a tsetse eradication campaign, it was considered to be a control area. The sample was distributed such that the numbers in the Sine area were much greater than in the Niayes area. The data was collected in two phases: the first phase involved gathering qualitative data followed by a second phase of quantitative data collection. In addition, secondary data was used as part of this study to provide further evidence of the effects of the eradication campaign.

3.1. Pre-diagnosis and qualitative data collection mission

When assessing the socio-economic impact of an intervention, it is essential to combine quantitative and qualitative analyses to gain a better understanding of the social dimension of the intervention and better interpret the quantitative results. A pre-diagnostic mission was therefore carried out in both areas.

This mission took place from 31 October to 5 November 2023 in the Niayes — in Dakar and Thiès in particular — and in the Sine, more specifically in the department of Foundiougne.

Objectives and work carried out during the pre-diagnosis mission

The purpose of the mission was to conduct a pre-diagnosis and collect qualitative data from the officials and focal points of the tsetse fly eradication campaign in the Niayes area. The mission also provided an opportunity to meet livestock farmers and technical livestock services in the Fatick area to understand the impact of the tsetse fly and trypanosomosis.

In the project area (Niayes), we conducted interviews and focus groups in the regions of Dakar (Rufisque department) and Thiès (Thiès, Mbour and Tivaouane departments). In each department, a separate interview was held with the head of the department’s livestock service, and focus groups were run with project technicians, project farmers and with farmers outside the project. In each individual and group interview, we addressed matters relating to changes in a number of indicators before and after the project's intervention, in particular herd size, the local and exotic breeds present, levels of income from livestock, the presence of tsetse flies, the prevalence and incidence of animal trypanosomosis, etc. In addition, we collected the contact

details of a number of intensive farm managers and private veterinarians to discuss their views on the tsetse fly eradication campaign and its impact on animals and farmers.

Table 2: Types of stakeholders and their role in the project

Study location	Stakeholders we met	Role in the project
Dakar (Rufisque, Bambilor, Sébikhotane, etc.)	Head of the department's livestock service	Coordinate field activities at departmental level by acting as the interface between the project coordination team and the technicians.
	Project technicians	Set up traps, conduct entomological monitoring of fly catches and collect blood samples from herds for epidemiological and parasitological monitoring.
	Project livestock farmers	Provide access to the herds selected by the project for the blood samples required for epidemiological monitoring of trypanosomosis.
	Farmers outside the project	Provide access to herds whose flocks were at risk of trypanosomosis.
Thiès (Thiès, Pout, Kayar, etc.)	Head of the department's livestock service	Coordinate field activities at departmental level by acting as the interface between the project coordination team and the technicians.
	Project technicians	Set up traps, conduct entomological monitoring of fly catches and collect blood samples from herds for epidemiological monitoring. parasitology?
	Project livestock farmers	Farmers whose herds were selected by the project for the blood samples required for epidemiological monitoring of trypanosomosis.
	Farmers outside the project	Livestock farmers in the study area who were not involved in the project but whose herds were at risk of trypanosomosis.
Foundiougne (Keur Saloum Diané, Toubacouta, Diagane Barka, Nioro Alassane Tall, etc.)	Head of the department's livestock service	There were no project interventions in this area, which was chosen solely as a control. An area with a high density of tsetse flies and a high prevalence of trypanosomosis.
	Livestock farmers in the area potentially affected by tsetse flies and trypanosomosis.	

3.2. Sampling methodology for livestock farmers surveyed

3.2.1. Description of sampling frames

The sampling frames used in this study came from the regional and departmental livestock and animal production services. They included livestock farmers identified by the livestock services in both areas. These sampling frames were used to identify 457 farmers in the Niayes area and 424 farmers in the Sine area, particularly in the department of Foundiougne.

3.2.2. Sample size

The minimum sample size was 660 farmers — 220 in the Niayes area and 440 in the Sine-Saloum area — based on probability sampling. This, however, was increased by 10% in each area to allow for possible non-responses and deletions during the data processing. The total sample was 726 livestock farmers: 242 in Niayes and 484 in Sine.

In the Niayes area, the three blocks were stratified to form much more homogeneous groups. A weighting strategy was defined to determine the number of livestock farmers to be surveyed in each block. The table below shows the distribution of the Niayes area sample by block.

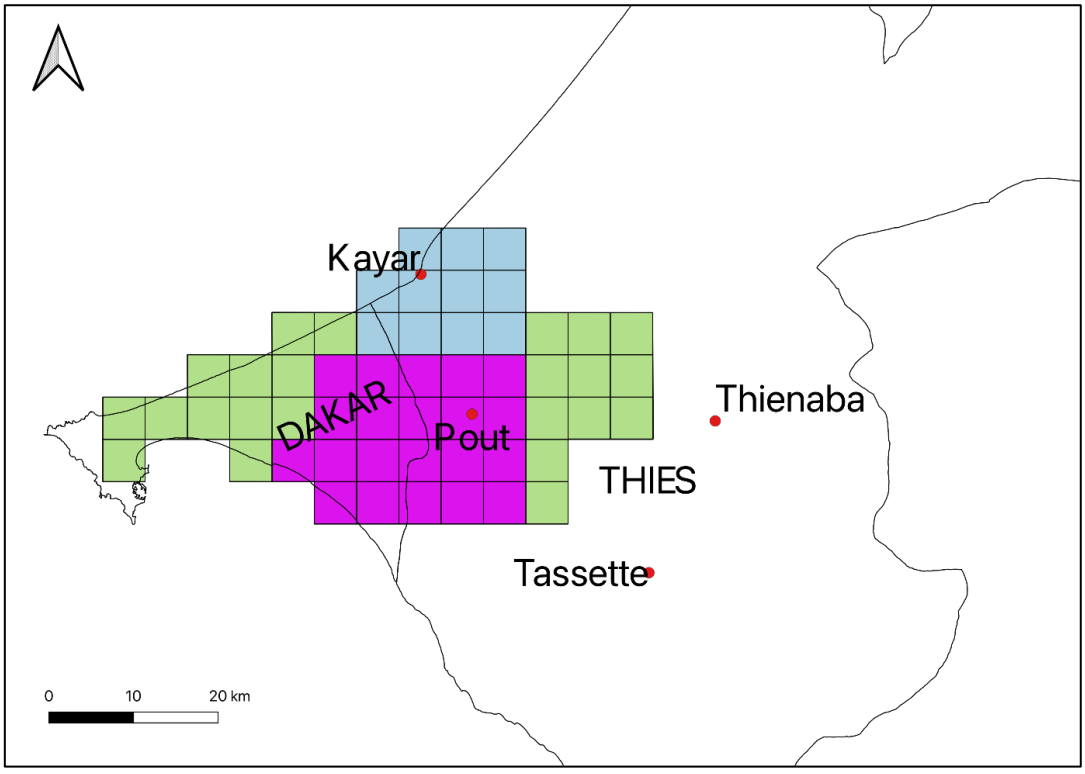

***Figure 3**: Location of the three blocks*[1]

[1] Study sites (red dots) and area covered by block 1 (light blue), block 2 (purple) and block 3 (green). Each grid cell represents an area of 25 square kilometres (5 km by 5 km).

Table 3: Distribution of the Niayes area sample by block

Block	Number of livestock farmers identified	Weight	Sample size
Block1	104	0.227571116	55
Block2	179	0.391684902	95
Block3A	65	0.142231947	34
Block3B	109	0.238512035	58
Total	**457**		**242**

Source: authors' calculations based on data from departmental livestock services

3.3. Survey plan

4.2.1. For livestock farmers in the Niayes area

The sample design used was a stratified random sample at block level. The farmers to be surveyed in each block were drawn at random without replacement. Replacements were drawn from each block if any farmers could not be found or were unavailable.

4.2.2. For livestock farmers in the Sine area

In the control zone, the farmers identified were all counted and surveyed as the list was fairly limited and did not allow us to draw a sample of 484 farmers identified.

3.4. The questionnaire

The questionnaire for evaluating the impact of the tsetse fly eradication campaign in the Niayes area was made up of four (4) sections. The first section identified the respondent farmer by geographical location. The second section provided information on the composition of the household, the characteristics of the head of the household, the people involved in managing the herd, changes in the initial objectives set by the household for its livestock activity and the reasons for moving the herd. The third section dealt with agricultural production and crop residues used as animal feed. It also provided information on transhumance and changes in household agricultural activity. The fourth section contained information on the composition of the herd in terms of species, breeds, numbers, age, sex of the animals and income from livestock. This section also included information on the various diseases affecting livestock, the cost and treatment methods used by the household. The last part of the questionnaire

provided information on changes in household income and methods of financing livestock farming.

3.5. Methodological approach to impact assessment (PSM model)

The non-experimental PSM method was used for the quantitative part of this assessment of the impact of the tsetse eradication campaign in Niayes. Two methodologies are often used for quantitative evaluations of projects or programmes: experimental and non-experimental.

According to the literature (Gertler et al., 2016; Diagne, 2006, etc.) experimental methods[2] lead to more robust results insofar as they overcome the fundamental problem of impact assessments — the impossibility of observing the counterfactual — which is the state in which a beneficiary would be in if she or he had not benefited from the programme, or the state in which a non-beneficiary would be in if she or he had benefited from the programme. The fact that the counterfactual cannot be observed renders it a missing piece of data in the process of evaluating the effects of an intervention.

Applying the experimental method requires some preparation. In fact, before any project or programme is implemented, it is necessary to ensure that the impact evaluation system is in place using a baseline study that enables future beneficiaries and potential controls to be selected at random from the eligible population. In most cases, however, the impact assessment begins well after the project. This is partly how this assessment has been configured, as the baseline study conducted at the start of the project only relates to the intervention area, without first defining an area that could act as the control. For this reason, the methodological choice was to use non-experimental methods.

There are a multitude of non-experimental (or quasi-experimental) approaches that could be used. They all attempt to find a counterfactual (or control group or comparison group) using the same principle as experimental methods. These techniques therefore produce comparison groups that resemble the target group, at least in the characteristics observed using econometric methods. ***The most commonly used in the literature are the PSM method, the double difference method, the instrumental variables method and the regression discontinuity method.*** As mentioned above, we opted for the PSM method because we felt it was the most appropriate for the study context (informed decision on the beneficiaries), the dataset available

[2] Also known as the random method or randomization method or the controlled experiment evaluation method.

to us and the study's aim. Despite the range of methods, the choice of impact assessment method generally depends on the study objectives and the type of data available.

The PSM procedure attempts to match each treatment individual (intervention area) with one or more non-treatment individuals (control area) whose observable characteristics are as close as possible to those of the treatment individual. The aim of this method is to construct a control (or counterfactual) group comparable to the treatment group to enable an unbiased estimate of the effect of the treatment on the treatment group by attempting to eliminate selection bias. It is generally accepted that this method can help to reduce bias, although there is no guarantee that it will completely eliminate it (Mendola, 2006).

Two characteristics of the work, however, are required to apply the PSM method. First, independence conditional on observable variables and second, common support. Conditional independence generally requires including a large number of conditioning variables that have no direct effect on the impact variables. Without this condition, matching can be difficult in practice. The problem of the size of the conditioning variables is greatly reduced by a property highlighted by Rosenbaum and Rubin (1983). The property of independence conditional on observable variables involves independence conditional on a summary of a single dimension, which is the probability of treatment (benefiting from a programme or project) or score for propensity to be treated. Common support requires the propensity score to be greater than zero and less than one. This improves the quality of the matching because extreme values are excluded. However, it results in a smaller sample size.

The propensity score, which is the probability of treatment (benefiting from a programme or project), is generally estimated using the logistic regression model, although the probit or tobit are also used. The choice of model for estimating the propensity score, however, has little influence on the results. In reality, the choice of one of these models depends only on assumptions about the regression errors.

Once this estimate has been made, the matching phase is carried out, which involves linking each individual in the intervention area with one or more controls chosen from the Sine-Saloum area, based on the propensity scores. Several algorithms are implemented using statistical calculation software, and the choice depends on the user (see Caliendo & Kopeinig, 2008). Indeed, Goussé et al. (2010) have shown that the results are not very sensitive to the algorithms used. In this study, we will use the NN algorithm. The kernel method will also be used in certain cases to test the robustness of the results. Finally, to assess the impact or effects of the intervention, the estimator of the mean effect of the treatment on those treated will be used.

Match quality

The propensity score method naturally produces a biased estimator precisely because the data do not come from a randomized experiment. To limit this bias, a quality match needs to be carried out to compare comparable observations. Three criteria will enable us to assess the quality of the match:

– *The mean standardized bias*

For each variable, the mean standardized bias is the difference between the mean of the treatment and control group samples, divided by the square root of the sum of the variances of the explanatory variable in each group. A good match should have a mean standardized bias of less than 5% on all variables (Rubin, 2002).

– *The significance test*

This is the classic test to measure the quality of a match. It involves comparing the means of the explanatory variables between the treatment group and the control group. After matching, these differences should not be significant.

– *Joint significance and pseudo-R-squared*

This step involves estimating the propensity scores a second time for the sample of matched observations and then comparing the pseudo-R-squareds before and after matching. The latter should be minimal because the treatment is assumed to be random, conditional on the vector of observable variables (Sianesi, 2004). Another way of judging the quality of the matching is to perform a likelihood ratio test on the joint significance of all the dependent variables, before and after matching. This test should be rejected after matching, not before.

As with any methodology, the PSM method has some limitations. The main one being that it constructs counterfactuals solely on the basis of observable characteristics. There could, in fact, be a number of unobservable variables which could be sources of selection bias and are ignored by this procedure.

As part of this assessment, ***the modelling exercise will focus primarily on the objectives of eradication, in particular by targeting income indicators and the productive performance of the livestock farmers surveyed (herd size, introduction of more productive exotic breeds, milk production and the purchase of trypanocides).*** These indicators will be set out in the results section.

IV. Study results

4.1. Qualitative survey results

The analysis of the qualitative data collected during individual interviews and focus groups has enabled us to make a number of observations and to draw up preliminary results for both the Niayes and the control area (Sine). This initial analysis also enabled us to identify perspectives to take into account at the end of the eradication campaign to ensure that the gains made are sustained.

4.1.1. Major and significant changes observed in the Niayes area between 2010 and 2023

4.1.1.1. The results of the entomological monitoring of flies and epidemiological monitoring of trypanosomosis show that the eradication campaign has been successful.

In the Niayes area, catching flies in the wild has become increasingly rare. In the Kayar commune, for example, no flies have been caught for more than 10 years. Similarly, no wild flies have been caught in the Bargny and Sébikhotane areas for more than five years. The prevalence of animal trypanosomosis has fallen sharply, even reaching zero in some areas.

According to livestock farmers in the Rufisque area, tsetse flies and trypanosomosis emerged around the 1970s, causing a number of livestock to die or be abandoned. Transhumant cows died more quickly because they were poorly adapted. For more than 10 years, no positive case of trypanosomosis has been recorded in the Rufisque area.

This observation has been made by technical agents from the departmental livestock service and livestock farmers in the Rufisque area. Between 2018 and 2019, however, a few samples taken in Cambérène detected the presence of trypanosomes at ISRA goat farms in Sangalkam. Sick animals were treated as a prelude to vector control. The situation was quickly managed by the intervention team, which began by cutting the grass and then releasing sterile males. For more than two years, traps set in the area have shown no sign of wild flies, and samples taken from animals have been negative.

The same observation was made in the Thiès area, where agents have seen no trace of trypanosomosis since 2021. This situation can be attributed to the interventions in the area and the use of trypanocides to treat the animals. In 2020, samples taken in Pout showed the presence

of the vector in an imported case. This led to enormous resources being deployed to eradicate it. It should be noted, however, that the Thiès region, which used to be home to livestock farmers from the Rufisque area due to urbanization, is now threatened with having the protection of its forests lifted.

In addition, interviews with technical agents in the Niayes area showed that the interventions had not been significantly affected by COVID-19. Aware of the restrictions imposed by the public authorities, the intervention team changed its organizational set-up to perform its task more successfully during the pandemic.

4.1.1.2. Building the technical team's capacity was a key factor in the effectiveness of the interventions during the eradication campaign

One of the key factors in the success of the eradication campaign was the capacity building of technical staff. The training the technical team received in Bobo Dioulasso improved the agents' perception of vector control techniques and their methods for locating fly breeding sites. It also enhanced action taken to control the flies. Other factors, such as urbanization, have led to a significant reduction in forest and grazing areas, thus contributing to the eradication of tsetse flies in Rufisque. However, this urbanization has also caused the livestock to move from Rufisque to Thiès, where, according to livestock farmers, there are still grazing areas.

4.1.1.3. A variety of animal species observed since the start of the eradication campaign

The presence of tsetse flies in the Rufisque area resulted in limited diversity of animal species, particularly horses which were the most vulnerable. According to Rufisque's technical officers, the battle against wild flies has led to an increase in the numbers of horses and donkeys, which has had a positive and significant impact on time spent working in the field. Cattle have been replaced by horses for field work, and there has been an increase in the physical productivity of cattle used as draught animals as they now enjoy better health. According to livestock farmers, there are now more livestock farmers in the Niayes area, but less land dedicated to their animals. In addition, income from livestock farming in the Niayes area has increased considerably as some residents prefer to raise livestock, which is easier to sell, than buy land, which takes a long time to sell. In the Thiès area, small ruminants have added to the diversity of animal species over the last 10 years. Farmers in this region have also seen an increase in herd sizes.

4.1.1.4. The presence of mixed and exotic breeds of cattle will increase between 2010 and 2024

Before the eradication campaign, exotic breeds were rarely found in the Niayes area. The only breeds were the N'damas, and not only because they were trypanotolerant. Since the eradication campaign, new modern and traditional livestock farmers in Rufisque increasingly have exotic breeds. In addition to the eradication programme, Rufisque has also benefited from livestock development programmes such as ANIPL,[3] which is funded by the Government of Senegal and has encouraged the creation of new intensive farms. Moreover, artificial insemination campaigns have also helped to increase the number of exotic breeds present in the area. Exotic breeds such as Montbéliardes are very common in the Thiès region. The presence of new breeds could partly be attributed to the tsetse eradication campaign.

4.1.1.5. Increased milk production over the last 10 years

Before the eradication campaign, milk production in the Niayes was considered to be very low. The only dairy farm in the Rufisque area was SOCA,[4] which used exotic breeds for milk production. Since the start of the eradication campaign, dozens of dairy farms have been set up, and the health of the livestock has improved significantly, resulting in increased milk production. In some areas, local milk processors believe that the growing demand from industry, increased local consumption owing to population growth, and climate change present real challenges to the regular availability of milk in Rufisque. Farmers in the Thiès region believe that the development of exotic breeds has improved milk production. The price, however, remains high due to the cost of the livestock feed. It is therefore expected that the effects of the eradication campaign on animal health will be offset by the high cost of livestock feed.

4.1.1.6. Awareness-raising and communication: the two weak links in the eradication campaign

At the start of the campaign, advertising spots were broadcast in a number of local media, however awareness-raising and communication were subsequently more or less neglected. According to the project team, awareness-raising among livestock farmers and the administrative and traditional authorities should begin before the eradication campaign gets

[3] National Association for the Intensification of Dairy Production

[4] SOCA (Food Company), based in Sébikhotane (40 km from Dakar), was created in 1988 with Senegalese and Dutch capital. In 1997, it had a herd of around 500 dairy cows (compared with 700 in 1994), including 150 milk-producing cows, mainly Holsteins, Montbéliardes and Jersey heifers imported from Denmark, producing 1 200 000 litres of milk a year.

under way and continue on a regular basis throughout the life of the project. For example, the trapping equipment (stakes, mosquito nets, etc.) stolen or sold to scrap dealers, or taken away by children or transhumant herders out of curiosity, as well as the reluctance of some herders who complained about the bites caused by mosquitoes that have been released, are essentially attributable to a lack of awareness and communication. This can be explained by a low level of awareness, which is at the root of the lack of knowledge about the usefulness of these project mechanisms. Another external factor affected the progress of the operations, namely the strike by administrative staff, which slowed down work for 10 days. These constraints did not, however, significantly affect the project's implementation. A relationship based on trust between the staff in the livestock department and the farmers made it easier to intervene. Moreover, most of the farmers not involved in the eradication campaign have no knowledge of the project. Others who had already heard about the project were unaware of the actions being implemented. However, they acknowledged that the flies biting and sucking the blood of the cattle had decreased considerably in their respective areas.

4.1.2. In Foundiougne and Toubacouta, the presence of tsetse flies and their negative effects on livestock are well understood by livestock farmers in the area

4.1.2.1. A high density of tsetse flies in favourable breeding areas (water and vegetation)

The Foundiougne area is characterized by the presence of the Sine-Saloum river and a number of forested landscapes, making this department an area that lends itself to the breeding of tsetse flies. According to livestock farmers, the worst affected communes are Djilor, Diossong, Keur Saloum Diané, Keur Samba Guèye, Nioro Alassane Tall and Toubacouta. In the last five years (2018 to 2023), flooding in certain areas has led to wild mosquitoes becoming an increasing concern. For livestock farmers, trypanosomosis, foot-and-mouth disease, ticks — known as *métos* — are the most common diseases in the department, causing enormous damage to livestock, particularly cattle.

4.1.2.2. Farmers' perception of trypanosomosis

According to livestock farmers, trypanosomosis affects all species, especially cattle and is manifested by a staring hair coat, lacrimation, generalized weakness, weight loss, a drop in milk productivity and mouth odour in affected animals. For farmers, disease symptoms are visible in the livestock, with a lack of appetite and slow growth. Foundiougne department has few

intensive farms. However, there are mini-farms that generally have fewer than five exotic cattle. The only large farm was created two years ago.

4.1.2.3. Treatments to protect livestock against trypanosomosis are considered too expensive

To treat the disease, farmers turn to public and private vets. The cost of treatment is estimated to be 9000 CFA francs per head of cattle, including the veterinary surgeon's travel expenses of around 2000 CFA francs. The treatment is carried out on each animal in three phases. The cost of treatment sometimes forces farmers to administer the doses themselves or to resort to traditional forms of treatment (prayers, *gris-gris* and other ancestral practices).

4.1.3. Prospects for sustaining the achievements of the eradication campaign

Despite the considerable results achieved by the project to eradicate tsetse flies and reduce the prevalence of trypanosomosis, the Niayes is still full of areas where tsetse flies are able to breed. In other words, wetlands where there is lots of vegetation, such as the Mbao Classified Forest, the Hann Zoological Park and many others. The risk of re-infestation is minimal, but technical staff suggest that a permanent monitoring system should be put in place to prevent any possibility of re-infestation. In the Sangalkam area, suspected infected flies appeared in 2023 showing that continuous monitoring is a prerequisite for long term eradication. In future, it is recommended to consider:

- **Raising awareness among the population and local authorities of the usefulness of traps.** The livestock farmers acknowledged that people have a better understanding once they have watched a video or film about the consequences of the disease. This means using social media to achieve a stronger impact. It is also important to identify people with a good knowledge of the disease to convey this information to the farmers.
- **Involving local young people in setting and monitoring the traps has produced results in some places.**
- **Sharing epidemiological results from sampling with farmers.** This feedback must be given to the farmers directly involved in the project as well as to those who are not involved.
- **A reward in kind for farmers who take part in the sampling.** Farmers believe that blood taken from cattle must be compensated for in the form of cattle feed or medicines.

However, this approach may not be sustainable as project resources are generally limited.

- **An effective risk management system (health insurance, risk premiums and significant compensation) for technical staff.** There are usually wild animals (reptiles and other predators) in these areas. Moreover, tsetse fly bites could cause sleeping sickness and therefore affect the agents' productivity. A better system is therefore needed to motivate and retain field staff.

4.2. Descriptive analysis

4.2.1. Characteristics of households surveyed.

The households surveyed were, on the whole, headed by men. Rural households are generally patriarchal, with very few responsibilities given to women, apart from the elderly and widows. This trend is the same for both groups, with around 98% of heads of household being male.

Table 4: Gender of head of household (HH)

Gender of HH	Controls	Beneficiaries	Overall
Men (%):	98.1	97.6	97.9
Women:	1.9	2.5	2.1

Source: ISRA-BAME household survey 2023

Household size in the controls is significantly larger than among the beneficiaries, with an average sample size of 12 people. This number is slightly higher than the national average of nine (9) people (ANSD. RGPH-5, 2023). Rural households need this labour because of the production systems in place (agriculture and livestock farming) where there is very little mechanization.

Table 5: Household size

Mean household size	Obs	Min	Mean	Standard deviation	Max
Controls	411	1	**13**	7	57
Beneficiaries	245	2	**10**	5	38
Overall	656	1	**12**	7	57

Test	diff = mean (Controls) – mean (Beneficiaries) > 0; Pr(T > t) = 0.0000

Source: ISRA-BAME household survey 2023

The head of the household has often had a religious education with around two thirds having attended a Qur'anic school and 11% having been in the conventional (French) system. Just over 15% have not been in any education system at all. Most heads of household have had a continuous apprenticeship in their trade, which has developed with the experience accumulated over the years.

The level of education of heads of households in the conventional system is higher among beneficiaries than among the controls. This may explain why they have a greater aptitude for collaboration with the research and development partners. Indeed, 12.5% of beneficiaries have completed higher education, compared with 1.6% of controls.

Table 6: Type and level of education of heads of household

Education of heads of household (HH)	Controls	Beneficiaries	Overall
Education of heads of household (HH)			
None (%)	11.7	22.6	**15.4**
Qur'anic school (%)	**71.6**	**64.3**	**69.1**
French (%)	9.6	12.1	10.5
Arabic (%):	6.6	0.0	4.4
Literacy (%)	0.5	0.5	0.5
French-Arabic (%)	0.0	0.5	0.2
HH's level of education			
None (%)	4.7	0.0	3.4
Pre-school (%)	1.6	0.0	1.1
Primary (%)	57.8	58.3	58.0
Middle (%)	29.7	12.5	25.0
Secondary (%)	4.7	16.7	8.0
University (%)	**1.6**	**12.5**	4.6

Source: ISRA-BAME household survey 2023

Heads of household have a higher number of multiple activities than other household members. Fifty-four per cent of other household members are unemployed, demonstrating their dependence on the head of the household. Among the beneficiaries, most household members are involved in livestock rearing (22%); the main activity among controls is agriculture (22.4%). Other activities include trade, the private sector and crafts (Table 7).

The head of the household is mainly active in the primary sector, particularly livestock farming and agriculture. Among the beneficiaries, the head of the household is active in livestock activities (70%) and agro-pastoral activities (20%). In the control group, there is greater diversity, with the head of the household active in livestock farming (36%), agriculture (29%) and agro-pastoral activities (19%). Beneficiary households therefore specialize more in livestock farming than control households. Nearly half of the heads of household among beneficiaries do not have second jobs, unlike the controls, nearly half of whom have jobs in livestock farming and agriculture.

Table 7: Employment of members of the household and the head of the household

EMPLOYMENT	Controls	Beneficiaries	Overall
Jobs of members of the household			
None	55.4	52.6	**54.5**
Livestock farming	6.9	**22.0**	12.2
Agriculture	**22.4**	2.7	15.5
Agropastoral	2.7	2.5	2.6
Fishing	0.0	0.1	0.7
Agri-food processing	0.6	0.1	0.1
Public administration	0.4	0.4	0.5
Private sector	4.0	4.5	1.9
Trade in goods	1.1	5.9	4.7
Crafts	0.1	1.0	1.1
Emigration	5.3	0.0	0.1
Other		8.3	6.3
Main job of the head of the household (%)			
None	5.8	3.5	5.1
Livestock farming	**35.5**	**70.4**	47.2
Agriculture	**29.2**	2.0	20.1
Agropastoral	**18.5**	**20.**1	19.1
Fishing	1.0	0.0	0.7
Public administration	0.3	0.0	0.2
Private sector	0.0	1.0	0.3
Trade in goods	4.6	1.0	3.4
Crafts	0.5	0.0	0.3
Other	4.6	2.0	3.7
Second job of head of household (%)			
None	19.2%	**46.1%**	29.2%
Livestock farming	**45.6%**	19.2%	35.8%
Agriculture	**45.4%**	17.6%	35.0%
Agropastoral	2.4%	0.8%	1.8%

Forestry	0.0%	0.0%	0.0 %
Fishing	2.4%	0.4%	1.7%
Agri-food processing	0.5%	0.0%	0.3%
Public administration	0.7%	0.8%	0.8%
Private sector	0.2%	2.4%	1.1%
Trade in goods	11.7%	8.6%	10.5%
Crafts	0.5%	0.0%	0.3%
Emigration	0.0%	0.0%	0.0%
Other	4.6%	7.3%	5.6%

Source: ISRA-BAME household survey 2023

Farming is the main activity in rural areas and employs almost the entire agricultural workforce. It is highly diverse and plays a vital role in feeding and generating household income. In our two study areas, farming is very important in the control households (89%), most of whom use an agro-pastoral cropping system. On the other hand, less than half of the beneficiaries (44%) are active in agriculture, reflecting their pastoral orientation.

Table 8: Agricultural practice

Agricultural practice (%)	Controls	Beneficiaries	Overall
No	10.7	56.3	27.7
Yes	**89.3**	**43.7**	72.3

Source: ISRA-BAME household survey 2023

Household members are not closely linked to farmers' organizations. Only one third (34%) are affiliated to them, showing that farmers are more open to the knowledge they have gained through their experience. We see the same trend in both groups, showing that greater openness is needed if they are to harness the technical and organizational innovations promoted by these farmers' organizations.

Table 9: Membership of a farmers' organization

Membership of farmers' organization (%)	Controls	Beneficiaries	Overall
No	66.0	65.7	65.9
Yes	34.0	34.3	34.1

Source: ISRA-BAME household survey 2023

In both areas, the crops being grown are similar, with a few differences. Arable crops and crop diversification are more common among controls, while market gardening, arboriculture and

fodder crops are more common among beneficiaries. There is a great deal of diversification within and between crop types to ensure a minimum level of production geared towards food and feed, as well as towards the market for cash income.

Table 10: Types of crops grown

Types of crops grown (%)	Controls	Beneficiaries	Overall
Arable crops	**42.5%**	**8.4%**	**34.8%**
Maize	60.9%	17.8%	51.2%
Sorghum	0.3%	2.8%	0.8%
Millet	94.8%	6.5%	74.9%
Peanut	95.1%	13.1%	76.6%
Cowpeas	2.7%	10.3%	4.4%
Rice	1.1%	0.0%	0.8%
Crop diversification	**12.5%**	**6.5%**	**11.1%**
Sesame	0.5%	0.0%	0.4%
Cassava	0.3%	2.8%	0.8%
Watermelon	11.7%	3.7%	9.9%
Arboriculture	0.0%	11.2%	2.5%
Fodder crops	**0.0%**	**1.9%**	**0.4%**
Market gardening	**0.5%**	**75.7%**	**17.5%**

Source: ISRA-BAME household survey 2023

Despite the importance of livestock farming in both areas, the area set aside for grazing is very small or non-existent. Pastoral and agro-pastoral households do not usually devote part of their land to grazing, as they practise extensive farming, taking advantage of natural rangelands and crop residues.

Table 11: Areas devoted to rangeland

Area reserved for grazing in ha	Obs	Mean	Standard deviation	Max
Controls	366.0	0.5	2.3	30.0
Beneficiaries	107.0	0.0	0.2	1.0
Overall	473.0	0.4	1.9959	30.0

Source: ISRA-BAME household survey 2023

Free-range grazing is practised by 94% of households in both areas, but is less important among beneficiaries, with 16% of households not practising it. This can be ascribed to specialization and intensification, which is more prevalent among beneficiaries. Extensive livestock farming is the most common type of farming in the country, hence the importance of rangeland.

Table 12: Use of rangeland

Free-range grazing	Controls	Beneficiaries	Overall
No	3.3	15.9	6.1
Yes	96.7	84.1	93.9
Test	Pearson's Chi-squared test = 23.06 Prob = 0.0000		

Source: ISRA-BAME household survey 2023

Transhumance is practised by 25% of households in both areas. This can be ascribed to the size of the herds, which are not very large, and by the fact that there are rangelands with sufficient fodder. Transhumance is more common in the control group, which has larger herds and uses a more extensive farming system. Hence the need to protect crops from roaming, especially during the dry months.

Table 13: Transhumance

Transhumance	Controls	Beneficiaries	Overall
No	71.74	85.05	74.74
Yes	28.26	14.95	25.26
Pearson's Chi-squared test = 7.78 Prob = 0.0053			

Source: ISRA-BAME household survey 2023

4.2.2 Characteristics of cattle herds

The main local cattle breeds identified among the controls and beneficiaries were N'dama taurine, Gobra zebu and Djakore. However, the percentage of livestock farmers with N'damas was higher in the controls than among the beneficiaries (74.7% compared with 53.5%). The main exotic breeds in both areas are Guzerat, Holstein, Montbéliarde, Jersey, Braunvieh, Girolando and Mocho Nacional. However, the Guzerats, Montbéliardes and Jerseys are more common among the beneficiaries than the controls.

Table 14: Percentage of cattle breeds owned

Cattle breeds owned by the farmer (%)	Controls	Beneficiaries	Overall
Zebu Gobra	**28.2%**	**29.0%**	28.5%
Zebu Maure	3.2%	2.0%	2.7%
N'dama taurine	**74.7%**	**53.5%**	66.8%
Djakore (N'Dama*Gobra)	**20.0%**	**25.3%**	22.0%
Gudali	0.0%	0.0%	0.0%

Holstein	1.5%	1.2%	1.4%
Jersey	0.2%	0.4%	0.3%
Braunvieh	0.2%	0.0%	0.2%
Montbéliarde	1.0%	1.2%	1.1%
Nelore	0.0%	0.0%	0.0%
Gir	0.0%	0.0%	0.0%
Girlando	0.2%	0.0%	0.2%
Mocho Nacional	2.0%	0.4%	1.4%
Guzerat	5.4%	**14.7%**	8.8%
Other	1.2%	5.7%	2.9%

In both areas, local breeds outnumber exotic ones. Nevertheless, the percentage of exotic breeds was higher in the beneficiaries than in the controls (20% compared with 10%).

Table 15: Percentage of local and exotic breeds

	Controls	Beneficiaries	Overall
Percentage of local breeds (Zebu + N'Dama + Djakore)	98.5%	96.7%	97.9%
Percentage of exotic breeds (other breeds)	10.0%	20.0%	13.7%

Source: ISRA-BAME household survey 2023

In the cattle herds, the number of females was greater than the number of males among both the beneficiaries and the controls. Nevertheless, the proportion of exotic breeds was higher among the beneficiaries (74% compared with 70.5%). There are more local breeds than exotic breeds. Conversely, exotic breeds are more common in the controls than in the beneficiaries (see Tables 16 and 17). This can be attributed to the fact that the farmers surveyed are mainly extensive pastoralists and agropastoralists, whereas in Niayes, exotic breeds are generally owned by intensive farms.

Table 16: Number of female cattle by breed and age group

	Controls					**Beneficiary**					**Overall**				
Cattle breeds	No. fem 0 to 18 months	No. fem 18 months to 3 years	No. fem 4 to 9 years	No. fem 10+ years	**Total**	No. fem 0 to 18 months	No. fem 18 months to 3 years	No. fem 4 to 9 years	No. fem 10+ years	**Total**	No. fem 0 to 18 months	No. fem 18 months to 3 years	No. fem 4 to 9 years	No. fem 10+ years	**Total**
Zebu Gobra	6	8	9	4	**27**	10	9	13	10	**42**	7	9	10	7	**33**
Zebu Maure	5	6	11	5	**27**	1	2	1	1	**5**	4	5	9	5	**23**

N'dama taurine	6	7	12	6	**31**	8	9	13	8	**38**	6	8	12	7	**33**
Djakore	4	6	8	5	**23**	8	7	24	9	**48**	6	6	14	7	**33**
Holstein	2	3	2	3	**10**	0	2	0	0	**2**	2	2	2	3	**9**
Montbéliarde	1	2	1	0	**4**	0	0	1	0	**1**	1	2	1	0	**4**
Mocho Nacional	4	3	12	7	**26**	0	0	0	0	**0**	4	3	12	7	**26**
Guzerat	8	5	7	2	**22**	4	3	3	2	**12**	5	4	5	2	**16**
Total	**36**	**40**	**62**	**32**	**170**	**31**	**32**	**55**	**30**	**148**	**35**	**39**	**65**	**38**	**177**

No. fem = Number of females

Source: ISRA-BAME household survey 2023

Table 17: Number of male cattle by breed and age group

	Controls					**Beneficiary**					**Overall**				
Cattle breeds	No. males 0 to 18 months	No. males 18 months to 3 years	No. males 4 to 9 years	No. males 10+ years	**Total**	No. males 0 to 18 months	No. males 18 months to 3 years	No. males 4 to 9 years	No. males 10+ years	**Total**	No. males 0 to 18 months	No. males 18 months to 3 years	No. males 4 to 9 years	No. males 10+ years	**Total**
Zebu Gobra	4	4	3	1	**12**	5	5	4	0	**14**	4	5	3	1	**13**
Zebu Maure	4	2	2	0	**8**	0	0	0	0	**0**	3	2	2	0	**7**
N'dama taurine	4	4	4	1	**13**	5	6	4	1	**16**	4	5	4	1	**14**
Djakore	3	3	3	0	**9**	6	3	2	0	**11**	5	3	3	0	**11**
Holstein	1	2	0	1	**4**	1	1	0	0	**2**	1	1	0	1	**3**
Montbéliarde	0	0	0	0	**0**	1	0	0	0	**1**	1	0	0	0	**1**
Mocho Nacional	2	2	3	3	**10**	0	0	0	0	**0**	2	2	3	3	**10**
Guzerat	8	3	4	0	**15**	3	2	2	0	**7**	5	2	3	0	**10**
Total	**26**	**20**	**19**	**6**	**71**	**21**	**17**	**12**	**1**	**51**	**25**	**20**	**18**	**6**	**69**

No. males = Number of males

Source: ISRA-BAME household survey 2023

Throughout the year, farmers record deaths for a variety of reasons (illness, accident, natural death, etc.). The number of deaths among females was greater than among males in both the controls and the beneficiaries. However, they are higher in the controls than in the beneficiaries (see Tables 18 and 19). In terms of mortality, the percentage of overall deaths in a herd is 20% in the controls and 15% for beneficiaries. The eradication of the tsetse fly in the Niayes area has probably contributed to a greater or lesser extent to this result.

Table 18: Number of dead females by breed and age group

	Controls					Beneficiary					Overall				
Cattle breeds	No. dead fem 0 to 18 months	No. dead fem 18 months to 3 years	No. dead fem 4 to 9 years	No. dead fem 10+ years	**Total**	No. dead fem 0 to 18 months	No. dead fem 18 months to 3 years	No. dead fem 4 to 9 years	No. dead fem 10+ years	**Total**	No. dead fem 0 to 18 months	No. dead fem 18 months to 3 years	No. dead fem 4 to 9 years	No. dead fem 10+ years	**Total**
Zebu Gobra	2	1	1	1	**5**	2	1	2	1	**6**	2	1	1	1	**5**
Zebu Maure	1	1	1	0	**3**	0	0	1	0	**1**	1	1	1	0	**3**
N'dama taurine	2	1	1	1	**5**	2	1	1	0	**4**	2	1	1	1	**5**
Djakore	2	1	1	1	**5**	2	1	1	1	**5**	2	1	1	1	**5**
Holstein	0	1	0	0	**1**	0	2	0	0	**2**	0	1	0	0	**1**
Montbéliarde	0	0	0	0	**0**	0	0	1	0	**1**	0	0	1	0	**1**
Mocho Nacional	1	1	2	5	**9**	0	0	0	0	**0**	1	1	2	5	**9**
Guzerat	5	0	2	0	**7**	1	1	0	0	**2**	2	1	1	0	**4**
Total	**13**	**6**	**8**	**8**	**35**	**7**	**6**	**6**	**2**	**21**	**10**	**7**	**8**	**8**	**33**

No. dead fem = Number of dead females

Source: ISRA-BAME household survey 2023

Table 19: Number of dead males by breed and age group

	Controls					Beneficiary					Overall				
Cattle breeds	No. dead males 0 to 18 months	No. dead males 18 months to 3 years	No. dead males 4 to 9 years	No. dead males 10+ years	**Total**	No. dead males 0 to 18 months	No. dead males 18 months to 3 years	No. dead males 4 to 9 years	No. dead males 10+ years	**Total**	No. dead males 0 to 18 months	No. dead males 18 months to 3 years	No. dead males 4 to 9 years	No. dead males 10+ years	**Total**
Zebu Gobra	1	1	0	0	**2**	1	1	0	0	**2**	1	1	0	0	**2**
Zebu Maure	1	0	0	0	**1**	0	0	0	0	**0**	1	0	0	0	**1**
N'dama taurine	1	1	0	0	**2**	1	1	1	0	**3**	1	1	1	0	**3**
Djakore	1	1	0	0	**2**	1	1	0	0	**2**	1	1	0	0	**2**
Holstein	0	0	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**
Montbéliarde	0	0	0	0	**0**	1	0	0	0	**1**	1	0	0	0	**1**
Mocho Nacional	1	1	0	0	**2**	0	0	0	0	**0**	1	1	0	0	**2**
Guzerat	3	1	1	0	**5**	1	1	0	0	**2**	2	1	1	0	**4**
Total	**8**	**5**	**1**	**0**	**14**	**5**	**4**	**1**	**0**	**10**	**8**	**5**	**2**	**0**	**15**

No. dead males = Number of dead males

Source: ISRA-BAME household survey 2023

4.2.3. Income trends for livestock farmers between 2010 and 2022

It was noted that the income of most farmers in the start-up year or in 2010 did not exceed 1 000 000 CFA francs per year. There was, however, a slight shift in income between 2010 and 2022. Both the control groups and the beneficiaries saw their incomes rise. In the control group,

33.68% of livestock farmers had an income of less than 500 000 CFA francs/year — that figure fell to 6.74% in 2022. Among the beneficiaries, 18.11% of farmers had incomes of between 5 000 000 and 10 000 000 CFA francs in 2010, whereas by 2022 the proportion was 34.16%. Those with incomes of between 1 and 5 million had risen from 55% to 59% (Tables 20 and 21).

Table 20: Average household income in 2010

Household income in 2010 (or start-up year)	Controls	Beneficiaries	Overall
0–500 000 CFA francs/year	33.68	1.23	21.14
500 001–1 000 000 CFA francs/year	48.45	23.87	38.95
1 000 001–5 000 000 CFA francs/year	17.36	55.14	31.96
5 000 001–10 000 000 CFA francs/year	0.52	18.11	7.31
More than 10 000 000 CFA francs/year	0	1.65	0.64
Test	Pearson's Chi-squared(4) = 233.4289 Pr = 0.000		

Source: ISRA-BAME household survey 2023

Table 21: Average household income in 2022

Current household income (2022)	Controls	Beneficiaries	Overall
0–500 000 CFA francs/year	6.74	0.41	4.29
500 001–1 000 000 CFA francs/year	38.08	2.06	24.17
1 000 001–5 000 000 CFA francs/year	53.11	59.26	55.48
5 000 001–10 000 000 CFA francs/year	1.81	34.16	14.31
More than 10 000 000 CFA francs/year	0.26	4.12	1.75
Test	Pearson's Chi-squared(4) = 216.6993 Pr = 0.000		

Source: ISRA-BAME household survey 2023

4.2.4. Cattle herd management

4.2.4.1. Livestock farming practices and positive changes observed

Although the majority of households started livestock farming before 2010, there have since been changes in goals, especially among beneficiaries (84% of households) and, to a lesser extent, among controls (51%). Positive changes were noted among the beneficiaries, particularly in terms of reduced pressure from tsetse flies (95% of households), increased

livestock productivity (56%) and higher incomes (46%). For the controls, the changes were due to an increase in livestock numbers (67%), livestock productivity (65%) and livestock farming income (56%).

Table 22: Livestock farming practices and positive changes observed

Farming year (%)	Controls	Beneficiaries	Overall
Pre-intervention (before 2010) %	81.1	97.1	87.1
Post-intervention (after 2010) %	18.9	2.9	12.9
Change in farming goals (%)	Controls	Beneficiaries	Overall
Yes	50.5	84.1	63.0
No	49.5	15.9	37.0
Types of positive change (%)	Controls	Beneficiaries	Overall
The tsetse fly population has fallen sharply	8.2	95.2	51.5
Livestock productivity has increased	64.9	52.4	58.7
Draught power has increased	15.4	2.4	8.9
The size of the herd has increased	66.8	24.3	45.7
Income from livestock has increased	56.3	46.1	51.2
Other	1.0	1.9	1.5

Source: ISRA-BAME household survey 2023

4.2.4.2. Feeding the cattle

The most common form of livestock management in both areas is extensive, favouring the use of natural rangeland. Although there is great diversity in cattle feed, most households favour natural fodder in their winter herd's diets. It is during this period that we see the availability of a diverse range of fodder with a high nutritional value and plenty of water. Other types of fodder are rarely used and are collected in the immediate surroundings. Some households, however, buy and/or produce fodder.

During the off-season, when there is less fodder available in the rangeland, it becomes more important to use other types of fodder. Although natural pasture is still favoured by control households and beneficiaries, it is far less so in the dry season (see Tables 23 and 24). During the dry season, there was an increase in tedding and fodder cultivation in both areas and for both periods, as well as an increase in the purchase of fodder, with a higher percentage of households among the beneficiaries. It is important to note that the households have a new

approach to the production of fodder during both seasons, which was not the case previously when the animals only had crop residue and natural pasture.

Table 23: Cattle feed in 2010

Cattle feed in the 2010 rainy season (%)	Controls	Beneficiaries	Overall
Natural fodder grazed by the herd	**86.6**	**80.6**	**85.2**
Grass cut and brought in	1.9	3.1	2.2
Tree leaves	0.7	0.8	0.7
Cultivated fodder	2.4	**9.3**	4.0
Purchased fodder (peanut hay, hay, etc.)	**7.9**	3.9	7.0
Leftover food and paper	0.5	2.3	0.9
Percentage of cattle feed in the 2010 dry season	Controls	Beneficiaries	Overall
Natural fodder grazed by the herd	52.55	36.67	48.06
Grass cut and brought in	11.82	24.81	15.5
Tree leaves	4.82	1.48	3.87
Cultivated fodder	8.61	9.63	8.9
Purchased fodder (peanut hay, hay, etc.)	21.17	21.85	21.36
Leftover food and paper	1.02	5.56	2.3

Source: ISRA-BAME household survey 2023

Table 24: Cattle feed in 2022

Percentage of cattle feed in the 2022 rainy season	Controls	Beneficiaries	Overall
Natural fodder grazed by the herd	83.29	77.44	81.91
Grass cut and brought in	0.93	3.76	1.6
Tree leaves	1.16	0.75	1.06
Cultivated fodder	3.25	10.53	4.96
Purchased fodder (peanut hay, hay, etc.)	10.9	4.51	9.4
Leftover food and paper	0.46	3.01	1.06
Percentage of cattle feed in the 2022 dry season (%)	Controls	Beneficiaries	Overall
Natural fodder grazed by the herd	48.76	35.25	45.01
Grass cut and brought in	10.77	23.38	14.27
Tree leaves	3.73	1.44	3.09
Cultivated fodder	8.56	12.23	9.58
Purchased fodder (peanut hay, hay, etc.)	25.97	21.94	24.85
Leftover food and paper	2.21	5.76	3.19

Source: ISRA-BAME household survey 2023

4.2.4.3. Expenditure on cattle feed

To supplement the cattle's fodder intake, the herders buy additional fodder to make up for the shortfall in the rangelands. In both areas, we see a change in food expenditure between 2010 and 2022, demonstrating strong pressure on local resources. In terms of beneficiaries, this expenditure fell as a result of better herd management.

Table 25: Expenditure on cattle feed in 2010

Change in expenditure on fodder as a percentage of total livestock expenditure between 2010 and 2022 (%)	Controls	Beneficiaries	Overall
Increased	74.7	81.7	76.2
Decreased	3.3	13.5	5.6
Remained constant	22.0	4.8	18.2

Source: ISRA-BAME household survey 2023

Alongside fodder, concentrated feed is distributed to the animals to balance and supplement their diet. Almost 70% of households distribute concentrates to cattle, with a high proportion among beneficiaries (94%) who are more focused on producing milk or meat for the markets. In the case of the controls, which generally have larger herds and are in the extensive system, concentrates are used more to sustain the herd during the dry season in order to cope with a shortage of fodder.

Table 26: Receipt of concentrates and duration of self-sufficiency in 2010 and 2022

Concentrates received by animals in 2010 (rice bran or groundnut cake) as a %	Controls	Beneficiaries	Overall
Yes	62.9	93.5	69.8
No	37.1	6.5	30.2
Months of concentrates received by animals in 2010	2.7	5.0	3.4
Concentrates received by animals in 2010 (rice bran or groundnut cake) as a %	Controls	Beneficiaries	Overall
Yes	80.8	93.0	83.6
No	19.2	7.0	16.4
Months of concentrates received by animals in 2022	3.1	5.9	3.8

Source: ISRA-BAME household survey 2023

The trends were the same for both periods, but there was a marked change in the use of concentrates in the controls, which can in part be attributed to the considerable variations in the availability of natural fodder owing to the country's changeable climate.

The length of time for which animals received concentrates was greater for beneficiaries than for controls. Between the two periods, the receipt of concentrates increased in controls from 2.7 to 3.1 months between 2010 and 2022, whereas in the case of beneficiaries the increase was from 5.0 to 5.9 months.

4.2.5. Herd health

Cattle

Cattle are attacked by a variety of diseases. These vary in scale and intensity between areas. Among the controls, trypanosomosis was the most prevalent disease in 92% of cattle herds, followed by lumpy skin disease and foot-and-mouth disease. The beneficiaries are characterized by a high incidence of foot-and-mouth disease, followed by external parasites (ticks) and lumpy skin disease. **Nineteen per cent of farmers in Niayes, however, declared that trypanosomosis was still present (this result should be treated with caution as it contradicts the results of the epidemiological monitoring of trypanosomosis in Niayes). This can be explained by the fact that farmers tend to confuse diseases that have more or less the same symptoms, such as trypanosomosis, pasteurellosis and contagious bovine pleuropneumonia.**

Table 27: Cattle diseases and overall cost of disease treatment

Main bovine diseases	Controls	Beneficiaries	Overall
None	4.2%	3.7%	4.0%
Trypanosomosis (*Daso, Sompto, Yopto*)	**92.0%**	19.3%	**63.9%**
Gastrointestinal parasites (*San, Dialbi*)	3.9%	1.7%	3.0%
Bovine lumpy skin disease (BLSD _ skin disease)	**74.9%**	**26.3%**	**56.1%**
Ticks (*Coutt, wéteign, méto*)	16.8%	**46.9%**	28.5%
Foot-and-mouth disease (*Safa*)	**74.6%**	**77.0%**	**75.5%**
Rift Valley fever (*Wompéré*)	1.3%	0.0%	0.8 %
Contagious bovine pleuropneumonia (Bovine *Djofé, Yédo*)	7.3%	14.0%	9.9%
Botulism (*Lath*)	1.3%	0.0%	0.8%

Enterotoxaemia (*Gnirla, Saye*)	0.0%	1.2%	0.5 %
Footrot (*Féthio*)	7.0%	1.7%	4.9 %
Distomatosis (*Walo*)	0.0%	0.0%	0.0%
Other	3.4%	23.5%	11.1%
Number of cattle affected by the disease	8.5	13.4	10.1
Overall cost of treating the disease	22 980.6	31 708.0	25 828.1

Source: ISRA-BAME household survey 2023

Various players in veterinary medicine are involved in treating these diseases. In both areas, public vets are the preferred choice, particularly in the case of controls (81% of herds). Private vets are used more often for beneficiaries' herds (38%). Livestock technicians and auxiliaries are seen more often at the control level. Indeed, as the intensive system is larger in Niayes, contractual relations with private vets are more important, even if there are more public vets, in particular as a result of vaccination campaigns, which are financed by the public service and are the largest operations in terms of mobilizing vets and animals.

The number of animals affected in the cattle herd ranges from 9 to 13 in both areas, with a sample mean of 10. The overall cost of treating the diseases was relatively similar in both areas, although slightly higher for beneficiaries (31 708 CFA francs) than for controls (22 981 CFA francs).

Sheep

A number of diseases affecting sheep are found in both areas. Among the beneficiaries, the sheep were less prone to disease than the control flocks. In fact, 64% of beneficiary households with sheep had no disease compared with 19% in the control group. The same diseases are present in both areas, with a greater or lower incidence of cases depending on the area. The diseases affecting sheep in the groundnut basin (controls) were trypanosomosis (43%), pasteurellosis (27%), peste des petits ruminants (21%), external parasitism (ticks) and foot-and-mouth disease (4.7%). These same diseases are observed in Niayes (beneficiaries) but with a lower incidence, except for ticks (11%). There have been no cases of trypanosomosis.

Table 28: Diseases observed in sheep

Main diseases in sheep	Controls	Beneficiaries	Overall
None	19.4%	**63.5%**	31.3%
Pasteurellosis (*Djofé* in sheep and goats)	**27.1%**	7.9%	21.9%

Trypanosomosis (*Daso, Sompto, Yopto*)	**42.9%**	**0.0%**	31.3%
Peste des petits ruminants (*Thiarrou, Thiarth*)	**20.6%**	**12.7%**	18.5%
Gastrointestinal parasites (*San, Dialbi*)	1.8%	3.2%	2.2%
Bovine lumpy skin disease (BLSD skin disease)	0.6%	0.0%	0.4%
Ticks (*Coutt, wéteign, méto*)	4.7%	**11.1%**	6.4%
Foot-and-mouth disease (*Safa*)	4.7%	**4.8%**	4.7%
Rift Valley fever (*Wompéré*)	1.2%	0.0%	0.9%
Contagious bovine pleuropneumonia (Bovine *Djofé, Yédo*)	1.2%	0.0%	0.9%
Other	4.7%	9.5%	6.0%

Source: ISRA-BAME household survey 2023

Farmers use treatments to combat these diseases. There were more treatments among controls (3) than beneficiaries (2), with relatively similar costs of between 9000 and 10 000 CFA francs in both areas.

Table 29: Number and cost of treatments

Treatments:		Obs	Min	Mean	Standard deviation	Max
No. of individual treatments	Controls	161	0	2.5	2.8	23
	Beneficiary	27	0	1.6	1.0	4
	Overall	188	0	2.4	2.6	23
Overall treatment cost	Controls	161	0	9202.5	40 342.0	500 000
	Beneficiary	27	0	10 203.7	20 868.3	100 000
	Overall	188	0	9346.3	38 120.4	500 000

Source: ISRA-BAME household survey 2023

Goats

Most farmers in the two areas say that peste des petits ruminants is a major disease affecting goats. In addition to peste des petits ruminants, ticks and pasteurellosis continue to affect goats in the Niayes area. Among the controls, pasteurellosis is the disease of greatest concern in goats according to 33% of farmers. According to 24% of farmers, trypanosomosis is a high-risk disease in goats after peste des petits ruminants. Susceptibility to this disease depends on whether the herd's environment is wet or not. Other major diseases, which are rarely observed by farmers, include foot-and-mouth disease, footrot, etc.

Table 30: Diseases in goats

Main diseases in goats	Controls	Beneficiaries	Overall
None	23.68%	31.15%	27.01%
Pasteurellosis (*Djofé* in sheep and goats)	33.33%	10.93%	23.36%
Trypanosomosis (*Daso, Sompto,Yopto*)	23.68%	0.00%	13.14%
Peste des petits ruminants (*Thiarrou,Thiarth*)	31.58%	37.70%	34.31%
Gastrointestinal parasites (*San, Dialbi*)	0.00%	0.55%	0.24%
Ticks (*Coutt, wéteign, méto*)	2.19%	19.13%	9.73%
Foot-and-mouth disease (*Safa*)	6.14%	2.73%	4.62%
Rift Valley fever (*Wompéré*)	0.00%	0.00%	0.00%
Botulism (*Lath*)	0.00%	0.00%	0.00%
Enterotoxaemia (*Gnirla, Saye*)	0.00%	0.55%	0.24%
Footrot (*Féthio*)	3.07%	1.64%	2.43%
Goat pox (*Badé*)	0.00%	1.09%	0.49%
Other	3.07%	8.20%	5.35%

Source: ISRA-BAME household survey 2023

To deal with these diseases, the farmers often use modern treatment methods, usually with support from a vet. Some, however, still use traditional methods to treat their goats. Traditional care is more common among beneficiaries (60%) because of the cost of the treatments.

Table 31: Treatment used in goats

Treatment used	Controls	Beneficiaries	Overall
Traditional treatment	8.77%	60.00%	12.90%
Modern treatment	94.15%	40.00%	89.78%

Source: ISRA-BAME household survey 2023

The number of individual treatments varied from 0 to 7 for controls and from 0 to 6 for beneficiaries. On average, goats receive two treatments in Foundiougne and one in Niayes. The number of treatments given to the animal depends largely on the duration of the disease. Farmers usually stop treatment when the health of the livestock begins to stabilize.

Table 32: Number of individual treatments

No. of individual treatments	Observations	Min	Mean	Standard deviation	Max
Controls	171	0	2	1	7
Beneficiaries	15	0	1	2	6
Overall	186	0	2	1	7

Source: ISRA-BAME household survey 2023

On average, however, the cost of treatment was higher for controls than for beneficiaries, at 4078 CFA francs versus 1750 CFA francs, respectively. The costs borne by control farmers can be as high as 25 000 CFA francs, while the maximum cost of treating goats is 15 000 CFA francs for beneficiaries. The high overall cost of treatment in controls is explained by the fact that the diseases are generally coupled with trypanosomosis, which increases their severity.

Table 33: Cost of treatment for goats

Overall treatment cost	Observations	Min	Mean	Standard deviation	Max
Controls	165	0	4078	4691	25 000
Beneficiaries	14	0	1750	4145	15 000
Overall	179	0	3896	4682	25 000

Source: ISRA-BAME household survey 2023

Beneficiaries have the highest incomes. The majority of control and beneficiary farmers have an annual income of between 1 000 000 and 5 000 000 CFA francs. A large proportion of farmers among the beneficiaries (34.16%), however, earn between 5 000 000 and 10 000 000 CFA francs per year. The high incomes recorded by the beneficiaries depend on the breed, weight and health of the animals, which has an impact on their selling price.

Horses

The main diseases seen in horses are trypanosomosis and, to a lesser extent, African horse sickness and pasteurellosis. Trypanosomosis is absent in the Niayes area, whereas it is the main disease in the Sine-Saloum.

Table 34: Diseases in horses

Main diseases in horses	Controls	Beneficiaries	Overall
None	25.26%	86.67%	33.53%
Pasteurellosis (*Djofé* in sheep and goats)	0.69%	2.22%	0.90%
Trypanosomosis (*Daso, Sompto,Yopto*)	**54.67%**	0.00%	47.31%
African horse sickness (horses and donkeys)	10.38%	6.67%	9.88%
Gastrointestinal parasites (*San, Dialbi*)	0.35%	0.00%	0.30%
Ticks (*Coutt, wéteign, méto*)	1.73%	0.00%	1.50%
Rift Valley fever (*Wompéré*)	0.00%	0.00%	0.00%
Botulism (*Lath*)	2.42%	0.00%	2.10%
Enterotoxaemia (*Gnirla, Saye*)	0.00%	0.00%	0.00%
Other	6.23%	4.44%	5.99%

Source: ISRA-BAME household survey 2023

These diseases are generally treated by veterinary doctors, but also by technicians and livestock representatives/auxiliaries. Traditional medicine is still used, but the percentage is higher among beneficiaries, which can be attributed to the farmers administering medication themselves.

Table 35: Equine treatments

Treatment used	Controls	Beneficiaries	Overall
Traditional treatment	8.02%	33.33%	8.64%
Modern treatment	93.25%	66.67%	92.59%

Source: ISRA-BAME household survey 2023

The number of treatments was just over twice as high among beneficiaries, which may explain the low incidence of disease in these herds, where 90% were disease-free compared with 26% among controls. It should be noted that horses are more prevalent in the Sine, where they play an important role in agriculture and transport.

Table 36: Number and cost of treatments

Number and cost of treatments		Obs	Min	Mean	Standard deviation	Max
No. of individual treatments	Controls	236	0	2.1	1.3	7
	Beneficiary	6	1	7.8	11.4	30
	Overall	242	0	2.3	2.3	30
Overall treatment cost	Controls	236	0	12 382	25 468	250 000

	Beneficiary	6	0	18 833	23 112	50 000
	Overall	242	0	12 542	25 388	250 000

Source: ISRA-BAME household survey 2023

Donkeys

Donkeys have fewer diseases in the Niayes area. African horse sickness affects 1.6% of livestock farmers in the region. A relatively small percentage (6%) of diseases not defined in this research, however, continue to affect donkeys in Niayes. On the other hand, in the Sine-Saloum area, according to 35% of farmers, donkeys are victims of trypanosomosis. In addition, 9.2% of control farmers believe that African horse sickness affected their donkeys. In Sine-Saloum, where agricultural farming is generally combined with livestock rearing, donkeys play an important role working in the fields. Donkeys with poor health can therefore affect agricultural productivity.

Table 37: Diseases in donkeys

Main diseases in donkeys	Controls	Beneficiaries	Overall
None	48.0%	92.4%	64.6%
Trypanosomosis (*Daso, Sompto,Yopto*)	35.0%	0.0%	21.9%
African horse sickness (African horse sickness and donkey sickness)	9.2%	1.6%	6.3%
Gastrointestinal parasites (*San, Dialbi*)	0.0%	0.0%	0.0%
Ticks (*Coutt, wéteign, méto*)	1.0%	0.0%	0.6%
Rift Valley fever (*Wompéré*)	0.0%	0.0%	0.0%
Botulism (*Lath*)	0.0%	0.0%	0.0%
Enterotoxaemia (*Gnirla, Saye*)	0.0%	0.6%	0.2%
Other	6.9%	6.0%	6.5%

Source: ISRA-BAME household survey 2023

The majority of farmers in both areas (89.8%) use modern treatments for donkeys. Given the absence of trypanosomosis in the Niayes area, however, farmers usually use traditional treatments to treat their donkeys (around 60%). In the control area, 94.2% of farmers use non-traditional methods to treat their donkeys. The presence of vets and trypanocides enable the use of modern treatments.

Table 38: Treatments used for donkeys

Treatment used	Controls	Beneficiaries	Overall
Traditional treatment	8.8%	60.0%	12.9 %
Modern treatment	94.2%	40.0%	89.8%

Source: ISRA-BAME household survey 2023

Overall, the number of treatments given to donkeys varied between zero and seven, with an average of around two treatments. In the Niayes area, the number can be up to six, with an average of around one treatment. This trend, observed in the Niayes area, is more marked in Sine-Saloum, where the number of treatments can be as high as seven, with an average of around two treatments. This high number of treatments is a strong indication of the inactivity of donkeys, which are generally used for transport or as draught animals in farming.

The overall cost of treating donkeys can be as high as 25 000 CFA francs in the control area and 15 000 CFA francs in Niayes. The average cost is estimated at 4078 CFA francs in Sine-Saloum and 1750 CFA francs in Niayes. This lower cost in Niayes is essentially explained by the number of treatments.

Table 39: Number and cost of treatments for goats

Number and cost of treatments		Obs	Min	Mean	Standard deviation	Max
No. of individual treatments	Control	171	0	1.7	1.0	7
	Beneficiary	15	0	1.4	2.0	6
	Overall	186	0	1.7	1.1	7
Overall treatment cost	Control	165	0	4078	4691	25 000
	Beneficiary	14	0	1750	4145	15 000
	Overall	179	0	3896	4682	25 000

Source: ISRA-BAME household survey 2023

4.3. Analysis of the effects of the eradication campaign on the cattle population and farmers' households

4.3.1. Description of variables used for matching

The table below summarizes the variables used to match individuals in the intervention area (Niayes) with those in the control area (Sine).

Table 40: Description of variables used for matching

Name of the variable	Description of the variable
Result variables	
Benef	Variable referring to the area (1 = Niayes; 0 = Sine-Saloum)
cost_treatment_try	Cost of treating trypanosomosis (CFA francs)
income_milk	Income from milk sales (CFA francs)
exotic_breed	Number of exotic breeds
house_size	Household size
Variables used for matching	
dum_no_sheep	Sheep ownership
dum_no_goats	Goat ownership
animal_rice bran_2022	Are your animals receiving concentrates in 2022 (rice bran or groundnut cake)?
inc_live	Income from livestock
house_size	Household size
farm_area	Total area (in ha) owned by household?
transhumance	Does your herd go on transhumance?

Source: ISRA-BAME household survey 2023

4.3.2. Match quality

Before interpreting the results of the impact, it is important to assess the quality of the matching. Matching was assessed according to the criteria of Rubin (2002), Kassie et al. (2011) and Bekele et al. (2014). Figure 4 below shows the standardized bias of each variable before and after matching. It is represented by small circles before matching and small crosses after matching. The graph shows a significant reduction in standardized bias after matching for all variables. Before matching, it exceeded 10% and even more than 50% for certain variables such as farm area. However, after matching, the bias decreases to less than 5% for most variables.

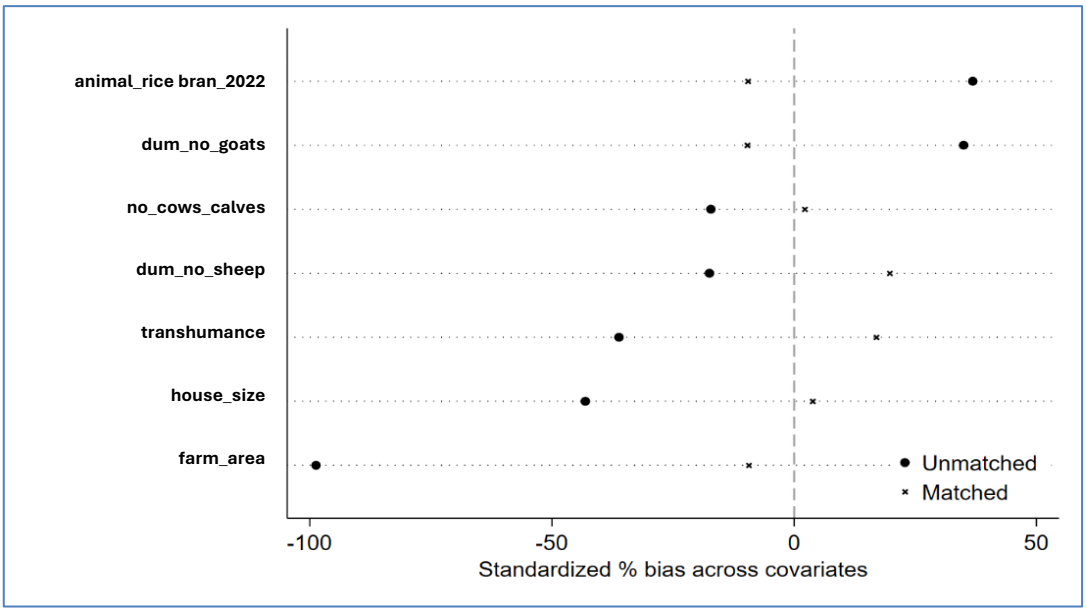

***Figure 4**: Standardized bias before and after matching*

Source: Authors' calculations based on survey data

According to Caliendo and Kopeing (2008), another important criterion for assessing the quality of a match is to observe overall indicators such as the maximum likelihood, the pseudo-R-squared and the mean bias, before and after matching. The table below shows these indicators. The results indicate good matching quality. Indeed, the pseudo-R-squared fell after matching from 0.262 to 0.038. In addition, maximum likelihood tests are rejected before matching but not after matching.

Table 41: Quality indicators before and after matching

Sample	Pseudo-R-squared	LR chi2	p>chi2	Mean bias
Not matched	0.262	122.54	0	40.7
Matched (kernel)	0.038	10.44	0.165	10.2

Source: Authors' calculations based on survey data

The final criterion to be checked for matching quality is the common support assumption. The result is shown in the graph below. The graph shows that the common support is reached through an overlap of the propensity probabilities of the treated and untreated groups. There is, moreover, no loss of observations.

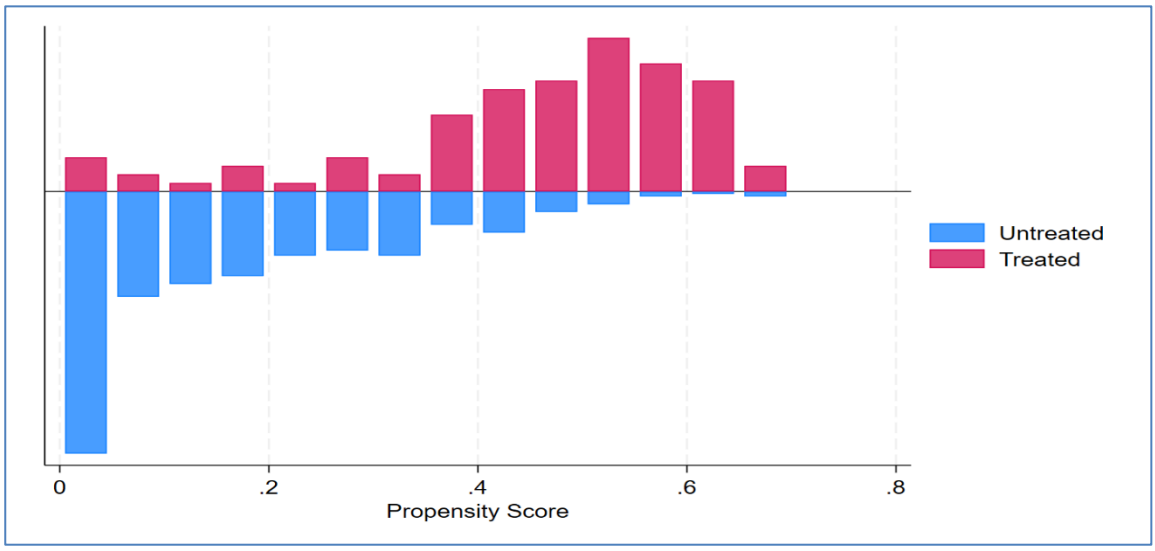

***Figure 5**: Distribution of propensity scores and common support*

Source: Authors' calculations based on survey data

The effect of tsetse eradication in Niayes can be interpreted as the model meets the criteria for assessing the quality of matching.

4.3.3. Effects of eradication on beneficiaries according to the PSM

The PSM shows that eradicating tsetse flies in Niayes has a positive impact on income from livestock farming and milk sales, the introduction of exotic breeds and the cost of treating trypanosomosis. Indeed, according to the kernel method, there is a positive and significant effect of 7 629 405 CFA francs on income from livestock farming and an estimated effect of 7 422 320 CFA francs using the NN method. **In other words, eradicating tsetse flies would increase the income of livestock farmers in the Niayes area by 45% using the kernel approach and 44% with the NN method.**

The impact on income from milk sales is also positive and significant. It is estimated to be 581 133 CFA francs using the kernel method and 583 483 CFA francs using the NN method. **According to these figures, the eradication of tsetse flies would increase the income from sales of milk for livestock farmers in the Niayes area by 60.9% and 61% for the kernel and NN methods, respectively.**

Eradication also has a positive effect on the composition of livestock farmers' herds, with the introduction of exotic breeds. **Eradicating tsetse flies would increase the income of livestock**

farmers in the Niayes area by 18% using the kernel method and 19% using the NN method.

The impact of the cost of treating trypanosomosis is estimated at -7306 CFA francs using the kernel method and -7355 CFA francs using the NN method. **Eradicating tsetse flies would reduce the cost of treating trypanosomosis among livestock farmers in the Niayes area by 7306 CFA francs (63.6%) and 7355 CFA francs (63.7%), respectively.**

Table 42: Effects of eradication on treated groups according to the PSM

Variable of interest	Matching	Treated	Controls	Impact	S.E.	T-stat
Income from livestock	Kernel	16 864 800	9 235 395	7 629 405.04	2 550 204	2.99
	NN	16 864 800	9 442 480	7 422 320	3 128 587	2.37
Income from milk sales	Kernel	954 436	373 302.6	581 133.45	110 567	5.26
	NN	954 436	370 952.8	583 483.2	113 446.6	5.14
Introduction of exotic breeds	Kernel	0.25	0.070391	0.17960898	0.072966	2.46
	NN	0.25	0.06	0.19	0.071244	2.67
Cost of trypanosomosis treatment	Kernel	4187.5	11 494.21	-7306.7066	7554.255	-0.97
	NN	4187.5	11 542.9	-7355.396	6578.405	-1.12

Source: Authors' calculations based on survey data

4.4. Change in the situation in Niayes before and after the eradication campaign

4.4.1. Change in the number of subsidized heifers imported

After the first seven years of the eradication campaign, farming conditions improved significantly, with a reduction in tsetse fly density and a fall in the prevalence of AAT in the Niayes area. Between 2009 and 2022, 4359 blood samples were taken from cattle and screened for trypanosomes using the buffy coat and enzyme-linked immunosorbent assay (ELISA) techniques, and since 2020 using PCR testing. In block 1, seroprevalence rose from 18.9% (95% CI: 11.2–26.5) in 2009 to 0% in 2017–2022, and from 92.9% (95% CI: 88.2–97) in 2010 to 0% in 2021 in block 2 (Seck et al., 2024). It was against this backdrop that in 2017 the National Association for the Intensification of Dairy Production (ANIPL), in collaboration with the State of Senegal, conducted its first campaign to import pregnant heifers with high milk production potential. Between 2017 and 2024, 5965 dairy cows were imported to boost milk

production in Senegal. Bearing in mind that these are pregnant cows, at least 11 930 exotic cattle have been introduced into Senegal.

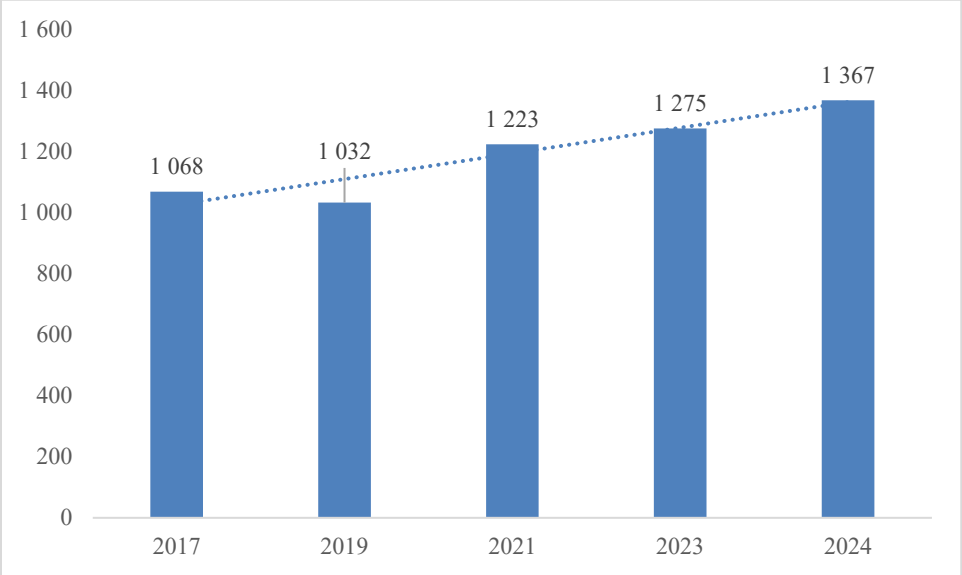

***Figure 6**: Change in the numbers of subsidized heifers imported*

Source: ANIPL, 2024.

4.4.2. Destination of imported heifers by region

In 2024, the majority of imported heifers (986 cows, or 72%) were distributed between the regions of Dakar, Thiès, Saint-Louis and Diourbel. Of these 986 exotic cows, **93% (920 cows) are destined for the Niayes area**: the regions of Dakar, Thiès and Saint-Louis. This further shows that exotic cattle can now live in the Niayes area, compared with the period before the tsetse eradication campaign. The main exotic breeds imported are Normande, Montbéliarde, Holstein and Braunvieh.

Table 43: Destination of imported heifers by region

Breeds	**Dakar**	**Thiès**	**Saint-Louis**	**Diourbel**	**Total**
Holstein	43	154	11	3	**211**
Normande	275	61	11	25	**372**
Montbéliarde	118	163	8	22	**311**
Braunvieh	23	46	7	16	**92**
Total (number)	**459**	**424**	**37**	**66**	**986**
Total (%)	47%	43%	4%	7%	100%

Source: ANIPL, 2024.

4.4.3. Change in number of recipients of pregnant heifers

Alongside the increase in imports of exotic heifers, the number of beneficiaries also rose between 2017 and 2024, from 64 to 432 livestock farmers or intensive farms. In 2007, three years before the start of the eradication campaign, there were barely 13 livestock farmers and intensive farms with exotic heifers. The increase in the number of beneficiaries further corroborates the improved conditions for rearing exotic cattle in Senegal, particularly in the Niayes area.

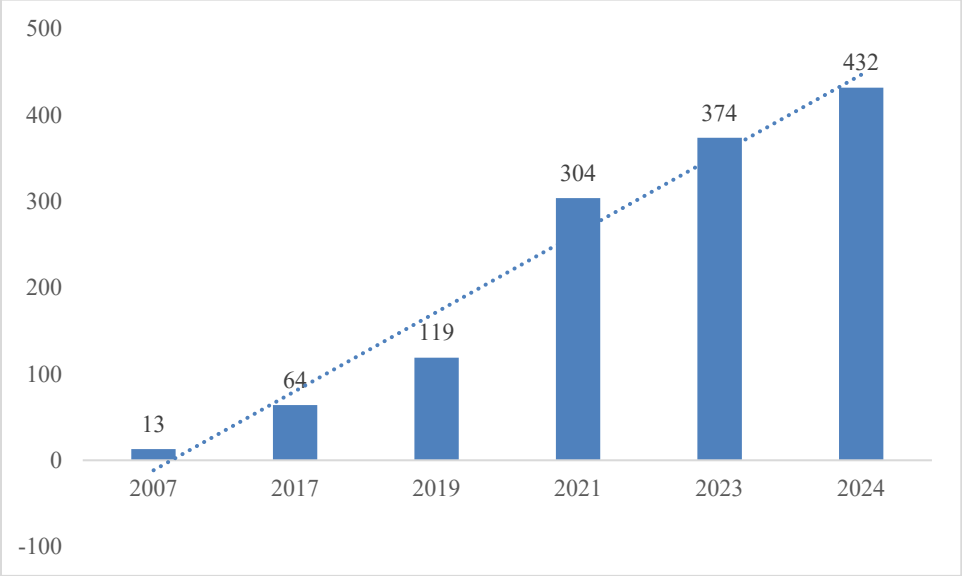

***Figure** 7: Change in number of recipients of pregnant heifers*

Source: ANIPL, 2024.

4.4.4. Trend in milk production of exotic breeds (in thousands of litres)

One of the main aims of importing pregnant heifers is to improve national milk production. Between 2018 and 2024, milk production from exotic cows rose from 4.3 to 62.5 million litres. The contribution of imported exotic cows to national milk production rose from 1.8% to 23% between 2018 and 2024.

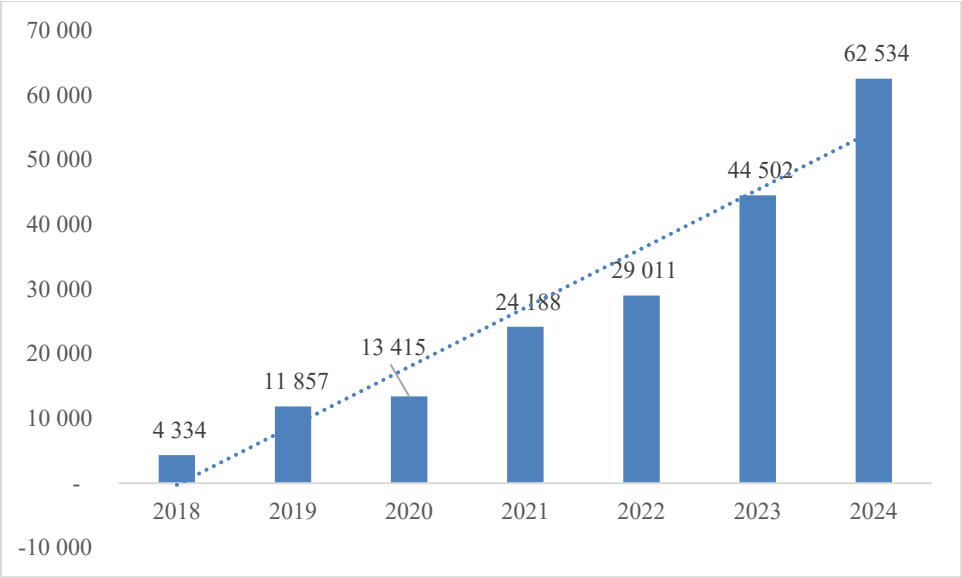

Figure 8: Trend in estimated milk production (in thousands of litres)

Source: ANIPL, 2024.

4.4.5. Changes in productivity indicators for the three production systems in Niayes between 2010 and 2023

Before the eradication campaign, the percentage of trypanotolerant cattle in the extensive system was 98%. In 2023, this percentage was 20%. For intensive systems focused on milk production, this percentage fell from 13% to 0% between 2010 and 2023. By contrast, the percentages of the Gobra breed increased over the same period for the extensive and intensive milk systems, rising from 0.1% to 21% and from 0.5% to 28.5%, respectively. The percentage of exotic cattle also increased over the period, rising from 1.5% to 15% and from 1.8% to 27% for the extensive and intensive meat systems, respectively. The quantities of milk sold per female producer rose sharply over the period for all three systems, from 157 L to 1823 L, from 110 L to 864 L and from 339 L to 2120 L, respectively. The sales prices per head of cattle also increased for all three systems. Herd sizes, however, decreased for both extensive and intensive dairy systems. This reduction in herd size is a positive factor in terms of environmental impact.

Table 44: Changes in cattle productivity indicators between 2010 and 2023

Detailed description of the three farming systems in Niayes						
INDICATORS	**Extensive system Trypanotolerant cattle**		**Intensive system Cattle for meat production (+70% Gobra)**		**Intensive system Cattle for milk production (-10% of Gobra)**	
	2010	**2023**	**2010**	**2023**	**2010**	**2023**
Percentage of Djakore cattle	98.40%	20%	0%	9.09%	13%	0%
Percentage of Gobra cattle	0.10%	21.38%	98.20%	36.36%	0.50%	28.57%
Percentage of exotic cattle	1.50%	15.17%	1.80 %	27.27%	65.00%	57.14%
Cultivated area (ha)	2	2	2.1	2.45	7	1.5
Area of pasture owned (ha)	0.03	0.04	0.85	0.28	2	0
Milk sold per female producer (litre)	157	1823	110	864	339	2120
Number of cattle sold	3.5	3.4	10.5	30	3.6	1
Price per head	174 485	279 679	288 621	340 601	152 182	679 166
Household size	52	48	28	35	31	16
Annual cost of trypanocides per head	361	7019	243	10 000	833	0

Source: ISRA-BAME 2023 household survey and 2010 baseline survey data

Conclusion

The socio-economic impact assessment of the tsetse fly eradication campaign in the Niayes area revealed satisfactory results. The main local cattle breeds identified in the control and beneficiary groups were N'dama taurine, Gobra zebu and Djakore. However, the percentage of livestock farmers with N'damas was higher in the control samples than among the beneficiaries (74.7% compared with 53.5%). In both areas, local breeds undoubtedly outnumbered exotic ones. Nevertheless, the percentage of exotic breeds was higher in the beneficiaries than in the control (20% compared with 10%). In terms of mortality, the results show that the rate is 20% in the control and 15% for beneficiaries. The eradication of the tsetse fly in the Niayes area has probably contributed to a greater or lesser extent to controlling cattle mortality.

With regard to livestock farmers' income, the results show that the income of most did not exceed 1 000 000 CFA francs per year in 2010. Following the eradication campaign, there was a positive trend in the farmers' incomes. Both the control groups and the beneficiaries saw their incomes rise. In the control group, 33.68% of livestock farmers had an income of less than 500 000 CFA francs/year — that figure is now 6.74%. Among the beneficiaries, 18.11% of farmers had incomes of between 5 000 000 and 10 000 000 CFA francs, whereas the proportion

is now 34.16%. Those with incomes of between 1 and 5 million have risen from 55% to 59% (see Tables 20 and 21).

Between 2010 and 2022, positive changes were noted among the beneficiaries, particularly in terms of reduced pressure from tsetse flies (95% of households), increased livestock productivity (56%) and higher incomes (46%). For the controls, the changes were mainly due to an increase in livestock numbers (67%), livestock productivity (65%) and an increase in livestock farming income (56%).

In terms of animal health, tsetse-borne trypanosomosis was the most prevalent disease in 92% of cattle herds, followed by lumpy skin disease and foot-and-mouth disease. The beneficiaries were characterized by a high incidence of foot-and-mouth disease, followed by external parasites (ticks) and lumpy skin disease.

Nineteen per cent of farmers in Niayes, however, declared that trypanosomosis was still present. This result should be treated with caution as it contradicts the results of the epidemiological monitoring of trypanosomosis in Niayes (see table 27). Trypanosomosis has not been reported in other species (sheep, goats, horses and donkeys).

The results of the PSM show that eradicating tsetse flies in the Niayes has a positive impact on income from livestock farming and milk sales, on the introduction of exotic breeds and on the cost of treating trypanosomosis. Indeed, according to the kernel method, there is a positive and significant effect of 7 629 405 CFA francs on income from livestock farming and an estimated effect of 7 422 320 CFA francs using the NN method. **In other words, eradicating tsetse flies would increase the income of livestock farmers in the Niayes area by 45%[5] using the kernel method and 44% according to my NN method.**

The impact on income from milk sales is also positive and significant. It is estimated to be 581 133 CFA francs using the kernel method and 583 483 CFA francs using the NN method. **According to these figures, the eradication of tsetse flies would increase the income from sales of milk for livestock farmers in the Niayes area by 60.9% and 61% for the kernel and NN methods, respectively.**

Eradication also has a positive effect on the composition of livestock farmers' herds, with the introduction of exotic breeds. **The eradication of tsetse flies would increase the income of**

[5] 45% = (7 629 405/16 864 800) * 100

livestock farmers in the Niayes area by 18% using the kernel method and 19% using the NN method.

With regard to the cost of treating trypanosomosis, the effect is estimated at -7306 CFA francs using the kernel method and -7355 CFA francs using the NN method. **Eradicating tsetse flies would reduce the cost of treating trypanosomosis among livestock farmers in the Niayes area by 7306 CFA francs (63.6%) and 7355 CFA francs (63.7%), respectively.**

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Annexes: Interview guides and household questionnaire

Annex 1: Interview guides

Interview guide for the Niayes area

1. Before the tsetse eradication campaign, what cattle breeds were in the Niayes area?
2. What cattle breeds are now found here?
3. How do you assess the presence of the tsetse fly in Niayes today?
4. Since the end of the tsetse fly eradication campaign:

4.1. Have you sometimes suspected symptoms of trypanosomosis in your animals?

4.2. Have you seen an increase in your animals' productivity (milk, meat, body condition, etc.)?

4.3. Have you seen an increase in your income from livestock, particularly cattle?

5. For agropastoralists: what would you say about the draught power of your animals, particularly your cattle, before and after the campaign?
6. What about the presence of horses in Niayes before and after the campaign?
7. How do you assess the use of trypanocides in Niayes before and after the campaign?
8. How would you assess the presence of intensive farms in Niayes compared with before the campaign?
9. Do you think there is a risk of re-infestation in the Niayes area?
10. Are there still areas in Niayes that are favourable to the development of tsetse flies?
11. Are you satisfied with the results of the eradication campaign (Not satisfied; Somewhat satisfied; Very satisfied)?
12. Have you noticed any negative consequences for the environment, your animals or yourself as a result of the chemicals used in the control phase?
13. Have you noticed any negative consequences for the environment, your animals or yourself as a result of using sterile males?
14. In your opinion, what are the strengths and weaknesses of the eradication campaign?
15. What improvements are needed in future interventions of this kind?
16. What are the prospects for consolidating and sustaining what has been achieved?

Interview guide for the Sine area

1. How do you assess the presence of tsetse flies in your area?
2. How long has your area been affected by tsetse flies?
3. Which communities are most affected by tsetse flies in the department of Foundiougne?
4. Do you suspect symptoms of trypanosomosis in your herds?
5. If so, which species are most prone to the disease?
6. How do you assess the level of productivity of animals affected by trypanosomosis?
7. How do you assess the use of trypanocides and trends in expenditure on trypanocides?
8. What breeds of cattle exist in your area?
9. Do you farm mixed breeds or only exotic breeds?
10. Do you think there are many intensive farms in your area?
11. If not, why do you think that is?
12. For agropastoralists: how do you assess the draught power of your animals, particularly your cattle?
13. What about the presence of horses in your area?

Annex 2: Household questionnaire

Tsetse fly questionnaire (2)_VF.pdf