Simplified Approval Process

Annex 2: Prefeasibility study

SAP: Upscaling "Naatanguee" integrated family and village farms for a resilient agriculture in Senegal

Senegal | Centre de Suivi Ecologique

June 2024

GREEN CLIMATE FUND

SECTION I: CLIMATE RATIONALE

The overall aim of this section is to provide a comprehensive assessment of the climate risks and vulnerabilities associated with the project, as well as the opportunities for adaptation and mitigation. It is essential for demonstrating the project's alignment with GCF funding criteria and the Paris Agreement's objectives.

This section provides a detailed analysis of the climate risks and vulnerabilities associated with the project area and sets up the scene to identify the project measures that will be taken to mitigate or adapt to these risks. It includes a review of existing climate data, projections of future climate scenarios, and an assessment of the project's thematic area exposure to climate risks.

The Climate Rationale together with the Baseline Assessment provides the foundation for the Upscaling Naatangue farms GCF SAP project, enabling it to address climate change challenges and promote sustainable agriculture practices in the project area.

1. Climatic and environmental pressures in Senegal

1.1. Overview

West Africa has been identified as one of the regions that is most susceptible to the impacts of climate change, with the situation worsening since the late 1970s. The region has experienced an increase in the frequency and severity of climate-related disasters, which have had devastating effects on its people, economy, and ecosystems. With the warming of the climate, the frequency and severity of climate change-related disasters (floods, droughts, violent storms etc.) is increasing.

Located in the far west of the African continent, Senegal is a country with a tropical, semi-arid climate, with temperatures averaging between 25°C to 32°C throughout the year, commonly referred to as “Sahelian”. It is characterized by high, inter-annual rainfall variability with two distinct seasons: a dry season from October to May and rainy season from June to September. It has an overall average rainfall between 300mm in the North and 1200mm in the South. It also has a strong maritime influence stemming from its 700km Atlantic coastline.

Senegal is not immune to the effects of climate change. According to the World Meteorological Organization (WMO), the average temperature in Senegal has increased by 1.5°C since the pre-industrial era, which is higher than the global average increase of 1.1°C[1]. In addition to the overall increase in temperature, Senegal is also reporting increased frequency and severity of extreme weather events, such as heatwaves, droughts and floods becoming more frequent, longer, and more intense[2].

With a population of approximately 16.7 million people and an agrarian economy that is heavily dependent on rain-fed agriculture (87% rainfed[3]), and which accounts for approximately 16% of the country's Gross Domestic Product (GDP), employs over 70% of the population in rural areas, and accounts for over 75% of the country's export earnings[4], climate change is posing a significant threat to food security, livelihoods, economic growth and natural ecosystems.

In Senegal specifically, one study found that temperature and precipitation are the main climatic variables that pose risks to agriculture. The vulnerability of Senegalese agriculture is largely linked to its heavy dependence on rainfall, of which its interannual variability is becoming increasingly difficult to predict, and to temperature, which has seen consistent increases throughout the last several decades[5].

Furthermore, agricultural production in Senegal is also impacted by soil degradation and pest attacks, which can reduce crop yields and quality. The Food and Agriculture Organization of the United Nations (FAO) reports that soil degradation is a significant issue in Senegal, with an estimated 61% of soils in the country being affected by

[1] World Meteorological Organization. (2020, December 2). WMO Provisional Report on the State of the Global Climate 2020—World | ReliefWeb. https://reliefweb.int/report/world/wmo-provisional-report-state-global-climate-2020
[2] USAID. (2015). Climate Change and Health Risks in Senegal.
[3] USAID. (2017). Climate Change Risk Profile: Senegal.
[4] World Bank. (2022). World Bank Open Data: Senegal. World Bank Open Data.
[5] Kone, Y. (2023). FAO shares mid-term results of country programming framework for Senegal. Food and Agriculture Organization of the United Nations.

erosion, salinization, and other forms of degradation, driven by a combination of factors, including inappropriate land use practices, overgrazing, deforestation, and climate change[6]. In addition to soil degradation, Senegal is also facing a biodiversity destruction and vegetation degradation in its ecogeographic areas. These issues are not unique to Senegal but are shared by many Sahelian countries. The Consultative Group on International Agricultural Research (CGIAR) reports that the Sahelian region has been experiencing a decline in vegetation cover, resulting in desertification and land degradation[7].

Overall, these environmental pressures put additional stress on agricultural production in Senegal and exacerbate the impacts of climate change on the sector. The negative effects of climate change on Senegalese agriculture will be felt more through the drop in the income of farmers. As many crops are seasonal, some farmers depend on single growing seasons for their entire yearly income, meaning that one poor growing season (insufficient rain, flooding, high temperatures) can result in many farmers falling into poverty for a long period.

This section will focus on the country-wide, climatic stressors that Senegal has faced, and how the frequency and severity of these stressors has changed over time.

1.2. Historical trends

Understanding historical climate trends is critical for developing a climate rationale as climate data from the past can be used to identify trends in temperature, precipitation, and extreme weather events, which are important indicators of climate change impacts.

Precipitation and temperature are two crucial parameters that play a significant role in understanding the increasing volatility of the agricultural sector. Temperature is a critical factor that determines the ability of crops to germinate, grow, and produce fruits, while rain provides essential water to an agricultural landscape that primarily relies on rainwater. Rain also helps maintain soil conditions necessary for the uptake of nutrients. Agriculture in Senegal is predominantly rain-fed, making it highly vulnerable to any changes in precipitation patterns. Despite the existence of drought-resistant crops or crop varieties, they can still be susceptible to scorching or lower yields. Examining historical natural disasters, such as droughts, floods and heatwaves across different regions of Senegal can offer further insights into the intra-country variability and potential climate risks faced by the agricultural sector.

1.2.1. Overview of Historic Changes

The historical changes were developed using observed data from the Climate Prediction Center (CPC).
CPC is a global temperature and precipitation dataset developed by the National Oceanic and Atmospheric Administration (NOAA). The data are daily reports from the Global Telecommunications System (GTS) with 6000 to ~7000 stations meshed using the Shepard algorithm at 50 km resolution on a daily basis available from 1979 to

[6] FAO. (2015). Status of the World's Soil Resources: Main Report.

[7] Patrice Savadogo, Jules Bayala, Antoine Kalinganire. (2017). Restoration of Degraded Lands in Mali: a review on lessons learnt and opportunities for scaling.

present. Data is available at https://psl.noaa.go. These data have been assessed with respect to other products in Africa and/or in Senegal and we found a good performance compared to GPCC, CHIRTS, ERA5 and ANACIM maproom. (http://213.154.77.59/maproom/index.html)

1.2.2. Temperature

Methodology

Temperature climatology are calculated for two time periods (1980-2000 and 2001-2021) by average annual temperature for each period across the whole Senegal. Differences between these two time periods are performed to evaluate the recent changes. Positive values indicate warming tendency and negative values cooling tendency. Student t-test are used to examine whether these changes are significant at 95% confidence level.

Results

The climate of Senegal has evolved over recent decades to respond to increasing anthropogenic forcing of greenhouse gases and other climate forcings. Recent IPCC report (IPCC, 2021) found that the countries of West Africa has experienced an increasing trend in temperatures. This is confirmed in Figure 1 for Senegal. Indeed, the highest temperatures which were found in the East and North of the country during the period from 1980 to 2000 have expanded to the West and the South during the period between 2001 and 2021. There is thus a general warming throughout Senegal with maxima of more than 1.5°C in Eastern Senegal, in the southeast of the Kedougou region, in the Groundnut Basin particularly in the south of the Kaffrine and Kaolack region but also in Casamance, especially in the regions of Sedhiou and Kolda as well as in the west of the Ziguinchor region. In the regions of Saint Louis and Matam, warming does not exceed 1°C and 0.75°C respectively. The minimum values of warming in Senegal are recorded in the Sylvo-Pastoral and Niayes zones, more precisely in the region of Louga, Diourbel and Thies.

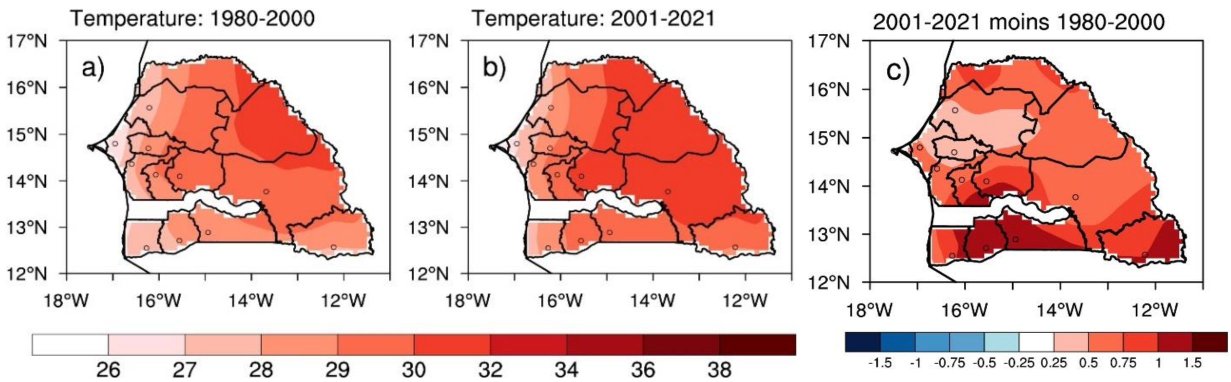

Figure 1: *Spatial distribution of Mean Annual Temperature averaged for the period 1980-2000 (a) and for the period 2001-2021 (b) as well as their difference (2021-2000 minus 2001-2021; (c)). Temperature and their difference are expressed in °C. For the difference (i.e. plot c), only areas where values are*

significant at 95% confidence level is shaded. Open circles denote regional capitals

1.2.3. Precipitation

Methodology

In Senegal, where most agriculture is rain-fed, the wet season is particularly critical for crop production. Changes in precipitation during this season can have significant impacts on agricultural yields and food security, making it essential to understand how these patterns have shifted over time. Additionally, changes in precipitation during the dry season can impact water availability for agriculture and domestic use, making it important to examine trends in precipitation patterns during this season too. There are significant inter-annual variability concerning the start and length of the rainy season in West Africa making it difficult to actually disentangle the wet and dry seasons. To assess the historical precipitation changes, cumulative annual precipitation is thus used.

Cumulative annual precipitation climatology are calculated for two time periods (1980-2000 and 2001-2021) across the whole Senegal. Differences between these two time periods are performed to evaluate the recent changes. Positive values indicate wettening tendency and negative values drying tendency. Student t-test are used to examine whether these changes are significant at 95% confidence level.

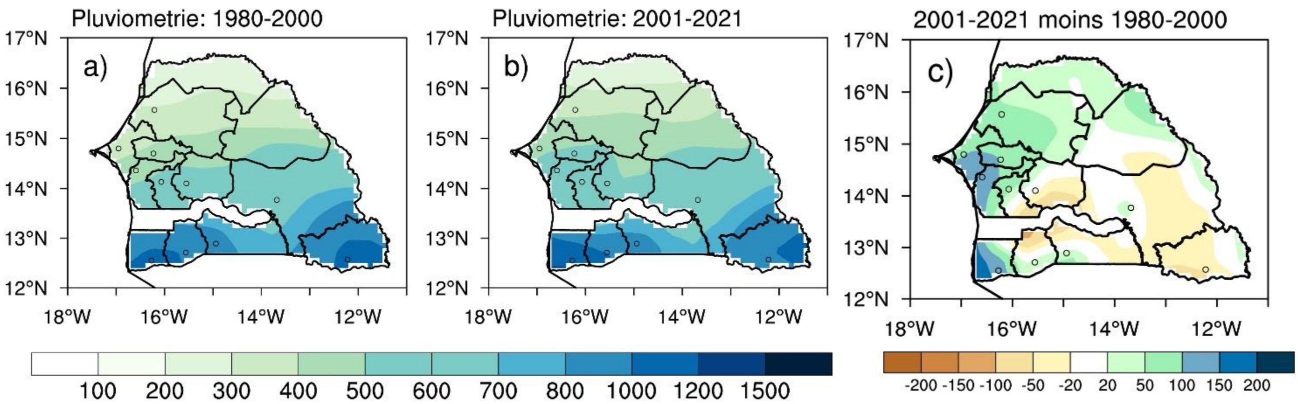

***Figure 2:** Spatial distribution of Cumulative Annual Precipitation averaged for the period 1980-2000 (a) and for the period 2001-2021 (b) as well as their difference (2021-2000 minus 2001-2021; (c)). Precipitation and their difference are expressed in mm/year. For the difference (i.e. plot c), only areas where values are significant at 95% confidence level is shaded. Open circles denote regional capitals*

Results

For precipitation, the 1970s and 1980s were marked by the famous episodes of drought in the Sahel (Tall et al. 2024). A wet period (1940-1970) and a dry period (1971-2000) over the Sahel. However, over the past decades, most Sahelian countries including Senegal have recorded a recovery of precipitation in some parts of their territory but the amount of rainfall is not at the level of the pre-drought period (Sylla et al. 2016). Recent data have confirmed this trend particularly the most recent IPCC report (IPCC, 2021). This is also highlighted in Figure 4 showing the spatial distribution of cumulative annual precipitation climatology for the periods 1980-2000 and 2001-2021 and their difference. In general, the wettest isohyets are found in the south of the country specifically in Casamance and Eastern Senegal, the isohyets with intermediate values in the center of the country encompassing the groundnut basin, the northern part of Eastern Senegal and the Sylvo-Pastoral zone and the lowest isohyets in the north in the Senegal River Valley. In the period 2001-2021 compared to 1980-2000, we note a movement of isohyets towards the north and an intensification towards the west. Indeed, the difference between the two periods shows that average cumulative annual precipitation has recently increased significantly in the west of the country with more than 150 mm in the groundnut Basin, particularly in the regions of Fatick, Diourbel and Thies, and more than 200 mm in the western part of Casamance precisely in the Ziguinchor region. The Niayes and Sylvo-Pastorale zones, mainly the regions of Dakar and Louga, as well as the Senegal River Valley, in particular the Saint Louis region and the north of the Matam region, have experienced a moderate increase in annual precipitation of the order of 20 to 100 mm in the recent period. The other parts of Senegal suffered a more marked decrease in precipitation, especially in the south of the Groundnut Basin (i.e. south of the Kaffrine region), in the north of Casamance (i.e. north of the Sedhiou and Kolda regions) and in Eastern Senegal (i.e. the regions of Kedougou and Tambacounda).

1.2.4. Climate hazards

The agriculture sector in Senegal is highly vulnerable to climate hazards such as extreme heat, droughts and floods. They led to significant losses in agricultural productivity and livelihoods, as well as the displacement of populations. In the past, they have induced natural disasters that caused severe damage to crops and infrastructure, disrupted supply chains, and led to food insecurity for many households. Furthermore, the economic losses associated with climate hazards have perpetuated poverty and inequality, making it even more difficult for smallholder farmers to recover from these events. It is therefore critical to understand the trends in climate hazards. By analyzing the historical data and understanding the nature of these climate hazards, we can better plan and design projects that will help build the resilience of the agriculture sector and protect vulnerable populations in the face of future climate risks.
In this section we thus assess observed extreme heat, droughts and extreme precipitation and how they have changed during the historical period.

- Extreme Heat

In this section, extreme heat is characterized by the heat wave index. To do this, we use a formulation based on percentiles. This is the Excess Heat Factor (EHF) developed by Nairn and Fawcett (2014) . It is based on excessive heat indices: a significant excess heat index (EHI)sig and an acclimation index (EHI)accl. These indices are calculated as follows:

$$EHI_{sig} = [(T_i + T_{i-1} + T_{i-2})/3] - T_{95} \qquad (1)$$

$$EHI_{accl} = [(T_i + T_{i-1} + T_{i-2})/3] - [(T_{i-3} + \cdots + T_{i-32})/30] \qquad (2)$$

Here, Ti is the daily maximum temperature at 2 meters above the ground for day i and T_{95} is the 95th percentile of the daily temperature using a running average over a 15-day window (Perkins and Alexander, 2013).
The first index (i.e. Equation 1) describes the anomaly of a 3-day window relative to an extreme threshold (i.e. the 95th percentile of temperature over the entire 42-year climatological period). Only positive values are considered. The second index (i.e. Equation 2) describes the anomaly over a 3-day window compared to the average temperature of the previous 30 days. EHF is given by the combination of equations (1) and (2) as follows:

$$EHF = EHI_{sig.} X \max\,[1, EHI_{accl.}] \qquad (3)$$

For the analysis, several aspects of heatwaves are considered:
- Frequency: the number of days contributing to identified heatwaves expressed in days.

- Intensity: the sum of all EHF values during heatwaves expressed in $^{o}C^{2}$.

- Amplitude: the daily maximum value of the hottest heat wave, corresponding to the highest magnitude of the heatwave, expressed in ^{o}C.

These three aspects of heatwaves are shown in Figure 3 for the periods of 1980-2000 (Figures 3a,d,g) and 2001-2021 (Figures 3b,e,h) and their differences (Figures 3 c,f,i) in order to identify recent developments in heatwaves across Senegal.
In the first period (i.e. 1980-2000; Figure 8a,d,g), the frequency of occurrence, the intensity and the amplitude of the most heatwaves episodes are rather moderate and of the order of 8 days to 12 days, 4 $^{o}C2$ to 10 $^{o}C2$ and 1.5 $^{o}C2$ to 2.5 $^{o}C2$ respectively in the northern half of the country, more precisely in the north of the Groundnut Basin the entire Sylvo-Pastoral zone and the entire Senegal River Valley. During the recent period (Figure 8b,e,h), there is a change in the configuration of all aspects of heatwaves. In fact, the most frequent and intense heatwaves, and those with the highest amplitudes are recorded in the Senegal River Valley, in particular in the center of the Saint Louis region. Many of them are also located in the center of the country encompassing the Groundnut Basin particularly in the south of the Kaolack region and the entire Kaffrine region. Finally they also occupy a large area in the south of the country specifically in Casamance and in the south-east of Eastern Senegal especially in the regions of Ziguinchor, Sédhiou and Kedougou.

The difference between the two time periods (Figure 8c,f,i) shows that all of Senegal have undergone more frequent (with an increase ranging from 10 days to 20 days per year), more intense (with an increase between 15 $^{o}C2$ and more than 35 $^{o}C2$ per year) and larger amplitudes (with an elevation between 1.5 $^{o}C2$ and 2.5 $^{o}C2$ per year) heatwaves during the recent period (i.e. 2001-2021) compared to the period 1980-2000. The most affected regions are the regions of Saint Louis, Kaffrine, Sédhiou, Kolda and Kédougou but also areas such as the south of the Kaolack region and the east of the Ziguinchor region.

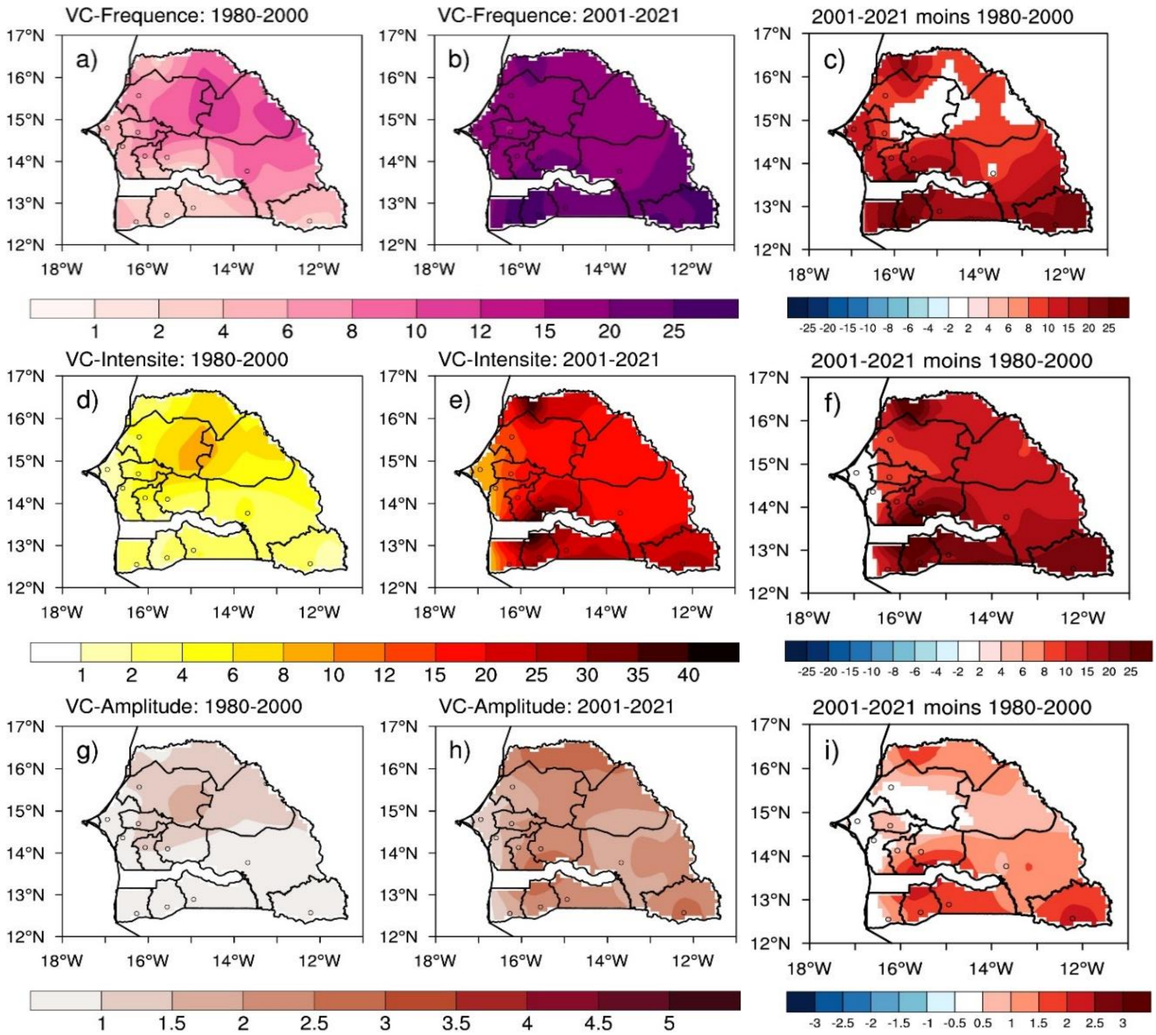

Figure 3: *Spatial distribution of Frequency (1st row), Intensity (2nd row) and Maximum Duration of heatwaves (3rd row) for the period 1980-2000 (1st column) and the period 2001-2021 (2nd column) as well as their difference (2021-2000 minus 2001-2021; 3rd column). The Frequency and the corresponding difference are expressed in days per year. Intensity and Amplitude as well as their corresponding difference are expressed in $^{o}C^{2}$ per year. For differences, only areas where values are significant at 95% are shaded. Open circles denote regional capitals*

- Droughts

To characterize droughts, we use the World Meteorological Organization (WMO) recommended index that the Standardized Precipitation Index (SPI) developed by McKee (1993). For more details about SPI application in Africa, see Tall et al. (2024). Since SPI can be calculated over different periods of precipitation accumulation. The different resulting indicators make it possible to estimate the different potential impacts of a meteorological drought (Vicente-Serrano et al. 2010). In this work, we considered 3 and 12 months of accumulation (i.e. SPI3 and SPI12) to get closer to the Senegalese context. Indeed, SPI3 gives an indication of the immediate impacts on the quantity of

seasonal precipitation, soil moisture, flow in small watercourses and is therefore strongly linked to the general yield of seasonal crops. In the other case, SP12 gives add indications of the impacts on groundwater and general river flow.
To characterize droughts, we consider the Frequency, Severity and Maximum Duration defined as follows:

- Frequency: the total number of occurrences of drought months (i.e. months with an SPI less than -1) in all drought episodes for a given period.

- Severity: the sum, in absolute values, of all SPI values less than -1 in all drought episodes for a given period.

- Maximum duration: the longest series of consecutive drought months (i.e. a month with an SPI less than -1) in a given period. This represents the longest drought episode.

Figure 4 shows the spatial distribution of frequency, severity and maximum duration of droughts for the period 1980-2000 and the period 2001-2021 as well as their difference considering SPI12. Here SPI12 is chosen to global perception of longterm drought. During the period 1980-2000, the most frequent, most severe and longest droughts are recorded in the north and west of the country, more precisely throughout the Niayes area, in the west of the Groundnut Basin and the Sylvo-Pastoral zone as well as along the Senegal River Valley thus affecting the regions of Dakar, Thies, Diourbel, Fatick, Kaolack, Louga, Saint Louis and Matam (see Figure 6a,d,g). In 2001-2021, the maxima on these characteristics have migrated to the east and south of the Groundnut Basin, in

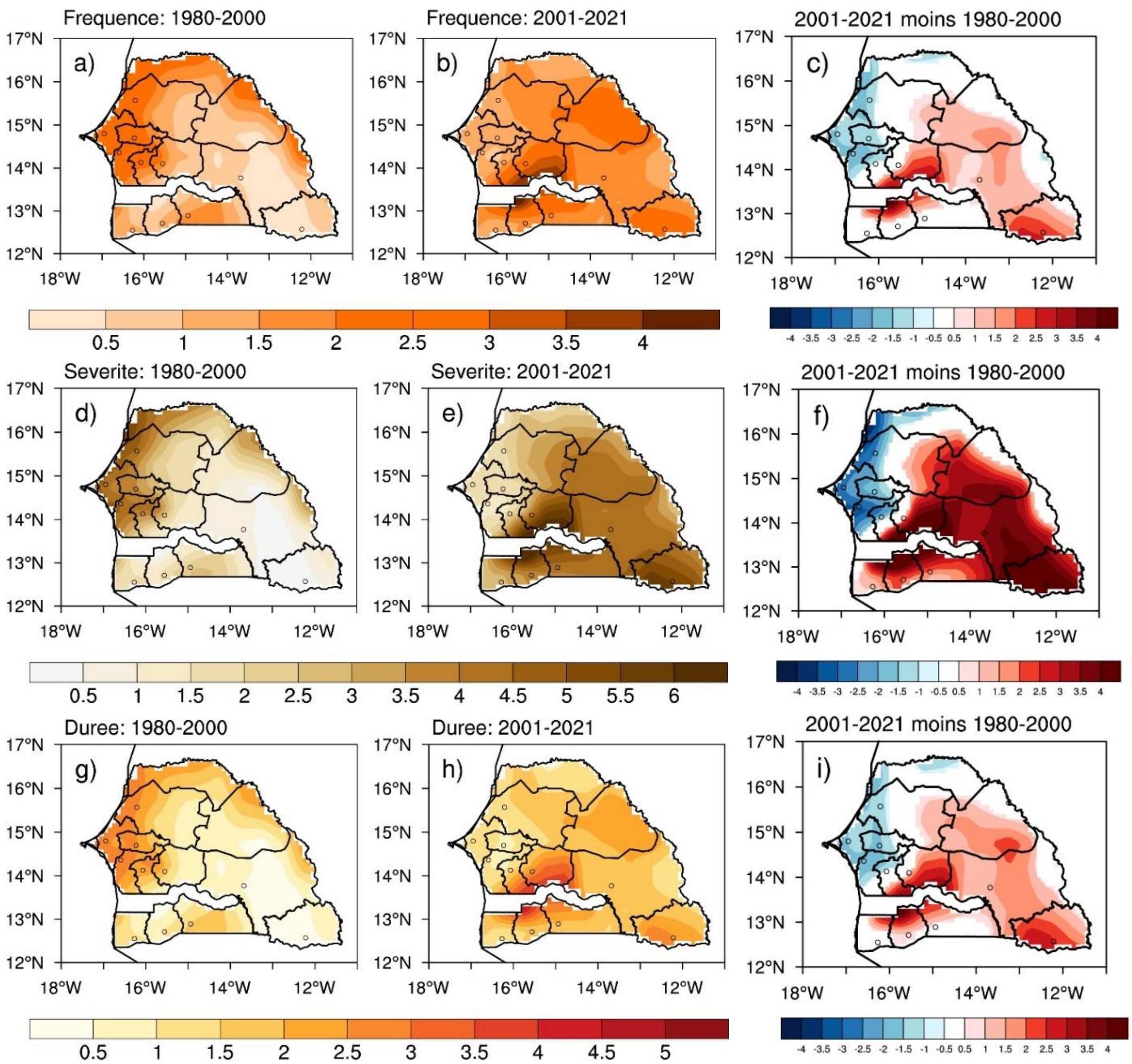

Figure 4: *Spatial distribution of Frequency (1st row), Severity (2nd row) and Maximum Duration of droughts (3rd row) for the period 1980-2000 (1st column) and the period 2001-2021 (2nd column) as well as their difference (2021-2000 minus 2001-2021; 3rd column). The Frequency and Duration as well as their corresponding differences are expressed in month per year. The Severity is unitless. For differences, only areas where values are significant at 95% are shaded. Open circles denote regional capitals*

the north of Casamance, in the east of the Sylvo-Pastoral zone and in the southeast of the country (i.e. Figure 6b ,e,h). There is a decrease (see Figure 6c,f,i) in the regions of Dakar, Thies, Diourbel, Fatick, and in the west of the region of Louga and Saint Louis during the recent period compared to 1980-2000.

In the contrary, a considerable increase in the frequency (of the order of 3 months per year), the severity (of more than 4 per year) and the duration (of more than 3.5 months per year) of Droughts occurred in the Groundnut Basin, particularly in the western and southern half of the Kaffrine region and in the south of the Kaolack region. Similarly, the north of Casamance, mainly the north of the Sédhiou and Kolda regions as well as the north-east of the Ziguinchor region, have also experienced an increase in frequency (up to 3.5 months per year), severity (more than 4 per year) and the duration (more than 4 months per year) of droughts. Finally, these droughts also affected the eastern half of the Sylvo-Pastoral zone and all of Eastern Senegal, impacting thus the regions of Kedougou and Tambacounda as well as most of the Matam region with an increase in frequency between 1 and 2, 5 months per year, severity of more than 4 per year and maximum duration ranging from 1.5 to 3.5 months per year.

In general, the regions of Kaffrine, Kaolack, Kedougou and Tambacounda as well as the western and southern half of the Matam region, the north of the Sedhiou and Kolda regions and the northeast of the Ziguinchor region were hit by more recurrent, more intense and longer duration droughts during the recent period compared to the more distant period 1980-2021.

- Extreme Precipitation

Over Senegal, floods occur following very heavy rainfall or a considerable accumulation of rain over several consecutive days. These events are mainly those whose intensities are above the 95th percentile (i.e. > 95P) of daily precipitation for the reference period, which we call here very wet events (TH). We also note those whose intensities are above the 99th percentile (i.e. > 99P) of the daily precipitation of the reference period which we denote here as extremely very wet events (ETH) leading to flash floods. These indices are defined by the Expert Team on Climate Change Detection and Indices (ETCCDI in English; Zhang et al. 2011) and by the IPCC (2021) are examined. To characterize the different aspects of these extreme precipitation, we consider:

- Frequency: the number of rainy days whose intensities exceed the 95th Percentile (95P) (or 99th Percentile (99P)) of daily precipitation for the reference period.
- Intensity: the cumulative intensity of rainy days whose intensities exceed the 95th Percentile (95P) (or 99th Percentile (99P)) of daily precipitation for the reference period.
- The amplitude: the intensity of the wettest day in the year in the case it exceeds the 95th Percentile (95P) of the reference period.
- Duration: the maximum number of consecutive rainy days in case the daily intensity of rain exceeds the 75th Percentile (75P).

Over Senegal during the period 1980-2000 (See Figure 5a), the largest occurrence of extreme precipitation is observed in eastern part of the country, mainly in the regions of Tambacounda and Kedougou. However, between 2001 and 2021 as shown in Figure 5b, they are found in the west of the country, particularly in the Niayes zone, in the west of the Groundnut Basin and the Sylvo-Pastoral zone as well as in the Senegal River Valley. We therefore note a clear increase in the frequency of extreme precipitation of up to 40% in the regions of Dakar, Thies, Diourbel, Fatick, in the north and south of the Louga region, in the west and north of the Saint Louis region and in the north of the Matam region (i.e. Figure 5c). In contrast, strong decreases are recorded in the regions of Eastern Senegal (i.e. Tambacounda and Kedougou), in the south of the Groundnut Basin (Kaffrine and Kaolack) and in the center of the Casamance regions (Sedhiou and Kolda).

Regarding the intensity of extreme precipitation (Figure 5d-f), the most intense rains during both periods are recorded in the north of the country and more precisely in the Senegal River Valley as well as in most of the Sylvo-Pastoral zone encompassing the regions of Saint Louis, Matam and Louga. However, a difference between the two periods clearly shows a significant increase in the intensity of extreme precipitation of the order of 20% to 40% during recent years in the same regions which have experienced an increase in the frequency of occurrence of these events namely the regions of Dakar, Thiès, Diourbel, Fatick, Saint Louis, Louga and Matam. In addition, although in the east of the Kaffrine region and in the west of the Tambacounda region, the frequency of extreme precipitation showed no change, their observed intensities showed a substantial increase of 25% during the period 2000 - 2021 compared to 1980-2000 indicating an intensification of the rainfall events.

The maximum duration (i.e. the number of consecutive days) of rain events whose intensity exceeds the 75th Percentile (moderate to heavy rain) reveals its maxima in the center of the country, in Eastern Senegal and in Casamance for both periods (see Figure 5g,h). However compared to the period 1980-2000, the recent period (i.e. 2001-2021) records an increase of 10% to 30% in the duration of these events in almost the same regions/areas which have experienced an increase in frequency and the intensity of

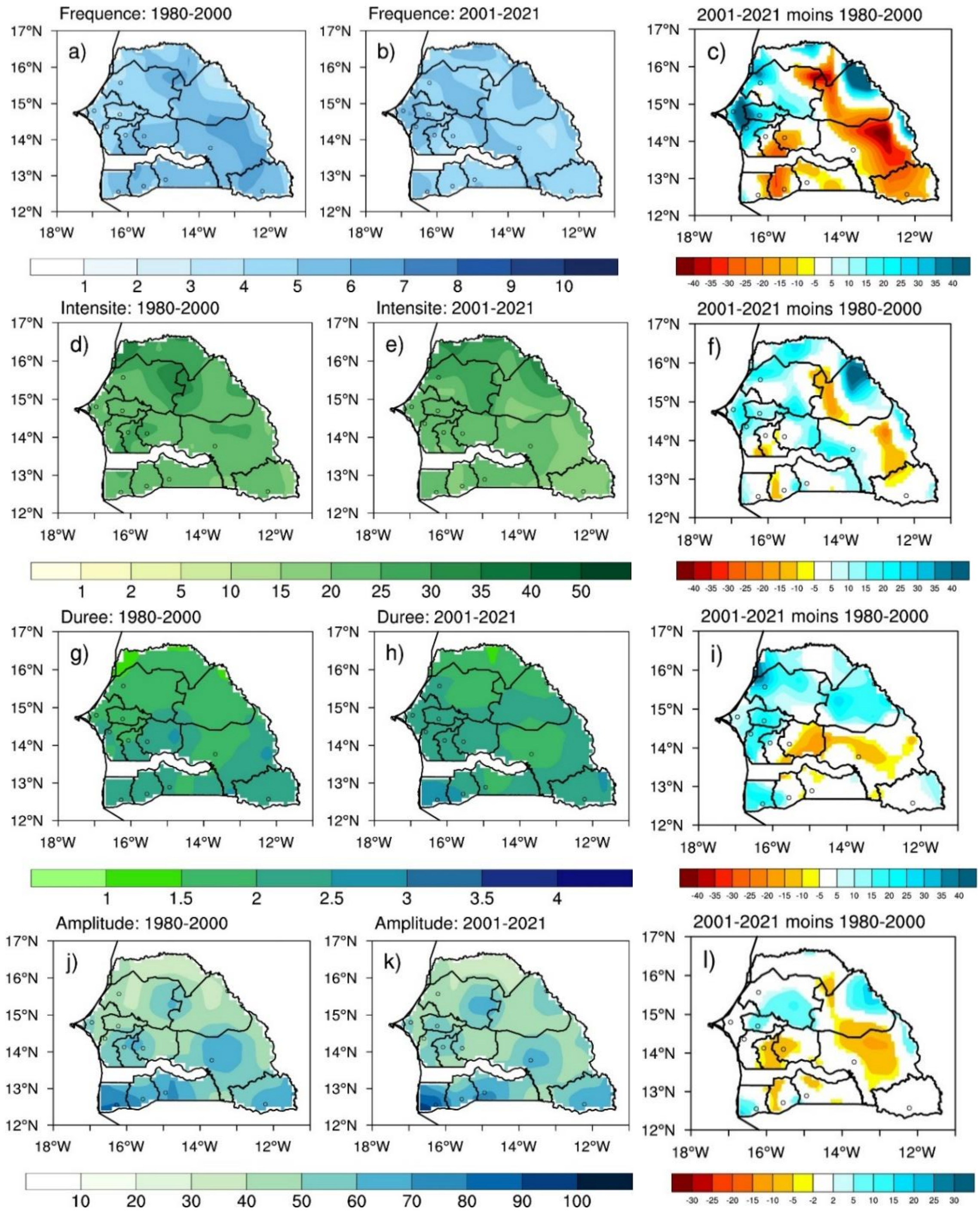

Figure 5: *Spatial distribution of Frequency (1st row), Intensity (2nd row), Maximum Duration of rainfall events above the 75th Percentile (3rd row) and Amplitude (4th row) of extreme precipitations for the period 1980-2000 (1st column) and the period 2001-2021 (2nd column) as well as their difference (2021-2000 minus 2001-2021; 3rd column). The Frequency and Duration as well as their corresponding differences are expressed in days. The Intensity and Amplitude as well as their corresponding differences are in mm. For differences, only areas where values are significant at 95% are shaded. Open circles denote regional capitals*

extreme precipitation (Figure 5i). It is important to note that in the Ziguinchor region where we have not observed an increase in the frequency and intensity of extreme precipitation, the duration of moderate to heavy rain events increased by up to 20% in the recent period (2001-2021) compared to the more distant one (1980-2000).

As for the amplitude of extreme rainfall, the only places where it is increasing are in the north of the Matam region, in the center and south of the Louga region, in the center of the Diourbel region and in the southwest of the Ziguinchor region (Figure 5j-l).

It is therefore clear that the increase in the frequency of extreme precipitation, their intensity, their amplitude and/or the duration of moderate to heavy rains have increased the risk of flooding in the regions of Dakar, Thiès, Fatick, Diourbel , Louga, west of Saint Louis, northeast of Matam and southwest of Ziguinchor.

In summary, during the recent period (2001-2021), the regions of Dakar, Thies, Fatick, Diourbel, Louga have experienced an increased risk of flooding compared to the more distant period (1980-2000), the regions of Kaffrine, Kedougou, Sedhiou, Kolda and Kaolack were rather affected by an intensification of droughts and heatwaves. Other regions such as Saint Louis, Matam and Ziguinchor present spatial heterogeneities. Indeed for the Saint Louis region, while in the west, the risks of flooding have increased, in the center, we note an amplification of heatwaves. Additionally, in the Matam region, while flood risks have increased in the northeast, severe droughts have increased throughout the region. Finally, in the Ziguinchor region, the risk of flooding increased in the southwest, droughts intensified in the northeast and heatwaves amplified in the eastern half of the region.

These climate hazards have brought a wide range of disasters that have affected the country. An overview is presented below.

1.2.5. Overview of Climate Disasters

This section will provide an overview of other climatic factors that threaten Senegal’s agriculture. This section will mainly provide an overview of past natural disasters, and the impacts they have had on the Senegalese population. The analysis draws on qualitative, secondary information and tabular data to contextualize the historical analysis of temperature, precipitation and related climate hazards and highlight the need for climate-resilient and adaptive measures to ensure the sustainability of the agricultural sector in the face of increasing climatic pressures.

Methodology

Data is sourced from the International Disaster Database [EM-DAT], which provides a comprehensive, time-series analysis of natural disasters across the world, as well as their impacts on people. The numerical data presented in this section is minimally processed as it already exists in tabular format, and mainly serves to demonstrate the prevalence and severity of natural disasters and climatic stressors on the agricultural sector.[8]

[8] Centre for Research on the Epidemiology of Disasters. (2023). Database | EM-DAT.

Results

As discussed above, Senegal is exposed to multiple climate hazards, including flooding, droughts and heatwaves, which have significant impacts on the agricultural sector. Flooding is a common occurrence in Senegal, particularly in the rainy season, with an average of 104 flood events per year. Severe flooding can cause displacement and damage to infrastructure. Droughts are a significant threat to agriculture in Senegal, particularly in the northern and eastern regions of the country. They have led to food insecurity and economic losses, particularly in the livestock sector. Heatwaves are becoming more frequent and intense, leading to health impacts and direct effects on agriculture. These climate hazards are expected to worsen in the future due to climate change, increasing the vulnerability of Senegal's agricultural sector.

Table 1 below shows an analysis of climate events provides an overview of the natural disasters that have occurred in Senegal from 1980 to 2022, as well as the impact they have individually had on the Senegalese population in terms of the number of people injured, affected, homeless and killed in the aftermath of the disaster. The natural disasters include floods, storms, droughts, pest infestations, health epidemics and are either localized (only impact certain regions in Senegal) or continental (impacting other, neighboring countries, as well). Table 1, below, provides a summary of the most recent natural disasters, where they occurred, and how many people were impacted as a result. The 1980s saw mostly pest infestations as the main challenges, with the exception of the drought of 1980, which impacted over 1.2 million people, and the flood of 1988, leaving over 300,000 people homeless. The 1990s did not see many major storms or climatic disasters; this is in line with the historical temperature and precipitation analysis, which saw relatively marginal changes in terms temperature and precipitation variations between the 1980s and 1990s. The 2000s and 2010s, however, saw significantly more climatic events than the 1980s and 1990s, with even more people impacted by a variety of climate disasters, namely droughts and floods. The significance of these trends is that the greater the diversity of climate-related disasters, the greater the challenges farmers have in preparing their fields to weather these events; this will require that farmers adopt a new farming system that can help mitigate the impact of flooding and droughts, simultaneously.

Table 1. Location of, and Impact of, natural disasters in Senegal (1980-2022)[9]

Year	Disaster Type	Location	Total Deaths	No. Injured	No. Affected	No. Homeless	Total Affected
1980	Drought				1 200 000		1 200 000
1983	Flood	Matam-Bakel			5 000		5 000
1984	Epidemic						
1985	Epidemic		300		3 100		3 100
1985	Flood	Lac De Guiers			3 000		3 000
1986	Insect infestation	Northern regions					
1987	Insect infestation						
1988	Insect infestation	Countrywide					
1988	Insect infestation	Northern, Eastern regions					
1988	Flood	Dakar, Diourbel, Thies, Tambacounda				300 000	10 000
1993	Flood	Kaolack region, Saint-Louis			5 000		5 000
1994	Flood	Saint-Louis region				500	17 500
1995	Epidemic	Louga, Diourbel Region) Fatick ,St. Louis, Thies	188		3 031		3 031
1998	Epidemic	Kaolack, Fatick and Kolda, Diourbel	372		2 709		2 709
1998	Flood	St Louis, Tambacounda, Kaolack, Kolda			300 000		300 000
1999	Storm	Casamance	165				

[9] Centre for Research on the Epidemiology of Disasters (CRED), 2023, EM-DAT The International Disaster Database: Senegal Disasters 1980-2023

1999	Storm	Kaolack, Thies & Ziguinchor	22		65 853	30 000	95 853
2000	Flood	Louga					
2002	Flood	Saint Louis, Matam, Louga	28		179 000		179 000
2002	Epidemic		7		121		121
2002	Epidemic	Dakar, Diourbel, Kolda, Tambacounda, Louga, Thies, Fatick regions	11		60		60
2002	Drought	Countrywide			284 000		284 000
2003	Flood	Matam province, Kaolack province Kaffrine Tambacounda, Kolda	8		1 277	6 492	7 769
2004	Epidemic	Dakar, Diourbel, Louga region	6		861		861
2004	Insect infestation	Matam					
2004	Storm	Kolda province)	2			1 000	1 000
2005	Epidemic	Fatick, Dakar, Kolda, Louga, Tambacounda, (Diourbel region)	303		23 022		23 022
2005	Flood	Dakar			50 000		50 000
2007	Flood	Thies, Matam, Kaolack, Tambacounda, Dakar, Saint louis, Diourbel provinces	8		5 300		5 300
2007	Epidemic	Dakar, Diourbel, Fatick, Kaolack, Louga, Saint Louis, Thies	16		2 825		2 825
2008	Flood	Thies, Diourbel, Saint louis, Kaolack, Dakar provinces	1		23 600		23 600
2009	Flood	Dakar, Saint louis, Kaolack, Kaffrine, Thies, Sedhiou, Fatick, Matam, Tambacounda, Kédougou, Kolda	6		264 000		264 000
2010	Flood	Kolda	2	9	22 116		22 125
2010	Flood	Saint Louis		54	80 337		80 391
2011	Drought	Kaffrine, Kédougou, Tambacounda, Saint-Louis, Matam, Diourbel, Kolda, Kaolack, Fatick, Louga,			850 000		850 000

2011	Flood	Thies		6	5 214		5 220
2012	Flood	Diourbel, Fatick, Dakar	19		57 000		57 000
2013	Flood	Fatick, Kaolack, Thies, Dakar	8	94	163 212		163 306
2014	Drought	Matam province), Saint Louis Fatick, Sedhiou			639 702		639 702
2014	Epidemic	Kédougou, Kolda, Sedhiou, Tambacounda, Ziguinchor		1			1
2016	Flood	Saint Louis, Kaolack , Kaolack, Kaffrine, Fatick	5	106	10 540		10 646
2018	Drought	Northern regions			320 000		320 000
2019	Flood	Dakar Region, Kaolack	6	49	8 919		8 968
2020	Flood	Dakar, Thiès, Diourbel, Kaolack, Fatick, Kaffrine, Saint-Louis, Matam, Kolda, Sédhiou, Tambacounda	11		17 000		17 000
2022	Flood	Dakar, Thies, Matam		172	19 838		20 010
TOTAL			**1 494**	**491**	**4 615 637**	**64 992**	**4 681 120**

1.3. Future projections

1.3.1. Overview of Projections

As part of the pre-feasibility study, considering the forecast of climate variables is crucial for establishing climate rationale. Analyzing projections of climatic variables can provide valuable insights into the potential impacts of climate change on the project's target area and assist in designing effective adaptation and mitigation strategies and enhance the project's effectiveness and long-term sustainability.

Projections of the same historical climatic variables previously analyzed provide insights into the necessity of revising current agricultural practices and underline the critical state in which Senegal may find itself within the next decades. This section will present detailed geographic and tabular information on the projected changes in Temperature and Precipitation.

Ces projections use the best available models' output. To date, many climate models outputs produced by the international scientific community are available. These are CMIP5 (Coupled Model Intercomparison Project, Phase 5), CMIP6 (Coupled Model Intercomparison Project, Phase 6), CORDEX (COordinated Regional Climate Downscaling Experiment) and CORDEX-CORE (COREEX Coordinated Regional Experiments). While CMIP5 and CMIP6 consist of outputs from global climate models (GCMs), CORDEX and CORDEX-CORE are done with regional climate models (RCMs). In Senegal because of the physical specificities of the terrain (i.e. topography, land use, vegetation gradient, etc.) and regional forcing phenomena such as the West African monsoon, it is more appropriate to use RCMs for the study of the climate change and associated risks (Sylla et al. 2015; 2016).

In this work, CORDEX-CORE is chosen over CORDEX, CMIP5 and CMIP6 thanks to its high resolution (i.e. 25 Km) and better coordination in the design and execution of the simulations. Indeed, the objective of CORDEX-CORE is to have a set of RCMs downscalling the projections of a set of GCMs in CORDEX domains in order to support regional assessments for the 6th report of the Intergovernmental Group on Climate Change (IPCC). Thus, three RCMs downscaled a set of three GCMs at a resolution of 25 km in all CORDEX domains including Africa for the period from 1979 to 2100 using RCP8.5. The table 2 below shows the different RCMs, the forcing GCMs and their institutions leading to the nine different experiments that were considered in this study.

Table 2: List of RCMs and the corresponding GCM downscaled

	GCM: NorESM **Institution**: UniO	GCM: MPI-ESM **Institution**: MPI-M	GCM: HadGEM2-ES **Institution**: UKMOHC
RCM: RegCM4 **Institution**: ICTP	&	&	&
RCM: REMO2015 **Institution**: GERICS	&	&	&
RCM: CCLM5 **Institution**: KIT	&	&	&

1.3.2. Temperature

Methodology

Two meters seasonal mean temperature is consider for each experiment and a multimodel ensemble of all 9 simulations are performed for the historical period and for two future time periods being 2031-2060 and 2071-2100. To quantify the changes, we considere Future minus Present. The Present-day which is our reference period is 1989-2018.

Results

The main objective of presenting these results is to communicate the projected temperature increases that are expected to occur both during and after the proposed project's implementation period. By doing so, the aim is to provide a clear understanding of the potential climatic risks that the Senegalese agricultural sector is likely to face in the future. These results can help underscore the urgent need for the proposed project to mitigate these risks and ensure the sector's long-term sustainability as well as inform the project design, to future-poof the proposed activities.

Figure 6 display temperature change for December-February (DJF) and June-August (JJA), the two seasons that show more significant changes, for the 2031-2060 and 2071-2100. During the first period, temperature increase is moderate and does not exceed 2.5^{o}C in the entire country. However, in 2nd period the increase is substantial in both seasons leading to a warming of 4 to 5^{o}C covering almost the whole country.

Given that, according to the historical analysis, average temperatures have already risen from 25.8^{o}C in the 1990s to 28^{o}C in the 2010s, such a projected increase will further imperil the resilience of the Senegalese agricultural sector. Even a difference of 2^{o}C can have dire consequences for Senegalese farmers; water will become scarcer for both rain-fed and irrigated crops, conditions will be drier, leading to the drying of crop fields and wildfires, which will encourage farmers to abandon their fields, thereby contributing long-term land degradation. For this reason, a systemic change in the organization and practices of Senegalese agriculture will be needed to adapt to the projected challenges of rising temperatures.

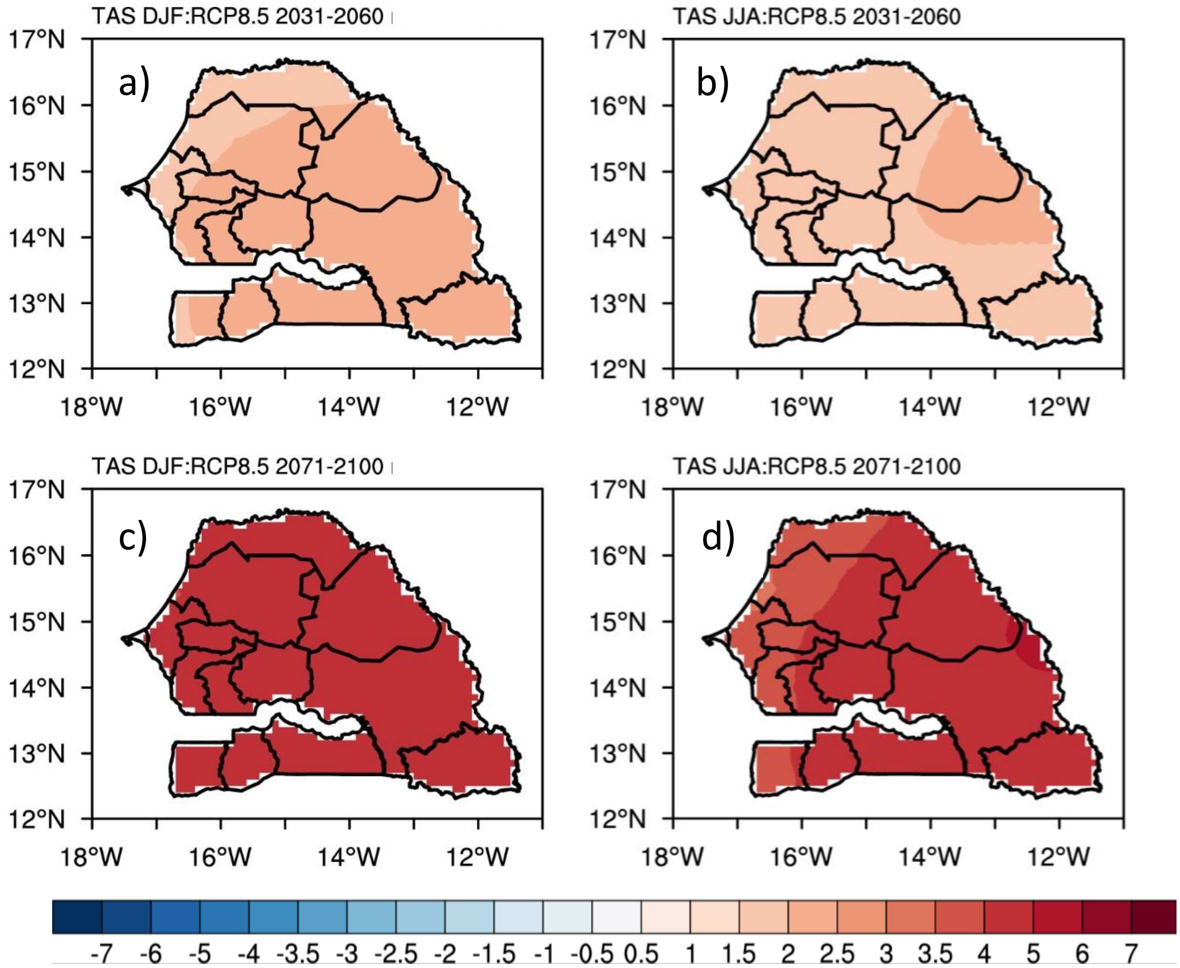

***Figure 6**: Projected Temperature changes (Future: 2031-2060/2071-2100 minus Present:1989-2018) for DJF (left panel) and JJA (right panel) during 2031-2060 (1st row) and 2071-2100 (2nd row)*

1.3.3. Precipitation

Methodology

Seasonal mean Precipitation is consider for each experiment and a multimodel ensemble of all 9 simulations are performed for the historical period and for two future time periods being 2031-2060 and 2071-2100. To quantify the changes, we considere Future minus Present. The Present-day which is our reference period is 1989-2018.

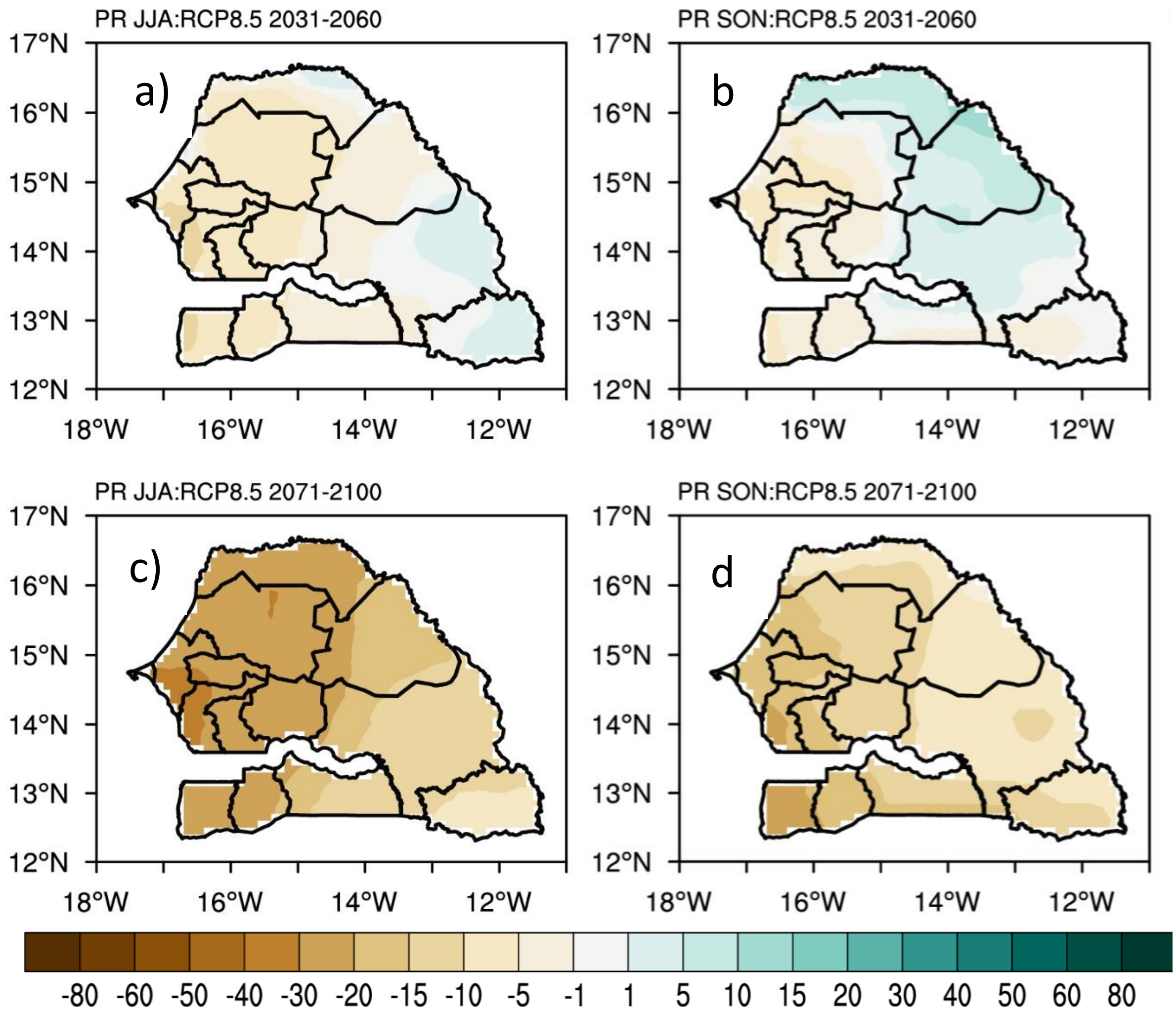

Figure 7*: Projected Precipitation changes (Future: 2031-2060/2071-2100 minus Present:1989-2018) for JJA (left panel) and SON (right panel) during 2031-2060 (1st row) and 2071-2100 (2nd row)*

Results

Projected rainfall is an equally important indicator for the Senegalese agricultural sector as most crops in Senegal are rainfed. Figure 7 provide a comparable analysis of projected rainfall changes in 2031-2060 and 2071-2100 under the RCP8.5 forcing scenario. The changes are expressed in percentage of reference period values. During JJA, the country is projected to experience a decrease in precipitation of up to 15% mainly in the Western half during 2031-2060. In 2071-2100, the decrease in precipitation has amplified and reach 40% in regions such as Thies and Kaffrine. Other regions such Saint Louis, Louga, Fatick, Kaolack as well Ziguinchor will also be affected

by a decrease of about 30%. The lowest decrease is projected in eastern Senegal, specifically in Kedougou and Tambacounda regions. SON reveals similar changes but with lower values.
These projected mean precipitation decreases are in line with the most recent IPCC report (IPCC, 2021) that shows a dipole with positive changes in eastern Sahel and negative changes in westernmost part of the Sahel encompassing Senegal. Such decrease will have profound impacts on the drought occurrences in the and will potentially negatively impact agriculture in the country.

1.3.4. Projected climate hazards

For this section, we assessed three climate hazard being extreme heat, drought and extreme precipitation that can cause floodings.

- Extreme Heat

For the extreme heat, we considere the Heat Stress index (HI) developed by NOAA and assessed in West Africa by Sylla et al. (2018). values are calculated for each day before a climatological seasonal average is undertaken. The seasons considered are DJF (December-January-February), MAM (March-April-May), JJA (June-July-August) and SON (September-October-November). HI values are sorted by ranges. Each range of values corresponds to a category of thermal stress defining the level of risk to human health. Table 3 summarizes the different categories, the corresponding risk levels and the health problems that can result from them. This index is thus chosen because it can quantify the risks outdoor workers are exposed and can definitely give an indication about the reduced labor hours for farmers due to heat stress.

Table 3: Heat index range of values and corresponding risks

HI (ºC)	**Risks**	**Categories**	**Health impacts**
=< 27	No risk	Sure	
27-32	Moderate	Caution	Fatigue possible with prolonged exposure and/or physical activity
32-41	High	Extreme Caution	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
41-54	Very high	Danger	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity

=>54	Extreme	Extreme Danger	Heat stroke highly likely

These values are calculated for the reference period (1989-2018), the short term (2031-2060), the medium term (2051-2080) and the long term (2071-2100). In addition to the climatological seasonal values, the change (Future - Reference) in the average annual frequency (i.e. the number of days) of occurrence of each category is calculated for the three future periods and expressed as a percentage of the duration of a year (i.e. 365 days). These calculations are made for each CORDEX-CORE experiment before an ensemble average of all experiments is performed. The results are presented for all of Senegal.

The spatial distribution of the seasonal heat index in Senegal (Figure 8) shows that the country generally does not incur any risk of extreme heat in DJF as well in the present (i.e. the reference period: 1989- 2018) than in the short term of the future. However, in the medium term, the regions of the Groundnut Basin (i.e. Fatick, Kaolack and Kaffrine), Casamance (Ziguinchor, Sédhiou and Kolda) and Eastern Senegal (Tambacounda and Kédougou) display a Caution category with a moderate risk. In the long term, this risk category expand to the north in the Sylvo-Pastoral zone and also encompasses the south of the Louga and Matam regions but also the entire region of Thies and Dakar.

In MAM in the reference period, most of the country is exposed to a moderate risk (i.e. Caution Category) except in the southeast of the country and in the Casamance area where the risk is high with an Extreme Caution category which takes place in the southeast of the Tambacounda region, throughout the Kaffrine region and in a large part of the Kolda and Ziguinchor region. This high level of risk extends spatially from the short term and also covers the entire Groundnut Basin and the southeast of the Sylvo-Pastoral zone, encompassing thus the regions of Diourbel, Fatick, Kaolack and Kaffrine, the southeast of the Louga region and the entire Matam region. In the medium and long term, it will spread to all regions of Senegal. Therefore regions such as Saint Louis, Dakar, Matam and Kaffrine will see their level of risk increases from moderate in the present to high in the medium and long term.

For the JJA season, the Extreme Caution category dominates the entire country both for the present and for the short and medium terms. In the long term, the Danger category appears in the southeast of the country, covering almost the entire Tambacounda region, the north of the Kédougou region and the east of the Kolda region. Therefore, in these regions in JJA during the period 2071-2100, the risk of occurrence of serious health problems due to extreme heat is very high.

Finally, during the SON season and throughout the country, the Extreme Caution category persists both during the present and during all three periods in the future with a high level of risk.
It is important to specify that these indices are climatological values and do not mean that certain higher risk categories do not occur during the periods considered. To get a clear idea of this, the change in frequency of occurrence of each risk category is calculated and analyzed in Figure 9.

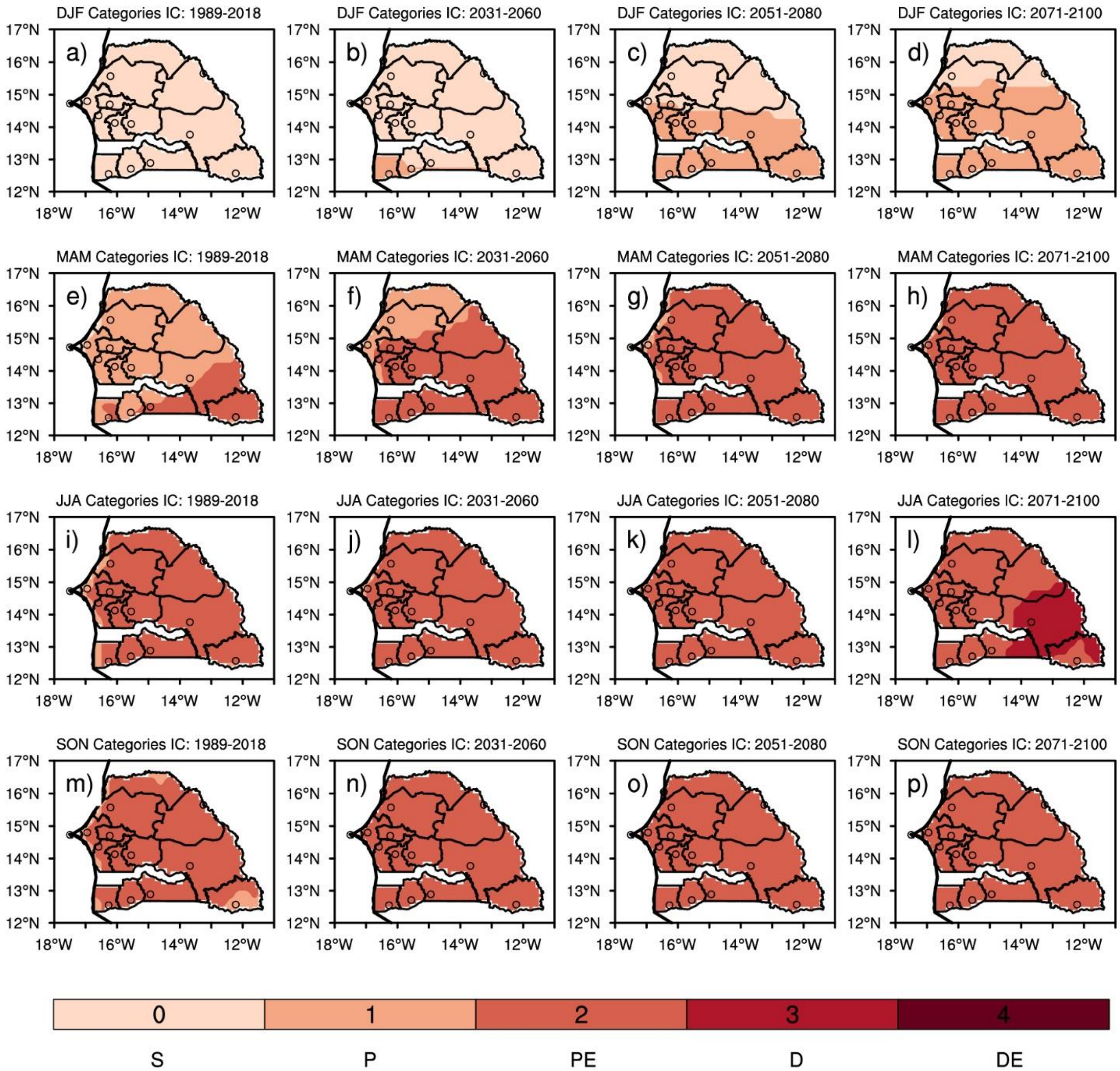

Figure 8: *Climatological maps of the Heat Index (IC in the map) with heat stress categories (S=Safe; P=Caution; PE: Extreme Caution; D=Danger; DE=Extreme Danger) in DJF (December-January- February: 1st row), in March-April-May (MAM: 2nd row), in June-July-August: 3rd row) and in September-October-November (SON: 4th row) for the periods 1989-2018 (1st column), 2031-2060 (2nd column), 2051-2080 (3rd column) and 2070-2099 (4th column)*

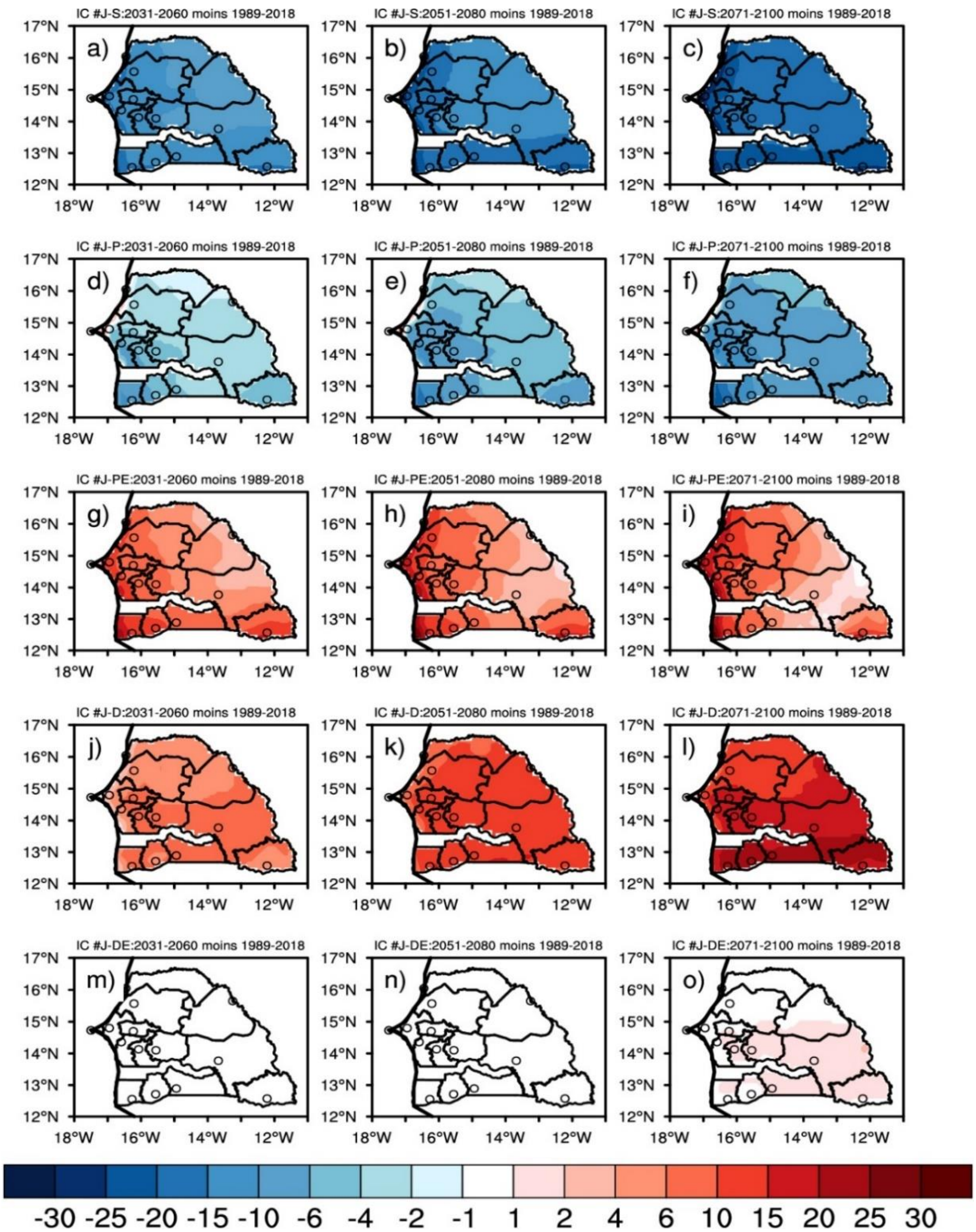

Figure 9: *Change (Future – Reference) in the annual frequency of occurrence of the different categories of heat stress which are Safe (J-S: 1st line), Caution (J-P: 2nd line), Extreme Caution (J-PE: 3rd line); Danger (J-D: 4th row), Extreme Danger (J-DE: 5th row) during 2031-2060 (1st column), 2051-2080 (2nd column) and 2071-2100 (3rd column). The change is calculated relative to the reference period 1989-2018 and is expressed as a percentage of the total duration of a year which is 365 days. Only places where the value of changes is significant at 95% are shaded*

Changes in the annual frequency of occurrence of the different categories of heat stress such as Safe, Caution, Extreme Caution, Danger, Extreme Danger during the 2031-2060 (short term), 2051-2080 (medium term) and 2071-2100 (long term) term) are respectively presented in Figure 9. The days with no risk (i.e. with the Safe category) decrease more and more as we move from the short term to the long term with the west and south of the country showing the highest reductions. Thus in 2031-2060, risk-free days decrease by 10% to 15% of the duration of a year compared to the present period. In 2051-2080, this reduction increases to 20% and during 2071-2100, it exceeds 30%. Similarly, days with moderate risk (i.e. with the Caution category) occur less and less in the future compared to the present. Thus during the three future periods, changes in frequency vary between -2% and -10% of the duration of a year with the greatest decreases in the west of the country.

These various decreases are done in favor of increases in days with a high and very high risk of occurrence of extreme heat with categories of Extreme Caution and Danger respectively. Indeed, changes in the frequency of occurrence of Extreme Caution days in the short term show a maximum increase between 10% and 15% in the west of the country along the coastal areas going from Saint Louis to Ziguinchor encompassing thus the Niayes zone, the west of the Sylvo-Pastoral zone and the west of the Groundnut Basin but also the south-east of Eastern Senegal especially the Kedougou region. As we progress into the future, the maxima intensify to reach 15% to 20% and stretch towards the east of the country and in 2071-2100, they cover the entire region of Dakar, Thiès, Diourbel, Fatick, Ziguinchor, the west of the Louga and Saint Louis regions and the entire Kédougou region. During this time, the number of days with a Very High Risk Danger category increases gradually. The maximum increase is projected between 4% and 6% during 2031-2060 in the southern half of the country and 10% to 15% during 2051-2080 across almost the entire territory.

In the long term, we distinguish three different zones. First, the south of the country experiences the highest increase in days with the Danger category (around 25% to 30%) in the regions of Ziguinchor, Sedhiou, Kolda and Kedougou. Then the north of the country encompassing the Sylvo-Pastoral zone and the Senegal River Valley, mainly the regions of Louga and Saint Louis are subject the lowest increase in the occurrence of Danger days (of the order of 15% to 20%). Finally, the center of the country covering the Groundnut Basin, notably the regions of Fatick, Kaolack and Kaffrine as well as the south of the Matam region and the north of the Tambacounda region, experiences an intermediate increase in Danger days of between 20% and 25 %.

Finally, projections on the frequency of days with the Extreme Danger category show no change in the short and medium term. On the other hand, in the long term, the southern half of the country including the Groundnut Basin, Casamance and Eastern Senegal experiences an increase in Extreme Danger days of around 1% to 2%. Therefore, in the period of 2071-2100, the regions of Kaolack, Kaffrine, Tambacounda, Kedougou, Kolda and Ziguinchor see the days of Extreme Danger increase from 3 to 8 days.

In summary, while the regions of Dakar, Thiès, Diourbel, Saint Louis, Fatick Ziguinchor and Kedougou are experiencing an increase in Extreme Caution days, Danger days are affecting the entire country, and Extreme Danger days are drastically threatening the regions of Kaolack, Kaffrine, Matam, Tambacounda, Kedougou, Kolda and Ziguinchor.

The impact of these extreme heat events will be felt mainly on the health of population, either through temporary fatigue due to heat, heat cramps, heat exhaustion, syncope or heat stroke. It is therefore clear that the most vulnerable people are workers who spend a significant part of their work outdoors including thus agricultural workers. This indicate that Senegalese farmers can experience reduced work productivity due to these projected heat stress patterns threatening thus the agricultural sector.

- Droughts

Drought is calculated using the SPI index mentioned in the historical analysis.
The change (Future - Reference) in the frequency of occurrence and the maximum duration (i.e. the maximum number of consecutive months) of drought is calculated for the three future periods and expressed as a percentage of the total duration of the period (i.e. 360 months). Severity is expressed as a percentage of the values from the reference period.
These calculations are done for each CORDEX-CORE experiment before an ensemble mean of all experiments is performed. The results are presented for all of Senegal.

Figure 10 presents the changes in drought frequency considering SPI3 and SPI12 for the periods 2031-2060 (i.e. short term), 2051-2080 (i.e. medium term) and 2071-2100 (i.e. the long term).
For the 3-month accumulation (i.e. SPI3, Figure 10a,c,e) in the short term, the increase in frequency of occurrence is minimal (between 5% and 10% of the period) and mainly located in the far east of the Tambacounda and Kedougou regions. During the medium term, there is an expansion of changes towards the west of the country and in the long term, they occupy the entire country with maxima going up to 30% to 40% in the eastern regions of Matam, Tambacounda and Kedougou and minima of around 5% to 10% in the regions of Saint Louis, Thies and Ziguinchor.

The 12-month accumulation (i.e. SPI12 Figure 13b,d,f) reveals more extensive and larger changes compared to SPI3. In fact, the peak values are generally projected in Eastern Senegal, i.e. the regions of Tambacounda and Kedougou during all future periods. However all areas of Senegal are affected by an increase in the occurrence of droughts in the future, notably the Senegal River Valley (i.e. Saint and Matam), the Sylvo-Pastoral zone (mainly the region of Louga), the north of the Groundnut Basin (more precisely the regions of Thies, Diourbel and the north of the regions of Fatick and Kaolack and almost the entire Kaffrine region) and Casamance (especially the Sédhiou region). These changes are much more intense in the long term where they reach values of over 60% and 80%. It is also important to mention that during this period, the increase in the frequency of occurrence of droughts is spreading in the Niayes area, thus covering the Dakar region.

The changes in drought severity considering SPI3 and SPI12 for the periods 2031-2060 (short term), 2051-2080 (medium term) and 2071-2100 (long term) compared to the reference period are shown in Figure 11. We notice a certain agreement between the spatial distribution of changes in severity and that of changes in frequency during the different periods, indicating that the frequency of droughts partly determines their severity. Indeed, in the short term, the severity of droughts characterized by SPI3 (i.e. Figure 11a,c,e) increases between 5% and 10% in places located in the far east of the regions of Tambacounda and of Kedougou. An expansion of changes towards the west of the country takes place during the medium term. In the long term, the entire country shows an increase in severity with maxima of up to 30% to 40% in the east of the regions of Matam, Tambacounda and Kedougou and minima of around 5 % to 10% in the regions, Saint Louis, Thies, Fatick and Ziguinchor.

On the other hand, the 12 month accumulation (i.e. SPI12 Figure 11b,d,f) reveals more widespread and larger changes compared to SPI3 indicating an increase in severity over almost the entire country. As in the case of changes in frequency, the predominant changes in severity peak at 50% during the short term, 60% in the medium term and more than 80% in the long term

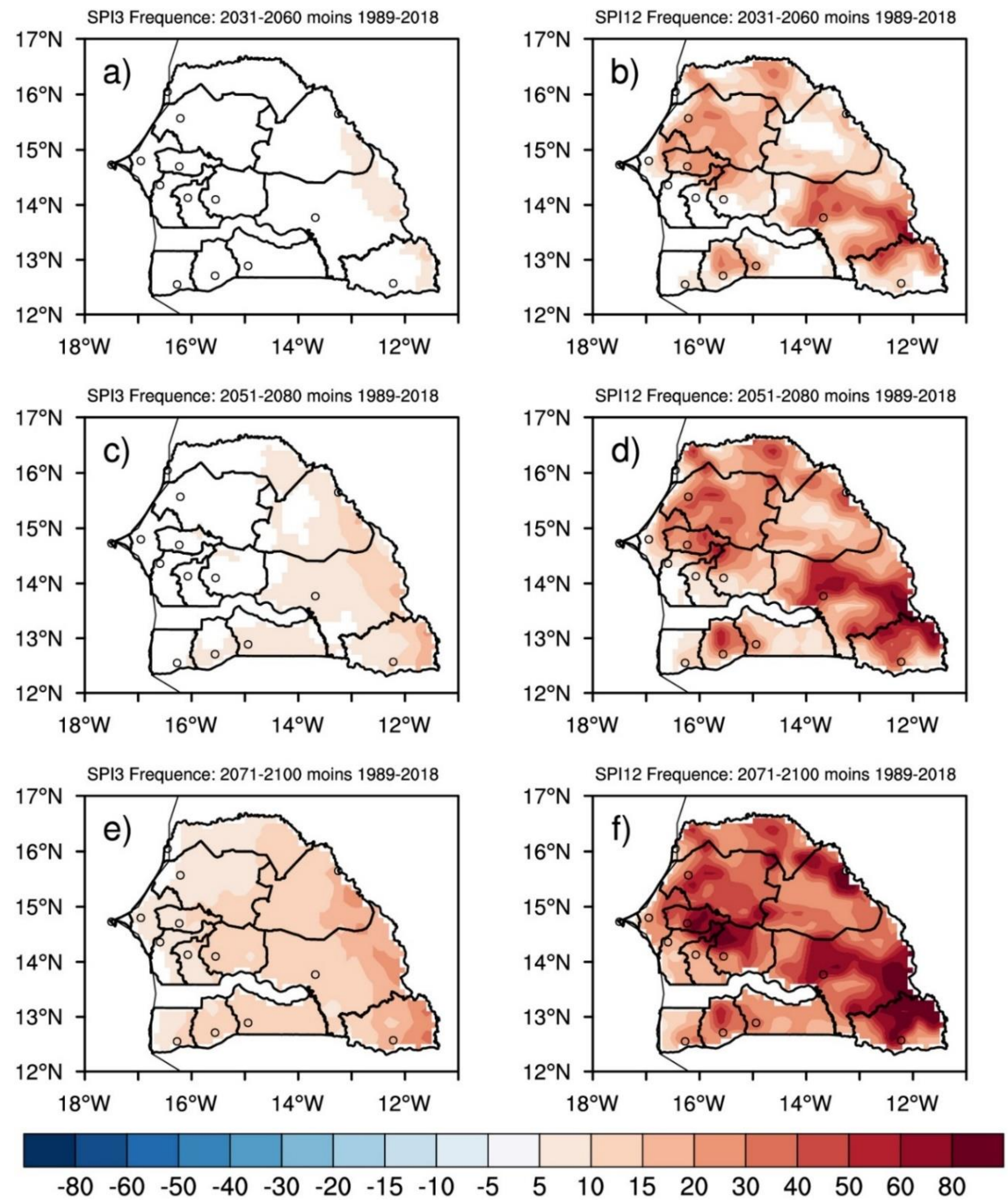

Figure 10: *Change (Future - Reference) in the frequency of droughts considering SPI3 (1st column) and SPI12 (2nd column) for the periods 2031-2060 (1st row), 2051-2080 (2nd row) and 2071-2100 (3rd row). The change is calculated with respect to the reference period 1989-2018 and expressed as a percentage of the total duration of the period (i.e. 360 months). Only places where the value of changes is significant at 95% are shaded*

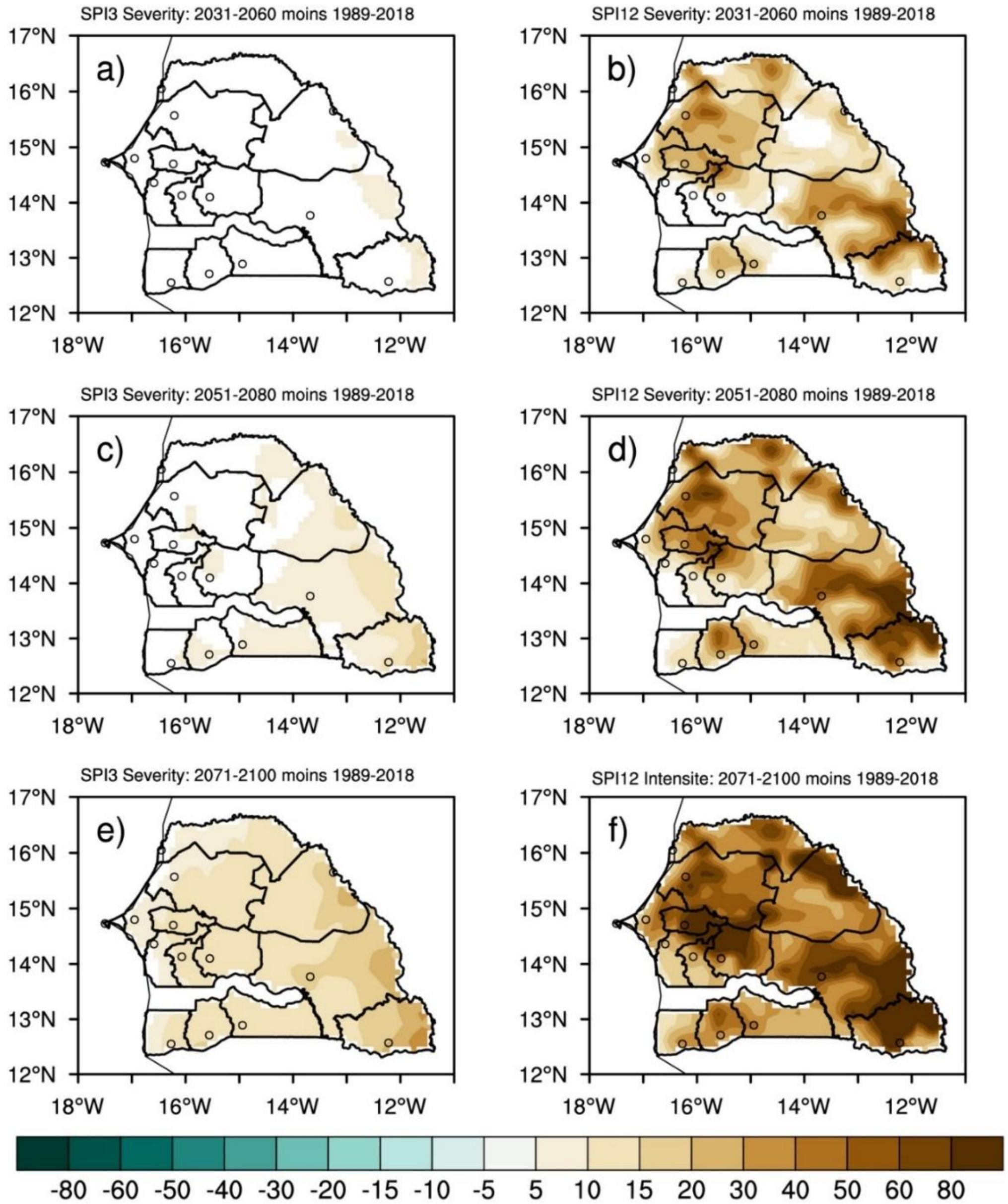

Figure 11: *Change (Future - Reference) in drought severity considering SPI3 (1st column) and SPI12 (2nd column) for the periods 2031-2060 (1st row), 2051-2080 (2nd row) and 2071-2100 (3rd row). The change is calculated relative to the reference period 1989-2018 and is expressed as a percentage of the reference period value. Only places where the value of changes is significant at 95% are shaded*

generally in Eastern Senegal more precisely in the regions of Tambacounda and Kedougou. In addition, intermediate changes of the order of 30% and 50% are found respectively in the short and medium term in the west of the Senegal River Valley, in the western half of the Sylvo-Pastoral zone and in the center of the Groundnut Basin affecting regions such as Saint Louis, Dakar, Louga, Diourbel and Kaffrine. In the long term, in addition to the maximum values in Eastern

Senegal, the east of the Senegal River Valley, more particularly the northeast of Matam, the Groundnut Basin more precisely the regions of Diourbel and Kaffrine but also the north of Fatick and Kaolack regions are experiencing a maximum intensification of drought severity of more than 80% compared to the reference period. It should also be noted that during this period, the increase in the severity of droughts is spreading in the Niayes zone, i.e. Dakar region and the west of the Louga region, and in the regions of Ziguinchor and Sedhiou up to 30% to 40%.

Figure 12 presents the changes in the maximum duration of droughts considering SPI3 and SPI12 for the short, medium and long term periods. For the case of SPI3 (i.e. Figure 12a,c,e), we note no significant change during the three future periods except in the long term in a small area in the extreme southeast of the region of Kedougou where changes do not exceed 10%. Regarding the 12-month accumulation (i.e. SPI12, Figure 12a,c,e), the changes also show some similarity with those of frequency. Indeed, the predominant values (around 15% to 20%) of changes in the maximum duration of droughts cover the west of the Diourbel region and the southeast of the Tambacounda region. However we also find low values (5% to 10%) in the Louga region, in the northwest of the Kaffrine region, in the east of the Saint Louis region, in the northeast of the Matam region and in the center of the Sédhiou region. During the medium term, we note the same spatial distribution with larger and more widespread change values. In the long term, all of Senegal experiences an increase in the maximum duration of droughts. The longest extensions (between 30% and 50%) are generally encountered in the Groundnut Basin, notably the west of the Diourbel region and a large part of the Kaffrine region, in Eastern Senegal particularly in the Tambacounda region and in the northern half of the Kédougou region and in the Senegal River Valley, i.e. in the west of the Saint Louis region and in a large part of the Matam region. Areas along the Niayes, the Ziguinchor region and the south of the Kedougou region are experiencing a minimal increase in the maximum duration of droughts of around 5% to 10%.

In summary, while SPI3 shows low change values, SPI12 projects larger and more widespread values throughout Senegal in all future periods but especially in the long term. The Groundnut Basin as well as Eastern Senegal, i.e. the regions of Diourbel, Kaffrine, Tambacounda and Kédougou, will be affected by a maximum increase in more frequent, more severe and longer droughts compared to the reference period. Other regions such as Louga, Saint Louis and Sédhiou will also be affected but through intermediate changes. The Niayes area, mainly the Dakar region and in the south of Senegal such as the Ziguinchor region will be affected by the smallest changes.

These changes will mainly impact soil moisture, surface water resources, groundwater resources, rain-fed agriculture, irrigated agriculture, livestock among others. Indeed, the level of ponds, lakes (for example Lake Guiers), rivers and groundwater tables may become lower and lower as we move forward into the future. The drought leading to the drying up of animal water points and the degradation of pasture land will considerably affect the activities of the Sylvo-Pastoral zone. It should be noted that the soils in the agricultural areas of the Groundnut Basin and in the Casamance area may dry out over time, leading to a strong impact on agriculture and ecosystems. This can lead to a mass migration of animals and farms, creating thus conflicts between livestock breeders and farmers. Finally, the irrigation of crops along the Senegal River Valley or dams could be affected considerably due to the scarcity of water reserves which will become more and more pronounced. All these changes will deteriorate rain-fed and irrigated agriculture, threatening thus food security in the regions and the country's economy in general.

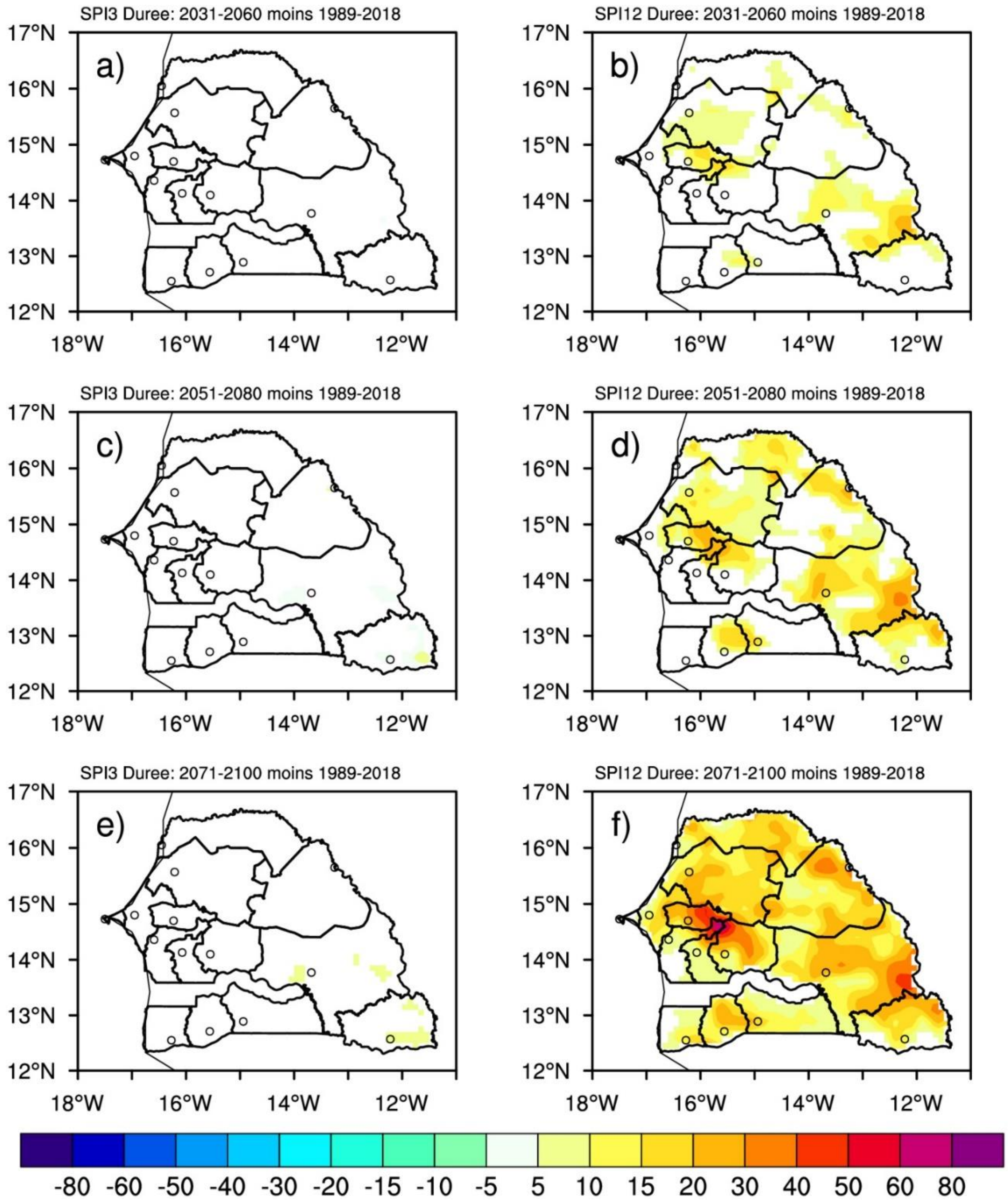

Figure 12: *Change (Future - Reference) in drought maximum duration considering SPI3 (1st column) and SPI12 (2nd column) for the periods 2031-2060 (1st row), 2051-2080 (2nd row) and 2071-2100 (3rd row). The change is calculated relative to the reference period 1989-2018 and is expressed as a percentage of the reference period value. Only places where the value of changes is significant at 95% are shaded*

- Extreme Precipitation

Extreme precipitation are characterized as defined in the historical period. These values are calculated for the reference period (1989-2018), the short term (2031-2060), the medium term (2051-2080) and the long term (2071-2100). The changes (Future - Reference) on the frequency of occurrence and the average annual intensity of each category of events (i.e. TH and ETH) are calculated for the 3 future periods and expressed as a percentage of the values of the historical period. These calculations are done for each CORDEX-CORE experiment before a multimodel ensemble of all experiments is performed. The results are presented for all of Senegal.

During the short term (2031-2060), changes in the frequency of very wet events (i.e. TH) which can lead to flooding show a decrease of 5% to 20% in the north of the country in the Senegal River Valley in particular in the regions of Saint Louis and Matam but also in the southeastern Senegal, i.e. Kedougou. Meanwhile, an increase of around 5% to 15% is projected in the west and center of the country mainly along the Niayes and part of the Groundnut Basin but limited only to the north of the Thies region, in the south of the Louga region and in the central areas of the Kaolack region (see Figure 13a). In the medium term (2051-2080; Figure 13c), both negative and positive changes intensify and extend spatially. In fact, the reduction in the occurrence of very wet events is spreading throughout the Matam region with a decrease of up to 30%, in the east of the Tambacounda region with a drop of up to 15% and in the center of the Kedougou region where negative changes of around 15% prevail. At the same time in the west of the Sylvo-Pastoral zone and in the Groundnut Basin, we note an increase of up to 30% in the frequency of these events in the south-western half of the Louga region, in the center of regions of Fatick and Kaolack but also in the south of the Kaffrine region. In the long term (2071-2100; Figure 13e), the spatial distribution of changes is almost similar to that of the medium term but with a difference in their extent. For example, in Matam and Tambacounda, the reductions are confined to the south of these regions. However, in the west of the Sylvo-Pastoral zone, an increase of more than 40% is projected in the south of the Louga region, and in the north of the Thies and Diourbel regions. Finally, at the Groundnut Basin and in Casamance, the increase in the events not exceeding 15% spread to the regions of Kaffrine, Sedhiou and Kolda.

Regarding extremely very wet events (Figure 13b,d,f), amost all regions of Senegal experience an increase in their occurrences during all future periods except in some parts of the Saint Louis and Matam region in the short and medium terms. In fact, throughout the Groundnut Basin, almost the entire Sylvo-Pastoral zone, a large part of Eastern Senegal and in the center and west of Casamance, the number of these events has considerably multiplied. The maxima of the changes are located in the Louga and Kaffrine regions but their magnitudes increase over time. For example, in the short term, they do not exceed 50%, during the medium term, they are around 60% to 70% while in the long term, they reach 80%.

Changes in the intensity of very wet and extremely very wet events reveal an increase which gradually becomes widespread throughout the whole Senegal as we move into the future (i.e. the forcing increases) as indicated in Figure 14. Indeed, very wet events are projected to become more intense in the short term with maxima of 20% in the regions of Louga, Tambacounda and Kédougou (Figure 14a). In the medium term (Figure 14c), all of Senegal experiences an intensification of these events but the most intense (up to 30%) are encountered along the Senegal River from Saint Louis to Kedougou across the west of the regions of Matam and Tambacounda, in the Sylvo-Pastoral Zone, over almost the entire Louga region, and finally in the Groundnut Basin especially the regions of Diourbel, Kaolack and Kaffrine. mainly throughout the Louga region, in the west of the Saint Louis region and in the north of the Matam region (see Figure 9e). We also note an intermediate increase of around 30% to 40% in the Niayes zone (especially in the Dakar region, the west of the Thiès region and the west of the Louga region), in the Groundnut Basin (especially the regions of Fatick, Kaolack and Kaffrine), in Casamance (particularly in the west of the Ziguinchor region, in the center of the Sedhiou region and in the southern half of the Kolda region) and in Senegal Eastern, particularly in a large part of the regions of Tambacounda and Kedougou.

The changes in the intensity of extremely very wet events in the short term (Figure 14b) display a spatial distribution similar to those of very rainy events (i.e. Figure 14a). However, the maxima are higher (up to 30%) and are found this time to the south of the Groundnut Basin and more precisely in the south of the Kaffrine region but also in Eastern Senegal i.e. in the west of the Tambacounda region and especially throughout the Kedougou region. In the medium and short term, as for the case of very wet events (i.e. Figure 14c,e), the intensification of extremely very wet events covers all of Senegal. The most extensive maxima are located in the west of the Sylvo-Pastoral zone, specifically in the Louga region and at the Groundnut Basin, particularly in the northern half of the Fatick and Kaolack regions, in the eastern half of the Diourbel region and the western half of the Kaffrine region. We also note other maxima in the north of the Matam region, in the east and southwest of the Tambacounda region, throughout the Kedougou region and in Casamance mainly in the Kolda region. However, the long term reveals more intense maxima of more than 75%. It is important to note that the region of Saint Louis, that of Dakar and that of Ziguinchor are experiencing an increase in the intensity of very wet extreme events in the order of 40% to 60%.

In summary, the part of Senegal which will be most affected by very wet and extremely very wet events with projections indicating an increase in the frequency and intensity are the regions in the Sylvo-Pastoral zone (mainly the region of Louga), the regions of the Groundnut Basin in particular Diourbel, Kaolack and Kaffrine, that in the southeast of Eastern Senegal more precisely the region of Kedougou and those in the Casamance zone which are Ziguinchor, Sedhiou and Kolda. In these regions, the risk of flooding increases with a greater occurrence of more intense precipitation as we move from the near future (2030s, 2040s) to the distant future (2080s, 2090s, etc.) . As for the regions of Saint Louis, Dakar and Matam, the risks of flooding are increased by only the intensification of very rainy and extremely very rainy events.

These projections in extreme precipitation could lead to devasting floods that can have dramatic impacts on people, infrastructure, economic activity and the environment. They will affect all sectors of daily life in Senegal. Indeed, in urban areas, especially in regional capitals, floods could partially or completely destroy homes, material properties and public or private infrastructure, causing considerable loss and damage. More importantly in rural areas, particularly in the agricultural areas of the Groundnut Basin, Sylvo-Pastoral zone and Casamance, flooding will affect both rainfed and irrigated agriculture but also livestock farming. They could cause waterlogging of plants, partially or totally destroy farms and decimate entire livestock, thus aggravating poverty and food insecurity and threatening the country's economy.

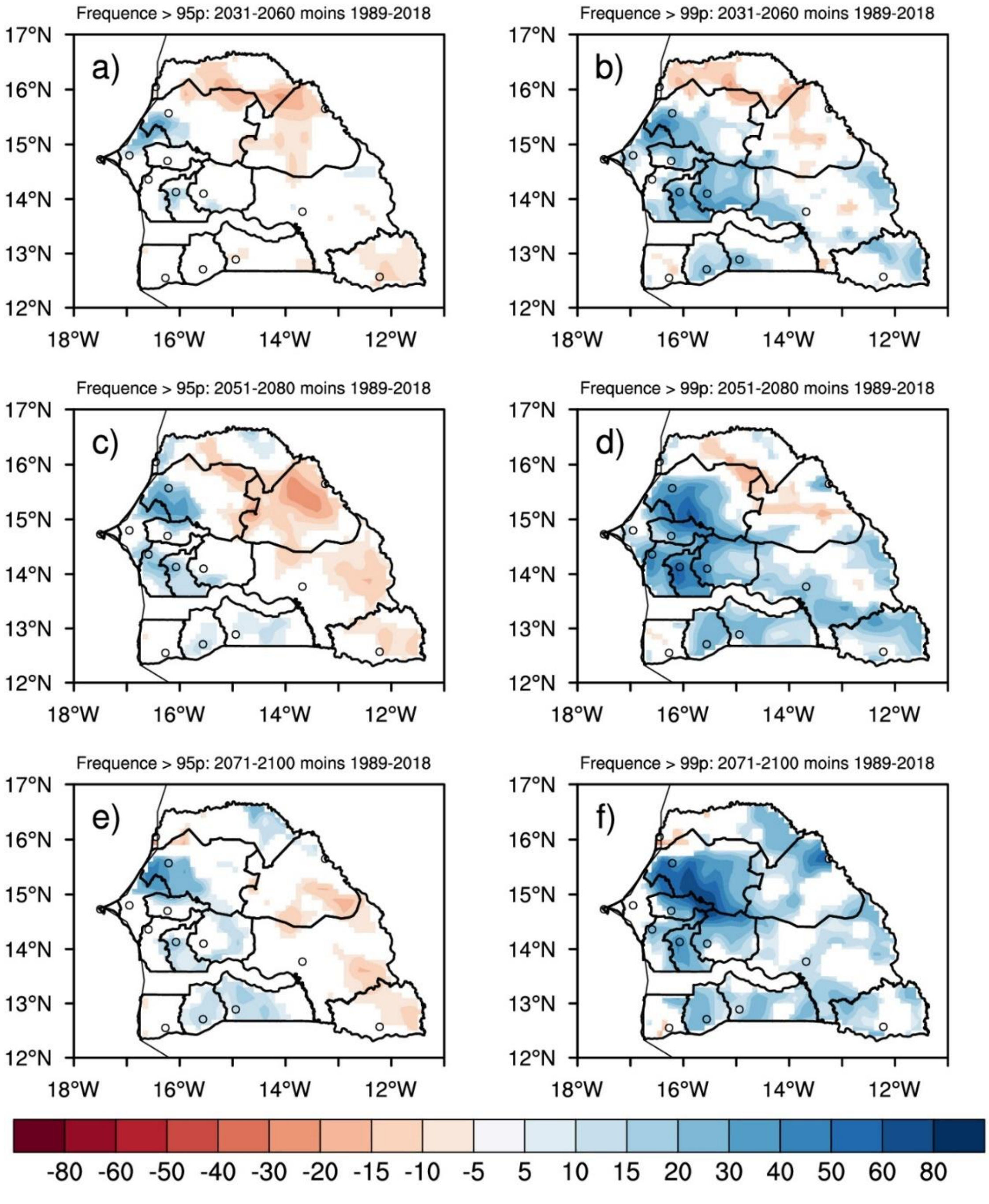

Figure 13: *Change (Future - Reference) in the average frequency of occurrence of very humid days (TH: 1st column) and extremely very humid days (ETH: 2nd column) which could lead to flooding during the periods 2031-2060 (1st row), 2051-2080 (2nd row) and 2071-2100 (3rd column). The change is calculated relative to the reference period 1989-2018 and is expressed as a percentage of the reference period value. Only places where the values of changes is significant at 95% are shaded*

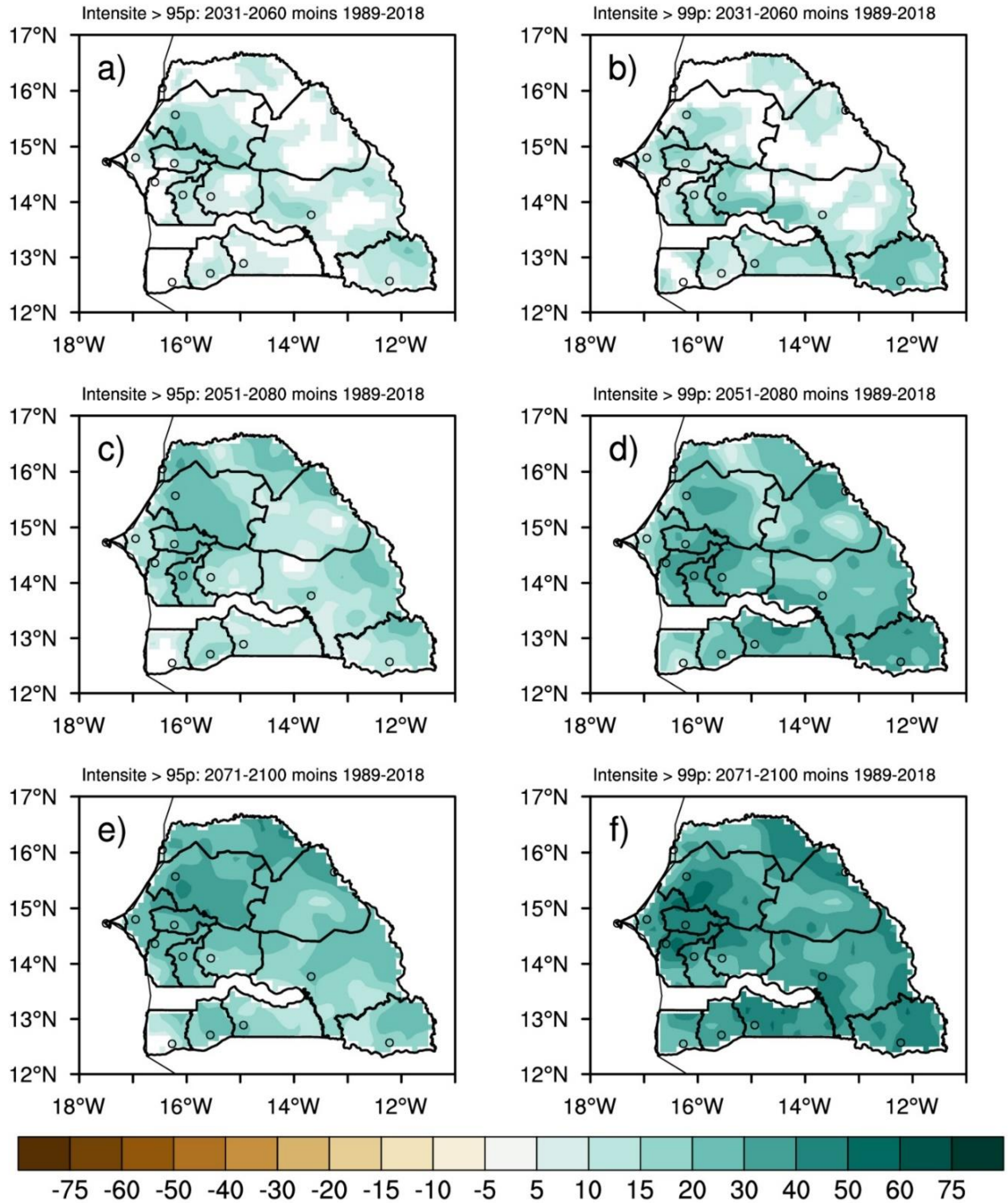

Figure 14: *Change (Future - Reference) in the intensity of very humid days (TH: 1st column) and extremely very humid days (ETH: 2nd column) which could lead to flooding during the periods 2031-2060 (1st row), 2051-2080 (2nd row) and 2071-2100 (3rd column). The change is calculated relative to the reference period 1989-2018 and is expressed as a percentage of the reference period value. Only places where the values of changes is significant at 95% are shaded*

2. Climate and Biophysical vulnerability of the Senegalese agriculture sector

Senegal faces several vulnerabilities that directly and indirectly weaken its ability to produce food and, inversely, the current agricultural system with its reliance on rain and inability to cope with changing climatic conditions, contributes to these vulnerabilities.

In this section, *vulnerability* is defined as the exposure and coping capacity of a country's biophysical conditions to a changing climate, with particular attention on how agriculture is impacted within these conditions. Only the biophysical and climate vulnerabilities are explored in this document, as the social and economic vulnerabilities are further explored in the Baseline assessment.

It is useful to first situate Senegal's vulnerability among other countries, so as to appreciate the urgency for a dynamic shift in the agricultural model of Senegal. Senegal is ranked relatively low among a list of 113 countries in the Global Food Security Index (2022) in terms of its food affordability and availability (82nd), quality and safety (86th), and sustainability and adaptation[10] (94th).[11] Similarly, the Notre Dame Global Adaptation Initiative (ND-GAIN) index ranks Senegal as the 34th most vulnerable country; this vulnerability is mainly due to its projected change in cereal yields (highly vulnerable), agricultural capacity, defined as the measure of agricultural technological capacity out of the amount of fertilizer/pesticide use, ability to equip agricultural area with irrigation, and frequency of tractor use (highly vulnerable), and dam capacity, defined as the ability of the country to store water in dams (highly vulnerable).[12]

To further examine these vulnerabilities of the agricultural sector, this section explores the ways in which biophysical factors that contribute to, and are affected by, climate change. The following sub-sections have split the varying types of biophysical vulnerabilities into several categories. Specifically, the various environmental threats related to agriculture, such as soil quality, natural disasters, pest infestations, land productivity, water quality and availability, sea-level rise and coastal erosion will be explored.

2.1. Biophysical exposure and vulnerabilities related to the agriculture sector in Senegal

2.1.1. Soil Quality

Soil quality is an important driver of the biophysical pressures that Senegal experiences and is key for Senegalese farmers in their selection of crops they choose to cultivate. In Senegal, soil quality has significantly declined; approximately 75% of all agricultural lands is impacted by soil degradation.[13] The main drivers of soil degradation in Senegal are soil erosion, nutrient depletion

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[11] Economist Impact. (2023). Global Food Security Index (GFSI). Global Food Security Index (GFSI).

[12] University of Notre Dame - Notre Dame Research. (2020). Country Index, Notre Dame Global Adaptation Initiative, University of Notre Dame. Notre Dame

[13] Ibid

due to monocropping, soil compaction due to over-grazing.[14] Other drivers include common agricultural practices, such as slash-and-burn agricultural techniques.[15] In addition, the over-use of common, synthetic fertilizers and pesticides further exacerbates the rate of soil degradation.[16]

With the rise of sea levels and drying water tables, both surface and groundwater have been subjected to rising salinization rates. This is particularly the case in upland rice cultivation, the vast majority of which is grown in the Fatick, Kaolack, Ziguinchor and Kolda regions.[17] Indeed, the main source of soil salinization in Senegal has been due to inundation and deposits of salt from the seawater intrusion. Soil salinization is also driven the decline freshwater resources because of rising salt waterbodies; the salinization of both freshwater resources, and in turn, soils, has subsequently contributed to the degradation of mangrove populations.[18]

Conversely, the uncontrolled cutting of mangrove forests along the Saloum river, which runs through Kaffrine, Kaolack and Fatick, contributes to the salinization of soils as mangroves act as a natural saltwater barrier; without these mangrove populations, saltwater intrusion in deeper soils has become more prevalent, which hinders crop production.[19] Soil salinity impacts as many 1.2 million ha of land across the country, with most soil salinization occurring in the Casamance biosphere (Ziguinchor, Kolda and Sedhiou; 300,000 ha), and in the Bassin Arachidier (Louga, Thies, Fatick, Diourbel, Kaolack, Kaffrine biosphere; 200,000 ha).[20] Salinization is of particular concern along the Saloum river's surrounding wetlands in the dry season, where many rice farmers have had to abandon their fields due to insufficient yields.[21] Likewise, groundnut production, which is the most important cash crops for Senegalese farmers has been threatened by rising soil salinization; the Groundnut Basin in Kaolack and Fatick has seen seawater intrusion in more than 17% of the regions' soils.[22]

Land degradation because of salinization and other drivers, without action, are projected to cost Senegal over USD 40 billion in the long term (30 years), and only $8.8 billion should the country mobilize resources to mitigate it.[23] Indeed, US$ 996 million are lost yearly because of inaction to

[14] University of Notre Dame - Notre Dame Research. (2020). Country Index, Notre Dame Global Adaptation Initiative, University of Notre Dame. Notre Dam

[15] Cherlet, M., Hutchinson, C., Reynolds, J., Hill, J., Sommer, S., & Von, M. G. (2018, November 22). World Atlas of Desertification. JRC Publications Repository. https://doi.org/10.2760/06292

[16] Feed the Future. (2016). Climate-Smart Agriculture in Senegal. USAID.

[17] Republique du Senegal. (2009). PROGRAMME NATIONAL D'AUTOSUFFISANCE EN RIZ.

[18] Plan National d'Adaptation au Senegal (PNA-FEM), (2022) Études de vulnérabilités approfondies aux changements climatiques dans les régions de Kaffrine, Kédougou, Matam (2022), Saint-Louis et Ziguinchor,

[19]Deutsche Welle (DW). (2017). Salt water threat to Senegal wetlands. Dw.Com.

[20] Centre de Suivi Ecologique. (2020). RAPPORT SUR L'ETAT DE L'ENVIRONNEMENT AU SENEGAL. Ministere de l'Environnement.

[21]Deutsche Welle (DW). (2017). Salt water threat to Senegal wetlands. Dw.Com.

[22] Diome, F., Tine, A.K., (2015). Impact of salinity on the physical soil properties in the groundnut basin of Senegal: case study of Ndiaffate. Int. J. Chem. 7 (2), 198. http://dx.doi.org/10.5539/ijc.v7n2p198

[23] Ibid

mitigating land degradation, and 9% of the country's yearly GDP is lost to the degradation of land.[24]

2.1.2. Natural Disasters

Natural disasters are also a key driver in the challenges that affect Senegalese agriculture. The diversity of Senegal's climate is reflected in its diversity of natural disasters, which range from floods and wet mass movements to severe droughts. Some regions face both droughts and floods, rendering existing systems highly vulnerable, and requires a systematic shift in agricultural practices that can simultaneously address divergent stressors. Nationally, droughts have impacted more than 3 million people since 1980; one modelling analysis of climate risks to agriculture in Senegal found that 10% of national crop loss can be attributed to drought events.[25] While floods (representing 45% of all natural disasters) are more frequent than droughts (6% of natural disasters), droughts have had more devastating impacts on the Senegalese agricultural sector.[26] Indeed, the 2000 drought saw peanut revenues fall by almost 75%, while millet/sorghum revenues fell by over 60%; both crops respectively represent most of the subsistence and financial needs of Senegalese farmers.[27] The Groundnut Basin is a good example of these trends, as it lies in areas in which both droughts and floods have been recurring more frequently; droughts have been responsible for the decline in soil fertility and degradation[28], while extreme floods during the wet season in Kolda have been responsible for the destruction of rice cultivation fields, and high-wind storms mainly impacting groundnut cultivation in Kolda.[29]

2.1.3. Pest Infestations

Increases in temperature have directly impacted the proliferation of pest infestations in Senegal. Indeed, the prevalence of locust attacks on crop fields has increased significantly in the past few decades. Locust reproduction increases as temperatures increase[30], with several studies confirming strong correlations between temperature increases and locust attacks on agricultural fields throughout sub-Saharan Africa.[65] In Senegal, pests (mostly locusts) account for 25% in crop yield reductions.[31] Locust attacks are often coupled with other natural disasters that facilitate their proliferation, such as droughts. Indeed, there have been 6 locust attacks between 1980 and 2012, half of which were also during extreme drought events.[32] In a 2004 locust infestation in Senegal, 20% of the Sahel region's food needs were lost from a single locust attack, and farmers lack the means of preventing and mitigating the impacts of locust attacks on their crops.[33] These locust

[24] Ibid

[25]World Bank. (2013). Initial Market Assessment—Country Scoping Note: Senegal.

[26] Climate Risk and Adaptation Country Profile: Vulnerability, Risk Reduction, and Adaptation to Climate Change - Senegal. (2011, May 4).

[27] Ibid

[28] Green Climate Fund (GCF). (2022). Approved Project Preparation Facility Application: Green Climate Finance Facility for fostering Climate-smart agriculture in Senegal.

[29] Draft Rapport Vulnerabilite Kolda- CSE

[30] FAO, & WMO. (2019). Weather and Desert Locusts.

[31] D'Allesandro, S., Fall, A. A., Grey, G., Simpkin, S., & Wane, A. (2015). Senegal: Agriculture Sector Risk Assessment. World Bank.

[32] Ibid

[33] Ibid

attacks are likely to worsen as temperatures are projected to rise, and as precipitation is projected to increase; this latter phenomenon is also of concern to farmers as wetter conditions foster locust breeding.[34]

2.1.4. Land Productivity

Land productivity is a key factor in assessing a country's agricultural sector as it indicates the ability of a parcel of land to produce food. A 2020 report from Senegal's Centre de Suivi Ecologique (CSE) conducted an analysis of land productivity in the country and provided a map (**Error! Reference source not found.**, below) of the state of Senegal's land, expressed as the change in productivity between 2001 and 2015. The map reveals that the primary areas in which land productivity was either stressed, showing signs of decline or in decline is concentrated in Fattick, Kaolack, Kaffrine, Thies, and Louga, Sedhiou and Kolda. There are important land productivity gains in Kédougou and Kolda, as well as in the south of Tambacounda.

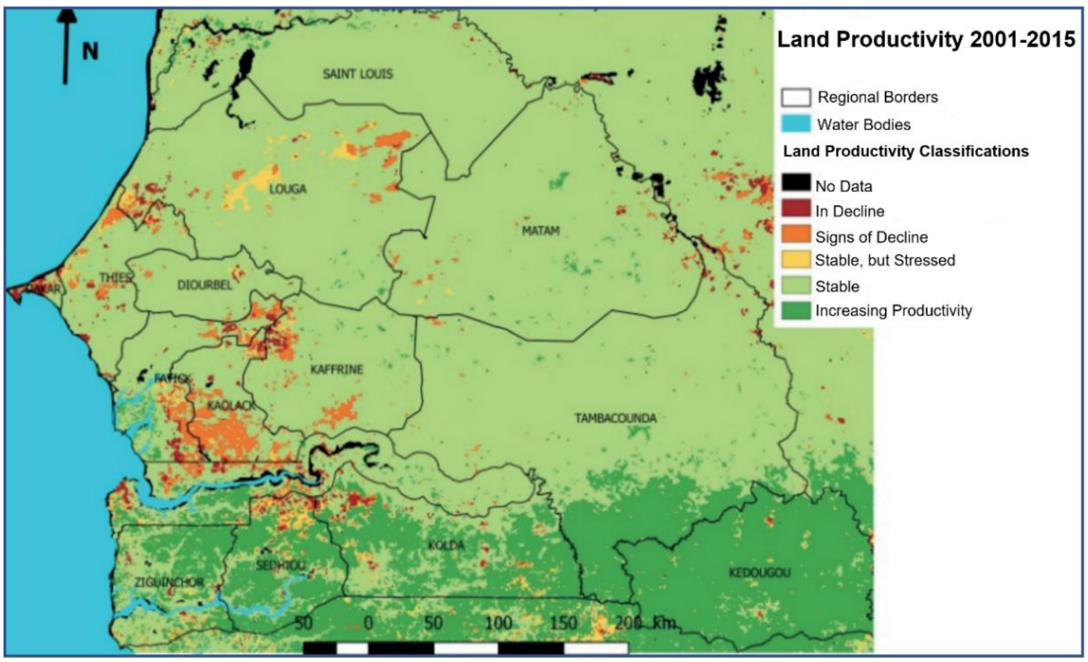

Figure 22. Land productivity of Senegal[35]

[34] World Bank. (2020). The Desert Locust Crisis and the World Bank Group. World Bank.

[35] CSE (2020) Rapport sur l'Etat de l'Environnement

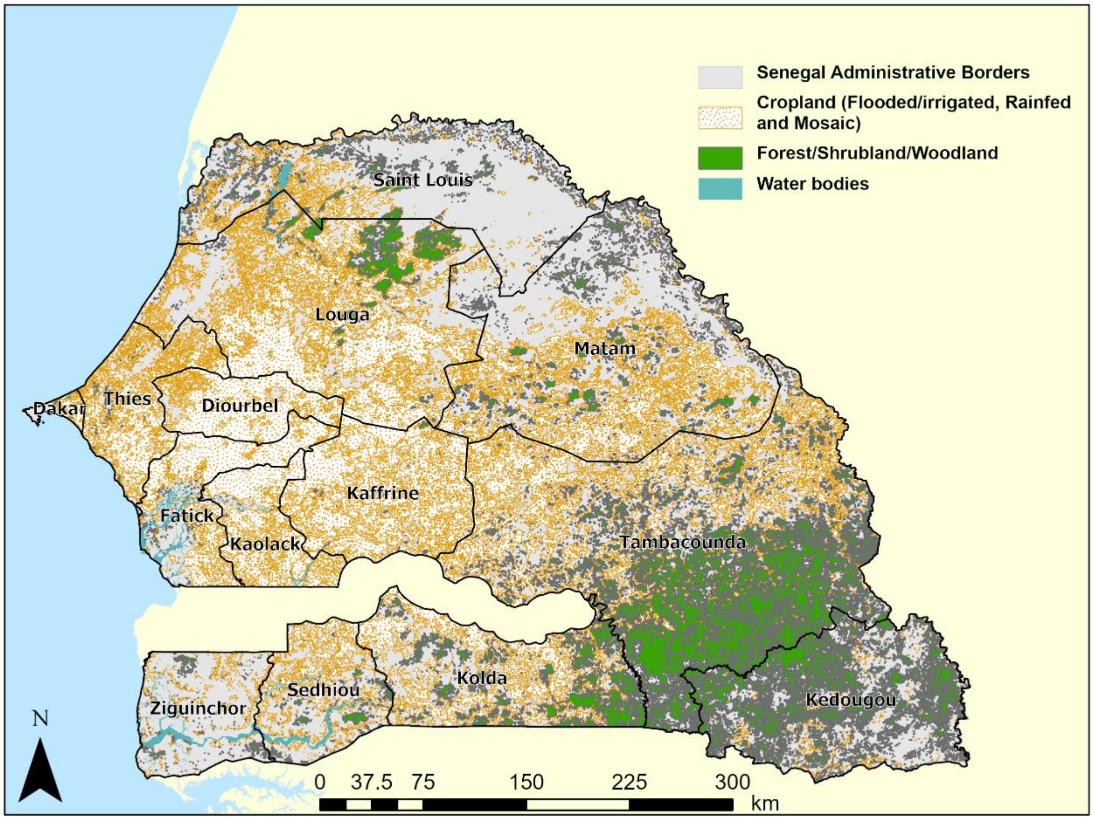

Figure 1. Land use of Senegal[36]

To contextualize the significance of land productivity degradation in Senegal, it is also important to identify in which regions cropland is the most dominant land-use type. Error! Reference source not found.**,** demonstrates the areas in which cropland and forest/shrubland are most prominent; land productivity degradation was most prominent in areas in which cropland is most prominent, as indicated by Figure 1; the regions of Kaffrine, Kaolack, Thies and Louga have the highest concentration of different types of cropland (flooded/irrigated, rainfed and mosaic). Though only 5.57% (10 748,1 km^2) Senegal's land is in a state of decline[37], most of this degraded land finds itself in the regions selected for the implementation of this project. This potentially signifies one or several of the following trends: cropland is likely to have suffered from land degradation, current agricultural techniques have driven land degradation (poor soil management and/or tillage techniques), or that natural disasters and changing climatic conditions (warmer temperatures have contributed to the loss of soil quality, leading to the abandonment of agricultural areas.

[36] Data from the following database was processed by the authors using the ArcGIS Pro software: FAO. (2023b). Global Land Cover—SHARE (GLC-SHARE) | Land & Water | Food and Agriculture Organization of the United Nations | Land & Water | Food and Agriculture Organization of the United Nations.

[37] Centre de Suivi Ecologique. (2020). RAPPORT SUR L'ETAT DE L'ENVIRONNEMENT AU SENEGAL. Ministere de l'Environnement.

2.1.5. Water Quality and Availability

Senegal's water resources are abundant, but their availability varies seasonally and regionally. The country's total renewable freshwater resource per capita of 3,459 m3 exceeds the threshold for water scarcity as defined by the Falkenmark Water Stress Index, but approximately 34% of its water resources come from outside the country. Senegal's surface water resources are estimated between 20.9 and 23.5 billion m3/year, but their distribution is uneven and mobilization is challenging.[38]. However, these water resources are unevenly distributed and poorly controlled. The question of the availability of water resources does not arise, but rather the difficulties related to their mobilization[39]. Approximately 90% of irrigation systems are built around surface water bodies such as rivers and lakes[40].

Most renewable water supply in Senegal is derived from surface water (see Table below) in five main drainage basins: the Senegal River, Gambia River, Casamance River, the Kayanga River, and the Sine Saloum. All of the basins flow into the Atlantic Ocean.

Table 2 Water Resources Data

TABLE 1. WATER RESOURCES DATA	Year	Senegal	Sub-Saharan Africa (median)
Long-term average precipitation (mm/year)	2017	686	1,032
Total renewable freshwater resources (TRWR) (MCM/year)	2017	38,970	38,385
Falkenmark Index - TRWR per capita (m^3/year)	2017	2,459	2,519
Total renewable surface water (MCM/year)	2017	36,970	36,970
Total renewable groundwater (MCM/year)	2017	3,500	7,470
Total freshwater withdrawal (TFWW) (MCM/year)	2002	2,221	658
Total dam capacity (MCM)	2015	250	7,085
Dependency ratio (%)	2017	33.8	23
Interannual variability	2013	1.8	1.55
Seasonal variability	2013	3.9	3.15
Environmental Flow Requirements (MCM/year)	2017	20,160	18,570
SDG 6.4.2 Water Stress (%)	2002	11.81	5.70

Source: FAO Aquastat

Notable exceptions are the Niayes region and Groundnut Basin where micro-scale irrigation takes place using groundwater from wells. Medium and large-scale irrigation are typically developed, financed, and managed by the government (e.g. the state agency for the development of the Senegal Delta and Faleme River, SAED — Société Nationale d'Exploitation des Terres du Delta et du Fleuve Sénégal and also Société de Développement Agricole et Industriel du Sénégal - SODAGRI) with a focus on the production of rice and other cereals. Irrigation using surface water is therefore quite widespread in Senegal, unlike irrigation using groundwater. Senegal's estimated irrigation potential is about 340,000 hectares, but current irrigation covers only 105,000 hectares, with a 60% exploitation rate, meaning that there are substantial opportunities for further development[41].

38 World Bank (2022). SENEGAL : Challenges and Recommendations for Water Security in Senegal at National Level and in the Dakar-Mbour-Thiès Triangle.

39 Centre de Suivi Ecologique. (2020). RAPPORT SUR L'ETAT DE L'ENVIRONNEMENT AU SENEGAL. Ministere de l'Environnement.

40 Ibid

41 GGGI. (2020). Landscape Analysis Report to scale up the installation of solar irrigation businesses in Senegal.

It is also worth noting that the peak of precipitation in Senegal is consistently being recorded later each year and currently occurs in September. In the central and northern areas, rainfall breaks have become prolonged, and the frequency of heavy rain showers has increased. Farmers in many regions are struggling to manage and control water throughout the year due to long dry seasons, irregular low rainfall, salty land, degraded soils. These conditions, combined with poor water management, heighten the vulnerability of small producers to land and crop loss from climate change. The production pressures combined with lower yields increase the risks of deforestation and extension of the agricultural front in these areas. Without well managed supported irrigation systems, water availability throughout the year remains a key constraint in the modernization and diversification of farming systems. In particular, groundwater pumping infrastructure which could address some of these pressures, it is generally either not available or very expensive (e.g., high diesel costs).

Groundwater, which is the proposed scope in this project, is a vital source for domestic consumption, livestock watering, mining and industry, and some irrigation. In Senegal, groundwater is unevenly distributed across four main aquifer systems: deep Maastrichtian, superficial, intermediate, and basement aquifers (Table 3). Despite the high productivity and depth of the deep Maastrichtian aquifer, the groundwater characteristics, including abstraction rates, water quality, and depth, are not well understood. Approximately 61% of new abstraction permits in 2019 were for agriculture, 29% for industry, and 10% for drinking water[42]. Overexploitation and low recharge rates are threatening groundwater availability, quality, and accessibility, and nationally, groundwater levels are decreasing by 0.30m–0.67m annually due to over-abstraction[43].

Table 3. Aquifer systems[44]

AQUIFER SYSTEMS	VOLUME OF WATER
Superficial aquifer system (QT, CT, OM)	Between 50 and 75 billion m³
Intermediate aquifer system (EO, PA)	Between 60 and 110 billion m³
Deep aquifer system (Maastrichian)	Between 300 and 400 billion m³
Basement aquifer system	Low volume, around 3.6 million m³

Groundwater is threatened by low recharge rates and overexploitation, particularly in the central western part of the country, which has continuously lowered water tables since the mid-1970s, and levels are expected to drop another 12m by 2050. The deep Maastrichtian aquifer, which is part of the Senegalo-Mauritanian aquifer, covers 80 percent of the country and accounts for 40 percent of groundwater flows. The deep aquifer system has the highest productivity and greatest depths, reaching up to 400 meters (m), although variability can be significant depending on location. The intermediate aquifer is the next deepest and is located along the northwestern border and in the

[42] USAID and SWP (2021) Senegal Water Resources Profile Overview", Water Resources Profile Series

[43] USAID and SWP (2021) Senegal Water Resources Profile Overview", Water Resources Profile Series.

[44] CSE, Rapport sur l'état de l'environnement au Senegal, 2020

east near Dakar. The superficial aquifer is shallower and productivity is low. The basement aquifer in the southeast has low productivity[45] .

The quality of groundwater varies according to the depth and the place of abstraction. The hydro-chemical parameters generally exceeding the WHO standards for drinking water are: chlorides, fluorides and to a lesser extent iron. The main problems related to groundwater are chlorides, fluorides and iron high concentration in some regions. Chlorides vary between 750 and 3500 mg/l and fluorides 1.5 to 7.5 mg/l, while the WHO standard is 600 mg/l for chlorides and 1.5 mg/l for fluorides. These elements constitute a limiting factor both for the water supply of populations and for market gardening and industry[46].

- Groundwater salinity is increasing due to over abstraction, saltwater intrusion, and irrigation. Groundwater salinity is increasing due to over abstraction, saltwater intrusion, and irrigation. Untreated wastewater and agricultural runoff, especially in coastal regions and arid central western Senegal, are also contributing to high nitrate concentrations (
- Figure 2 and Figure 3. Overview of challenges relative to groundwater .[47] The iron content constitutes a constraint for the exploitation of the aquifer. The iron content can reach values of 3.5 mg/l (accepted standard (3mg/l)). High iron levels can cause a reddish color on the walls of water drainage systems and clogging of drip irrigation lines[48] (see
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Figure 4).

[45] USAID and SWP (2021) Senegal Water Resources Profile Overview", Water Resources Profile Series.

[46] Centre de Suivi Ecologique. (2020). RAPPORT SUR L'ETAT DE L'ENVIRONNEMENT AU SENEGAL. Ministere de l'Environnement.

[47] USAID and SWP (2021) Senegal Water Resources Profile Overview", Water Resources Profile Series.

[48] Centre de Suivi Ecologique. (2020). RAPPORT SUR L'ETAT DE L'ENVIRONNEMENT AU SENEGAL. Ministere de l'Environnement.

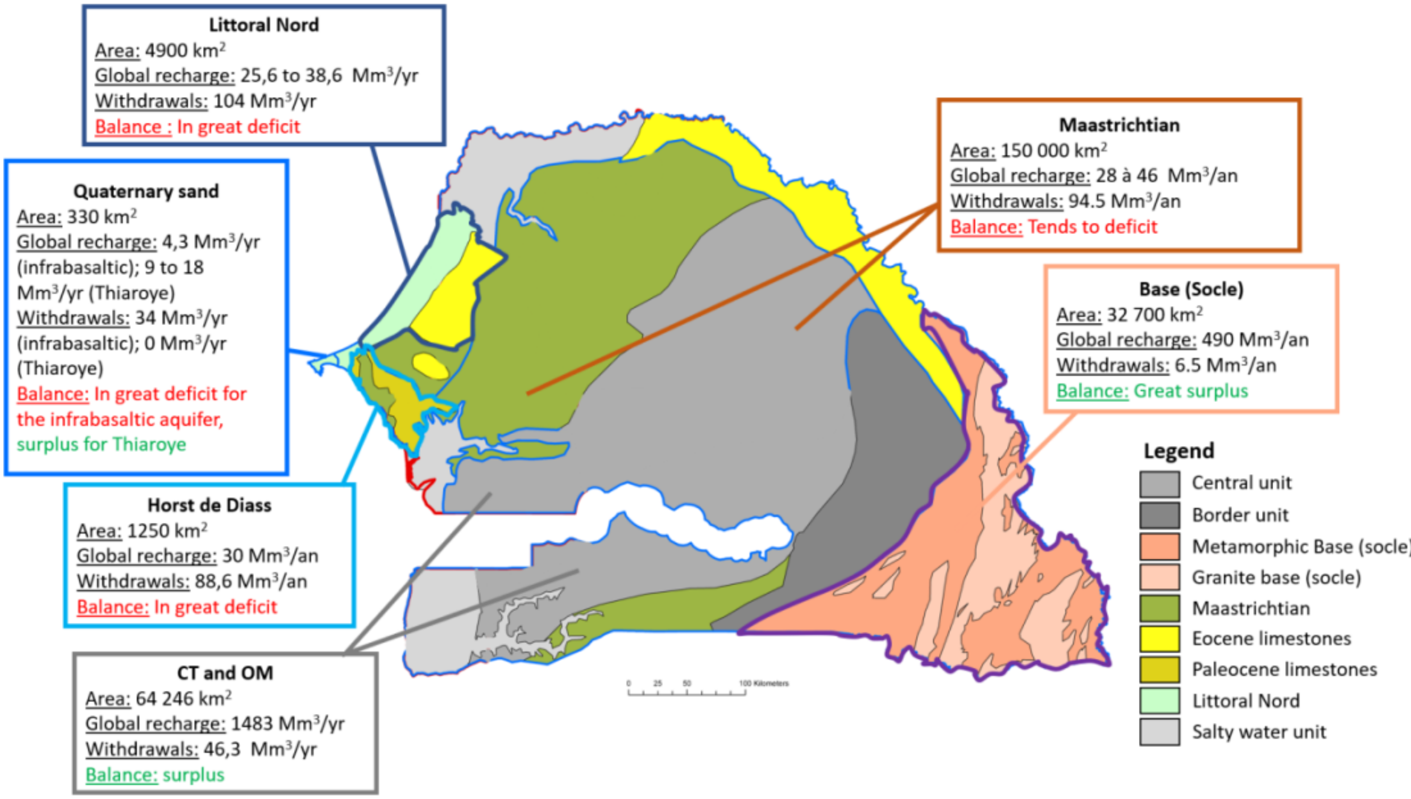


Figure 2. Overview of hydraulic potential of groundwater. [49]

[49] World Bank Group and GWSP (2022). Challenges and Recommendations for Water Security in Senegal at National Level and in the Dakar-Mbour-Thiès Triangle.

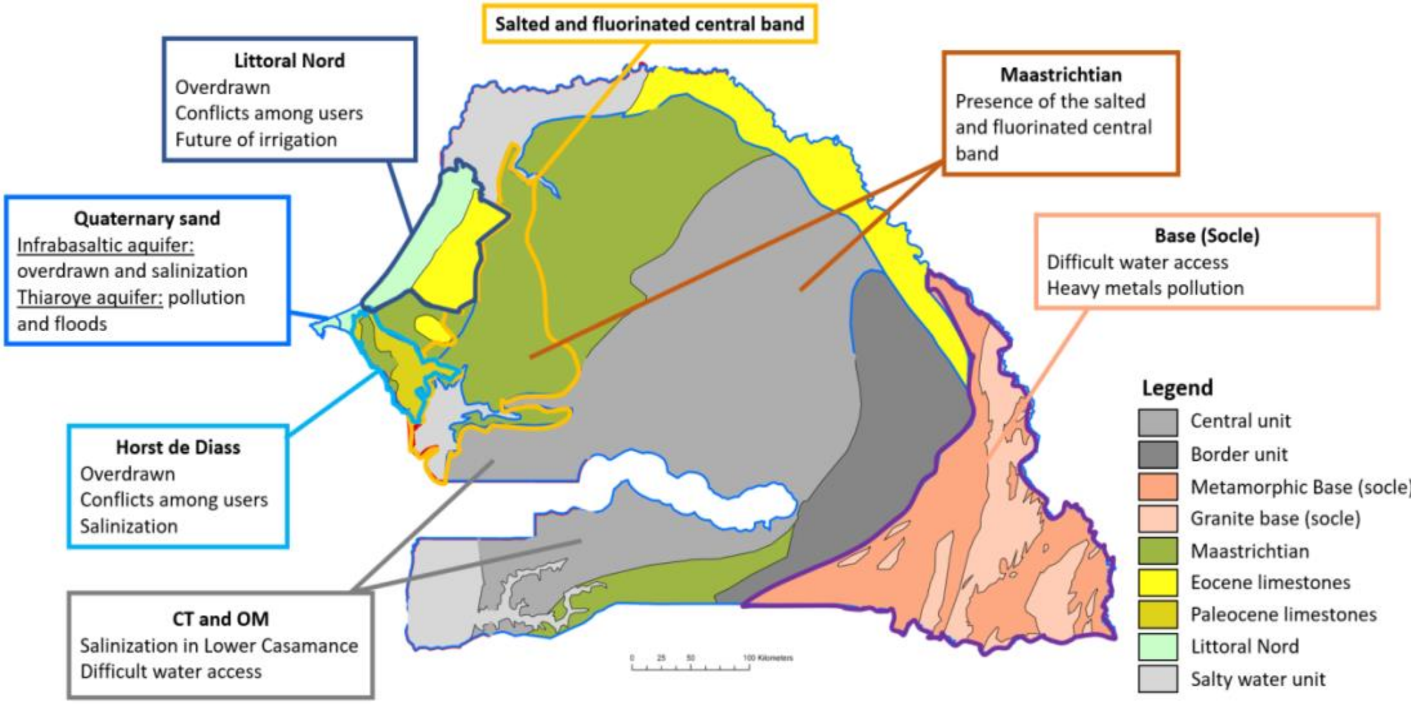
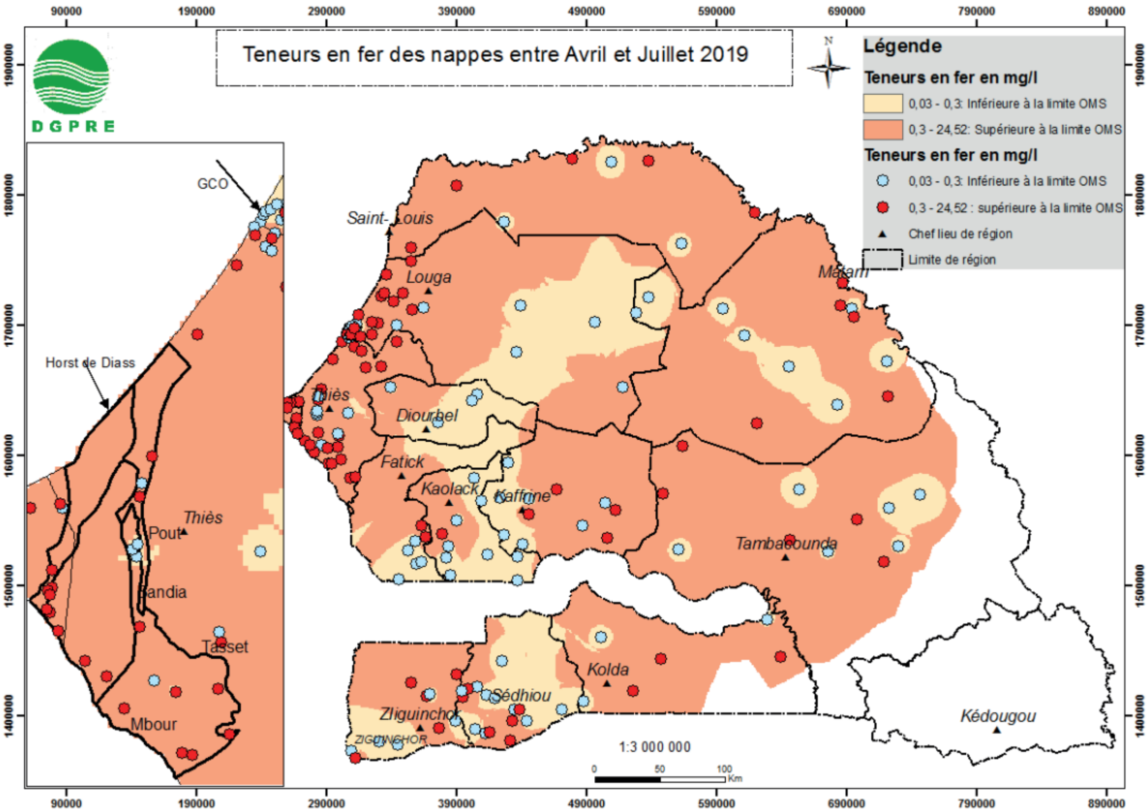


Figure 3. Overview of challenges relative to groundwater[50]

[50] Ibid

Figure 4. Iron content of underground water 2019.[51]



Climate change exacerbates the challenges of water management in Senegal. Droughts, rising sea levels, coastal erosion, and urban flooding threaten agricultural livelihoods and food security in Senegal. The impact of climate change delays the peak of precipitation consistently, heavy rainfall becomes more frequent, and prolonged breaks in rainfall are common in central and northern regions. These conditions, combined with degraded soils, limited market access, and salty land, affect farmers' ability to manage water throughout the year. Poor water management practices exacerbate the vulnerability of small-scale producers to crop loss and land degradation from climate change.

Effective management of water resources is vital for service delivery and risk mitigation. The national socio-economic development plan (Plan Senegal Emergent - PSE) aims to mobilize "abundant, good quality water for all, everywhere and for all uses, in a healthy sustainable living environment, for an emerging Senegal" by 2035. Reliance on surface water irrigation hinders the exploitation of the full agricultural potential of farmers and makes them more vulnerable to the adverse effects of climate change. Dependence on groundwater pumping infrastructure is also a challenge as it is generally either not fully available or very expensive due to high diesel costs. Thus, the modernization and diversification of farming systems require well-managed and supported irrigation systems to ensure water availability throughout the year. The accompanying Baseline Assessment provides further information of how the project aims to sustainable utilize water resources by strategically targeting actions, reducing waste and optimizing operations.

[51] CSE (2020). *Iron content of underground water from April to July 2019 (Rapport sur l'état de l'environnement au Senegal*

2.1.6. Sea level rise

Senegal has a strong maritime influence stemming from its 700 km of Atlantic coastline. The "sea level rise" estimated at 1.4 mm per year, constitutes a real threat for Senegal because of the impacts it causes: accelerated coastal erosion, loss of land and property, marine flooding, salinization of groundwater, and changes in the distribution and abundance of coastal and marine habitats and species[52]. However, the proposed project of Naatangue farms in Senegal may not be significantly affected by sea level rise directly due to their inland location. Despite this, the displacement of people from coastal areas due to sea level rise, coastal erosion and salinization can have indirect impacts on the target agricultural sector of this project. The influx of displaced people into inland areas can increase pressure on natural resources, such as water and land, and lead to competition for these resources among communities.

2.1.7. Coast erosion

Senegalese coasts are affected by erosion in the areas of the Langue de Barbary in Saint-Louis, in Cambérène, in Dakar, in the island of Gorée, Rufisque, Joal, the islands of the Delta Saloum and the islands of Basse-Casamance. The erosion phenomena in these areas are under the influence of human activities (extraction of sea sand, constructions, etc.) and factors natural (rise in sea level, swells, etc.). The damage caused by coastal erosion is the disappearance of beaches, the collapse of cliffs, the destruction of the infrastructures installed on the shore (quays, hotels, roads), travel of populations, the disappearance of the habitats of several floral and animal marine species, fragile ecosystems (mangroves), salinization land and aquifers[53].

2.2. Climatic Adaptation Options

In short, the various biophysical vulnerabilities identified in the previous section are worsened by changing climatic conditions. The vulnerabilities that Senegal faces are indicative of systems that cannot adapt to the challenges imposed by climate change. Rising temperatures and erratic rainfall patterns, along with natural disasters, will continue to exacerbate the existing, systemic issues driving the various social, economic, and biophysical vulnerabilities. The Senegalese agricultural sector will feel exacerbated vulnerabilities as climate change becomes more pronounced.

In response to these vulnerabilities, farmers, the Senegalese government, and international institutions have made efforts to help the agricultural sector adapt to climate change. For instance, it has become increasingly common for rice farmers to apply higher quantities of inputs, such as fertilizer and manure to combat higher salinization rates in the soil and water. However, the impact of these practices has been minimal, and financially unsustainable as they increase the operating costs of the farm and didn't lead to transformational change. [54]

Other, larger scale attempts to assist farmers adapt to climate change include the World Bank-funded West Africa Agricultural Productivity Program (WAAPP), which introduced 160 climate-

[52] Centre de Suivi Ecologique. (2020). RAPPORT SUR L'ETAT DE L'ENVIRONNEMENT AU SENEGAL. Ministere de l'Environnement.

[53] Ibid

[54] Thiam, S., Villamor, G. B., Kyei-Baffour, N., & Matty, F. (2019). Soil salinity assessment and coping strategies in the coastal agricultural landscape in Djilor district, Senegal. Land Use Policy, 88, 104191. https://doi.org/10.1016/j.landusepol.2019.104191

smart crop varieties, along with related technologies and training on how to optimize production using these varieties.[55] Climate-smart crop varieties have the advantage of being a tried and tested solution to tackling specific stressors, such as floods and droughts, without having to completely shift the production practices of farmers (more costly, systemic change). However, many regions in Senegal face a diversity of pressures to which resistant crops can only be partially effective. Even if a crop is both drought and flood-resistant, farmers will still need to address soil erosion and locust attacks by systemically changing their farming ecosystem and ensuring its input needs are adequate to a changing climate. Furthermore, there is still the issue of low widespread access to climate-resilient crop varieties and poor adoption of climate-smart agricultural practices, which leaves many farmers in vulnerable regions with a high degree of exposure and sensitivity to the impacts of climate change.

A modelling of projected yields in Senegalese agriculture reveals that piecemeal changes to farming practices will not be sufficient for farmers to adapt to climate change. Indeed, Table 4 reveals that regardless of whether inputs are increased or decreased, or whether crops are rainfed or irrigated, Senegalese farmers will experience losses as high as 100% by the 2080s.[56] For this reason, adaptation options in Senegalese agriculture should be screened for their ability to systematically address the impacts of climate change, rather than relying on individual interventions that maintain current practices. A systemic transformation towards climate-smart and socially equitable agriculture presents an opportunity to enhance productivity, build resilience, and improve livelihoods while contributing to sustainable development goals.

Table 4. Scenario Analysis of Small Interventions on Senegalese Agriculture (Projections)

	Baseline	**Future**			
Crop	**Baseline Yield (1961 - 1990)**	**Projected Yield**	**% Change**	**Period**	**Options**
Maize	8804	8637	-1.9	2020s	High Input, Rainfed
Maize	8804	7533	-14.44	2050s	High Input, Rainfed
Maize	8804	5372	-38.98	2080s	High Input, Rainfed
Maize	2307	0	-100	2080s	Low Input, Rainfed
Sorghum	7405	7515	1.49	2020s	High Input, Rainfed
Sorghum	7405	7251	-2.08	2050s	High Input, Rainfed
Sorghum	7405	5564	-24.86	2080s	High Input, Rainfed
Sorghum	1409	719	-48.97	2080s	Low Input, Rainfed
Pearl Millet	3471	3563	2.65	2020s	High Input, Rainfed
Pearl Millet	3471	3628	4.52	2050s	High Input, Rainfed
Pearl Millet	3471	2981	-14.12	2080s	High Input, Rainfed
Pearl Millet	1052	538	-48.76	2080s	Low Input, Rainfed
Best Cereal	8804	8637	-1.9	2020s	High Input, Irrigated
Best Cereal	8804	7781	-11.62	2050s	High Input, Irrigated
Best Cereal	8804	5959	-32.31	2080s	High Input, Irrigated

[55] World Bank. (2015). 'Times are Hard and Uncertain': Senegal Adopts Climate Smart Agriculture to Mitigate Effects of Climate Change [Text/HTML]. World Bank

[56] Climate Risk and Adaptation Country Profile: Vulnerability, Risk Reduction, and Adaptation to Climate Change - Senegal. (2011, May 4).

Best Cereal	2307	719	-68.83	2080s	Low Input, Rainfed

3. Climate vulnerabilities of project target regions

The whole country is subjected to climate change impacts and biophysical vulnerabilities, but each zone (north, center, south) has unique climate issues. Figure 5 details the different climate classifications of Senegal, with the Northern regions (Saint Louis, parts of Matam and Louga) belonging to the hot-desert climate classification, the Centre (Diourbel, Dakar, Matam, Kaffrine, Kaolack, Fatick) belonging to the hot-semi arid classification, and the South (Ziguinchor, Sedhiou, Kolda and Kédougou) belonging to the tropical Savannah classification. This diversity of climate areas results in unique climate-related challenges that mandate curated solutions that are appropriate to the challenges to each climatic zone.

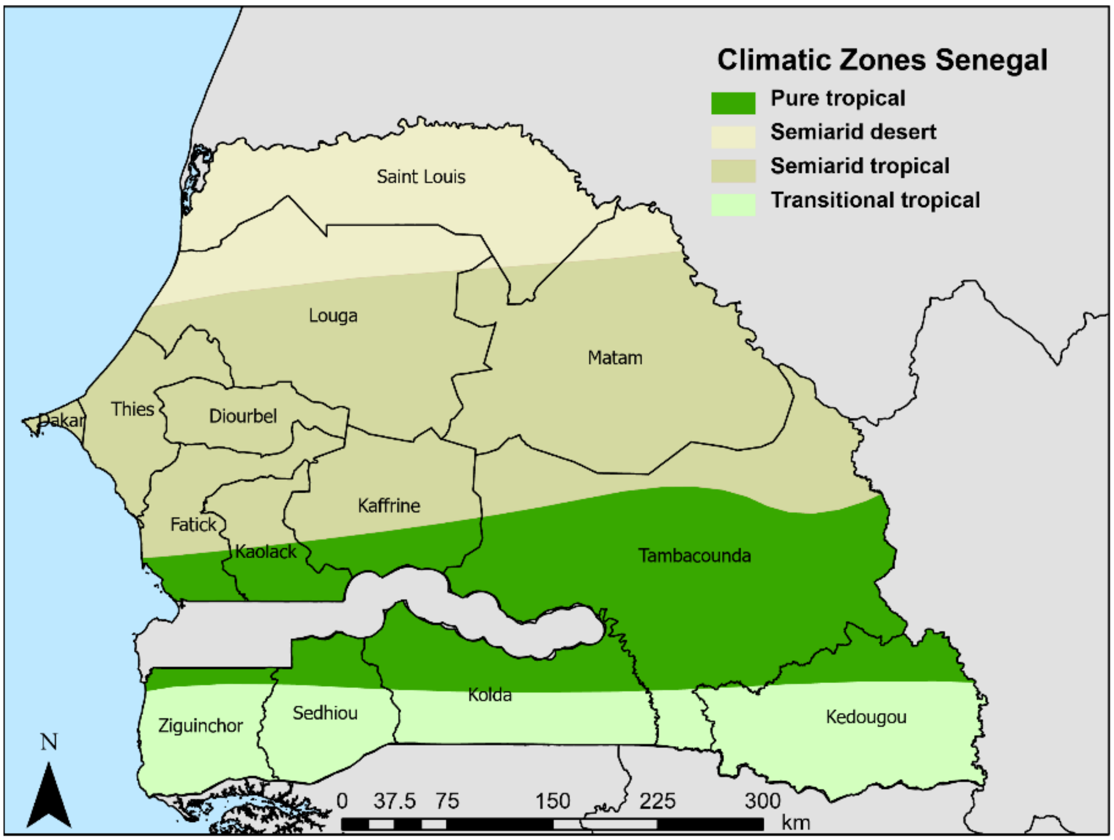


Figure 5. Climatic zones of Senegal[57]

The project is principally focused in areas with high agricultural potential and vulnerable to climate change as shown in Table 5, and include the regions of Thiès, Saint-Louis, Louga, Tambacounda, Kolda, Kaolack, Kaffrine and Ziguinchor. Detailed selection criteria for target municipalities are as follows:

1. Farm location in an area determined to be particularly exposed to climate change mainly drought and rainfall variability.

[57] Data was processed from the following data base using the ArcGIS Pro software: HUMDATA. (2017). Climatic zones in West Africa—Humanitarian Data Exchange.

2. Municipalities under ANIDA's coordination areas, taking into account territorial equity in terms of benefits sharing. For family farms, areas not yet covered by existing Naatangué farms.
3. Areas that have agricultural potential, determined by ANIDA.
4. Areas that have groundwater available, not exceeding depth of 50 meters for family farms.[58]

This section will provide an in-depth analysis of the climate pressures and vulnerabilities faced by the agricultural sector in each of the target regions. By examining the specific challenges faced by small-scale producers in each region, we will gain a better understanding of the unique impacts of climate change on agricultural production across Senegal. Through this analysis, together with the Baseline Assessment which explores socio-economic vulnerabilities of the regions, we demonstrate the need for intervention and explore strategies for enhancing the resilience of the agricultural sector in each region.

Table 5. Areas in Senegal particularly threatened by natural hazards[59]

Natural hazards	Geographical Risk Location	Real or potential Impacts of Risks
Drought	- The Niayes area between Dakar and St Louis - The Sahelian zone of the Ferlo - The Lake of Guiers - Groundnut Basin center	- Decrease in the level of groundwater; - Decrease in the flow of rivers - Early drying ponds, backwaters, rivers, and other valleys - Loss of biodiversity
Marine Intrusion	- River delta Senegal - Coastal area and Niayes - Lower valleys of Sine Saloum - Lower valley of the Casamance	- Land salinization - Water contamination surface and groundwater underground (salt, fluoride, etc.) - Regression of the mangrove
Coastal Erosion	Littoral zone of the country: - The Great Coast - The Dakar region - The Little Coast - The coast of Lower Casamance (Ziguinchor region)	- Elevation and advance of the sea level - Receding the coastline - Intrusion of the salt wedge - Openings of breaches coastal - Floods - Destruction of homes, hotel receptions
Floods	Regions of Saint Louis, Dakar,	- Destruction of crops

[58] For village farms, the boreholes already exist therefore, no authorization is required as ANIDA already has them. In addition, there will be no further expansion nor withdrawal of groundwater vis-à-vis the current practice.

[59] Ministère de la Gouvernance territoriale (2018). PLAN NATIONAL D'AMENAGEMENT ET DE DEVELOPPEMENT TERRITORIAL (PNADT) Horizon 2035

	Matam, Kaffrine, Kaolack, Fatick	- Human damage (the homeless; number of victims; waterborne diseases) - Economic damage (high financial cost, damaged infrastructure, cessation of activities) - Environmental damage (Discharges, unsanitary conditions)

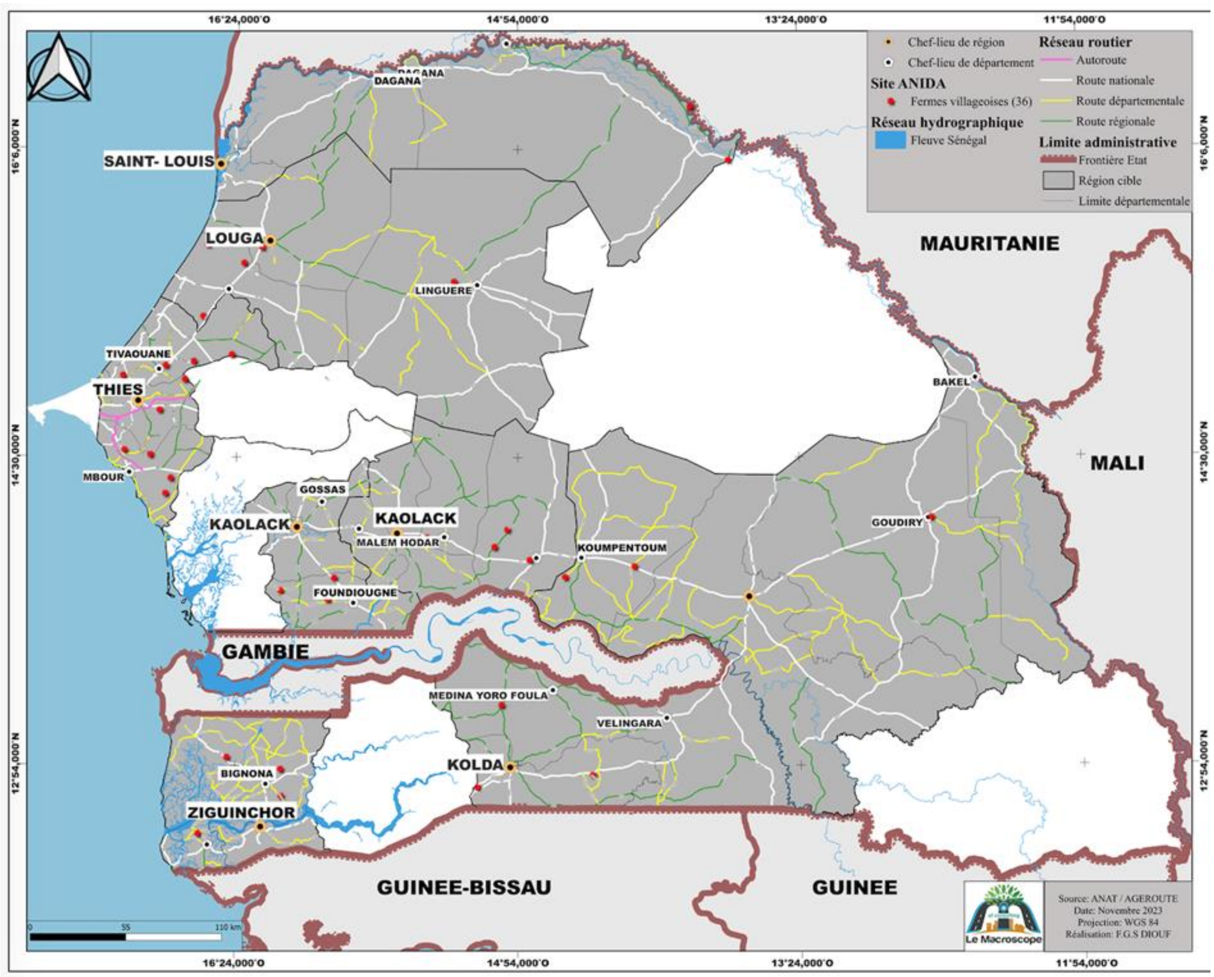


Figure : Location map of Natangué project sites

[Map of project target areas]

3.1. Thiès

Thiès is in the western part of Senegal, bordering the Atlantic coastline. The region's economy is highly diverse, with agriculture, fishing, and tourism as the main employment sectors of the region. The region is highly vulnerable to poverty, with a poverty rate of about 39%, which is higher than the national average (32.7%).[60] Thiès' population is estimated to be around 2 million, making it

[60] World Bank. (2023). Poverty and Equity Database | Data Catalog.

one of the most populous regions in Senegal. The region is home to a developing educational sector, as well as to a host of different universities and professional training centers.

Thiès, as with the rest of Senegal, has experienced considerable climate variability in terms of its average temperature change and precipitation levels throughout the year and in the wet and dry seasons. Indeed, between the 1980s and 1990s, average, yearly temperatures rose by 0.37 C, while the average temperatures rose between the 1980s and 2010s by 0.69 C, which is nearly double the temperature change. Likewise, changes in precipitation have drastically increased within a short timespan. Average precipitation changes between the 1980s and 1990s were very marginal, with the historical analysis indicating a 0.02 mm average change between the two decades. However, these changes increased significantly between the 1980s and 2000s, with an average of 6.67 mm in increased precipitation between the 1980s precipitation levels and 2000s precipitation levels. These trends further rose when comparing precipitation changes in the 1980s and 2010s, where average precipitation increased by 8.33 mm in the region.

However, these yearly changes do not reveal the stressors that Senegalese farmers face during the wet and dry seasons. Indeed, the historical analysis reveals that wet season, average precipitation rose drastically from 4.71 mm in increase precipitation in the 1990s relative to the 1980s, to 44.42 mm in average precipitation increase in the 2000s relative to the 1980s, and by 34.61 mm in average precipitation in the 2010s relative to the 1980s. The dry season results indicate that precipitation averages have continuously fell from marginally positive values in the 1990s relative to the 1980s, to negative values in the 2010s relative to the 1980s (-0.05 mm).

These results confirm country-wide trends that wet seasons are becoming wetter, while dry seasons are becoming drier, which increases the risk of both floods in the wet seasons and droughts in the dry season. In 2020, a major[61] flood occurred in Thies, during which 126.9 mm of rain fell on the region in just 24 hours, which significantly higher than the region's upper limit for "intensive rain" events (75 mm in 24 hours). In this singular, climatic event, 8,411 people were impacted, of which 211 were displaced, and 69.7% of homes run by women were damaged (higher than the country average of 53%).

3.2 Saint-Louis

Saint-Louis is located in the northwest of Senegal and borders the country's neighboring country, Mauritiania. Just as in Thies, the population of Saint-Louis depends on agriculture and fishing as the main sources of employment. Tourism is becoming an increasingly growing sector, with the region's capital city, Saint-Louis, experiencing considerable development to facilitate the region's growing, tourism infrastructure. The population, which is mostly rural, is estimated to be just over 900,000.[62] The region's proximity to the Senegal River allows the farmers in the region to irrigate their crops more easily than those reliant on groundwater resources. This irrigated-agriculture is key in the region's agricultural production, which mainly includes: rice, maize, millet and sorghum.[63]

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[61] Diene, P. I. (2022). Quelles leçons tirer des inondations de 2020 pour améliorer les Systèmes d'Alertes Précoces au Sénégal. Portail sur la résilience aux inondations.

[62] UNESCO World Heritage. (2022). Island of Saint-Louis. UNESCO World Heritage Centre.

[63] FAO. (2023a). FAO au Sénégal. https://www.fao.org/senegal/fr/

The historical and projection analysis reveal that average, monthly precipitation during the dry season has marginally declined between the 1980s and the 2010s (-0.03 mm), while average temperatures have substantially increased by 0.64 degrees during the same period. Projection data reveals that average temperatures in Saint-Louis are expected to further increase from 29.18 C to 30.36 C in 2021-2040, and further increase to 31.16C in 2041-2060, representing a 2 C increase in only 40 years. These tendencies are confirmed by Senegal's 2022, regional analysis report on climate tendencies, which found that losses in precipitation in Saint Louis are explained by more extended dry seasons. This will have considerable impacts on current agricultural practices, should they remain unchanged.

Flooding has also become more prevalent, especially during the wet season, which has seen more rain over time, as confirmed by the historical analysis. The increase in rain combined with the shortening of the wet season also makes it much more likely for flooding to occur.[64] Saint-Louis' proximity to the Senegal River, which often overflows, is one of the major sources of flooding; irrigated crops along this river are most highly prone to losses.[65] Rising sea levels also contribute to flooding, and lead to salt-water intrusion into freshwater surface water, another key limiting factor in agricultural production. With the salinization of surface water, farmers have had to turn to more costly water sources. Indeed, some farmers had had to resort to buying irrigated water from other farmers (which can cost 0.1 USD/m3), thereby driving up their production costs.[66]

It is also worth noting that irrigated and rainfed crops face different challenges in Saint-Louis. Irrigated crops face a higher risk of flooding due to their proximity to water bodies that overflow following heavy rains, as well as the drying of climate-sensitive crops, such as tomatoes, cauliflower and corn.[67] Rainfed agriculture suffers more from salinization due to longer dry periods and more frequent droughts favoring the uptake of salt in plants.[68] In response to these challenges, which are mainly driven by an inadequate supply of water, farmers have turned to increasing the supply of water to combat the erosion of the soil and ensure the uptake of water by plant roots.[69]

3.3. Louga

Bordering both Saint-Louis and Thiès in the northwestern part of the country, Louga ranks as one of the major agricultural producers of the country. Not only does agriculture employ the majority of people in the region, but also the region is one of the largest producers of crops (millet, sorghum, and rice) and livestock (cattle and sheep). The region's population is about 1.1 million, with most of the population living in rural areas. Louga suffers from a very high rate of unemployment (43.4% in 2018), despite being a key agricultural area of the country.[70]

Louga faces a diversity of challenges as it hosts both a semiarid desert and a semiarid tropical area, requiring a diversity of interventions that are appropriate to the specific areas within the region to

[64] https://www.climatelinks.org/sites/default/files/asset/document/senegal_adaptation_fact_sheet_jan2012.pdf
[65] Rapport d'analyse de la vulnérabilité approfondie aux changements climatiques de la région de Saint-Louis
[66] Bracco, S., Noubondieu, S., & Flammini, A. (2018). Costs and benefits of solar irrigation systems in Senegal. https://doi.org/10.13140/RG.2.2.21230.87364
[67] Rapport d'analyse de la vulnérabilité approfondie aux changements climatiques de la région de Saint-Louis
[68] Ibid
[69] Ibid
[70] Agence Nationale de la Statistique et de la Demographie. (2021). Enquête harmonisée sur les Conditions de Vie des Ménages (EHCVM) au Sénégal. Ministere de l'Environnement.

respond to different climatic pressures it faces. According to the historical analysis, average yearly temperature increases were 0.32 C in the 1990s relative to the 1980s. These temperatures further increased to 0.66 in the 2010s relative to the 1980s. Average, yearly precipitation changes have been particularly erratic between the 1980s and 2010s in Louga; the historical analysis reveals that there was an average loss of –0.44 mm of rain in the 1990s relative to the 1980s. In the 2000s and 2010s, however, there was an increase in average precipitation of 5.61 mm and 6.07, respectively, relative to average precipitation levels in the 1980s. Likewise, dramatic increases in average precipitation were recorded throughout the study period during the wet season; increases in average precipitation in the 1990s relative to average levels in the 1980s were marginal (1.36 mm). However, in the 2000s and 2010s, there were much higher increases in precipitation in the wet season, relative to the 1980s, with the region registering average increases of 36.27 mm and 28.21 mm, in the respective decades. The dry season has also become drier throughout the study period, with a marginal increase in average precipitation in the 1990s relative to the 1980s, and a loss of 0.03 mm in average precipitation in the 2010s, relative to the 1980s. This loss is higher than the average loss of rain in the dry season at the national level (-0.02 mm).

The latter trend is a significant contributor to the region's primary climate risk: droughts. Soil degradation continues to increase with the prevalence and duration of droughts, and is worsened by deforestation and windstorms, which are two climate phenomena that are particularly prevalent in Louga.[71] These climatic trends are particularly threatening to farmers in Louga, which hosts the majority of the country's groundnut production, which are among the most valued cash crops in Senegal.[72] Louga's Sahelian climate is becoming drier as the region experiences longer spells of drought events. As a result of a lack of rain and rising temperatures, the main vulnerabilities in the region are drought, locust infestation, soil erosion and desertification of agricultural areas.[73]

3.4 Tambacounda

Tambacounda, located in the south-east of Senegal, is the largest region, in terms of land area. The region's population is small relative to its size (640,000), with the majority of the population living in rural areas.[74] Farmers in Tambacounda produce the country's main cash crops: groundnuts. Despite being a major cash crop producer, the region suffers from a poverty rate of 61.4%.[75]

Tambacounda's climate, similar to Louga, is highly diverse; the region hosts three of the country's four climatic zones: transitional tropical, pure tropical and semiarid tropical. Average, yearly temperature increases in Tambacounda rose from 0.32 C in the 1990s, relative to the 1980s, to 0.70 C in the 2010s, relative to the 1980s, representing an average temperature increase that has nearly doubled in just 30 years. Yearly average precipitation increases were not uniform across areas of the region, with the north-western areas registering lower precipitation increases than in the south-eastern areas throughout the study period; overall, yearly average precipitation has steadily increased, relative to average precipitation values in the 1980s, from 4.63 mm in the 1990s,

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[71] Daraint. (2015). RRI Senegal.

[72] Ibid

[73] Ibid

[74] City Population. (2013b). Tambacounda (Region, Senegal)—Population Statistics, Charts, Map and Location.

[75] Agence Nationale de la Statistique et de la Démographie. (2023). Le Senegal en Bref. Agence Nationale de la Statistique et de la Démographie (ANSD) du Sénégal.

to 8.18 mm in the 2000s, and then to 10.99 mm in the 2010s; all of these values are higher than the average precipitation increases across the country. The dry season and wet season trends are similar to those in other regions; average wet season precipitation increases have continuously risen, relative to precipitation levels in the 1980s, from 12.84 mm in the 1990s, to 35.74 mm in the 2000s, and then to 40.78 mm in the 2010s. Dry season values have steadily decreases from increases of 0.04 mm in the 1990s, relative to 1980, to 0.01 mm in the 2000s and 2010s.

In rain-fed agriculture, dry spells occurring during the crop cycle or intra-seasonal episodes of "rain-free days" are detrimental events for the agricultural system. A high frequency of these pauses during the crop season (in vegetative and reproductive phases) also causes a decrease in agricultural yields. As for the rainfall deficit, it does not allow certain plant species such as peanuts to complete their development cycle, which often leads to poor seed filling and a considerable drop in yields. This situation was observed in 2016 in the municipalities of Koulor and Koussanar. In the dry season, the increase in temperatures combined with strong and hot winds tend to increase evapotranspiration in market gardening areas and increase the water needs of plants. Consequently, when these needs are not met, there is often a considerable decrease in yields (as was the case in Koulor in 2015) or crop losses. The consequences common to all the hazards identified in the target municipalities of the Tambacounda region are: a decrease in vegetable production (particularly forage production and agricultural yields) and a decrease in animal production (milk, meat, eggs, etc.).

3.5 Kolda

Kolda is located in the south of the country, between The Gambia and Guinea Bissau, and has a population of about 650,000[76]. It benefits from the Casamance River, allowing for irrigation agriculture, though most farmers depend on rain-fed techniques. Agricultural production in the region mainly concerns cash crops, such as peanuts, cotton and sesame. Production of cash crops has sharply declined in the region as a result of erratic climate conditions, resulting in a decline of 60% in peanut production in 2012.[77]

Average temperature increases across all decades in the study period of the historical analysis (1980-2019) indicate that Kolda has consistently experienced sharp increases in temperature. Temperature differences between the 1980s and 1990s indicate an increase of 0.40 C, higher than the national average increase in temperature (0.36) for the same period. Likewise, in the 2000s and 2010s, average temperature increases rose to 0.62 C and 0.73 C, respectively, relative to average temperature levels registered in the 1980s. Kolda’s average, yearly precipitation changes have also consistently increased, relative to average precipitation levels in the 1980s, from 3.81 mm in the 1990s to 7.52 mm in the 2000s, and then to 11.49 mm in the 2010s.

Kolda is the region in Senegal that has experienced the highest and most abrupt changes in precipitation during the wet season; average precipitation changes between the 1980s and 1990s were 20.57 mm (national average: 7.29mm), rising then to 51.95 mm in the 2000s (national average: 42.23 mm), and then to 50.78 in the 2010s (national average: 38.30 mm). Meanwhile, the dry season has seen consistently less rain, with changes between the 1990s, relative to the 1980s, reaching 0.16 mm (national average: 0.04), whereas these positive changes fell to 0.01 and 0.03 in the 2000s and 2010s, respectively, relative to the 1980s. The main climate challenges related to

[76] City Population. (2013a). Kolda (Region, Senegal)—Population Statistics, Charts, Map and Location.

[77] McCabe, C. (2012). In Kolda, Senegal, farmers are struggling to feed their families.

agriculture in the Kolda area are: the decrease in soil fertility, the decrease and variability of rainfall, the increase in temperature, crop infestations, late start of the season, and flash floods. These constraints have significant consequences on the value chains of rice and maize, particularly a significant decrease in yields accross production areas.

3.6 Kaolack

Kaolack is located in the west of the country, just north of The Gambia. The region benefits from the Saloum River, an important river system in which the region's capital, Kaolack, has a port. The main economic activities in the region are in peanut production and processing.[78] The region is also one of the main livestock producing regions of the country.[79]

Kaolack experienced some of the highest, consistent change in average yearly temperature throughout the country across the entire study period. Average temperatures rose by 0.41 C in the 1990s relative to the 1980s, and then further increased by 0.62 C and 0.74 C in the 2000s and 2010s, respectively, relative to the average temperature in the 1980s. All of these values were significantly higher than the national average temperature increases in each of the study period decades, relative to 1980 averages.

The change in average, yearly precipitation has been more erratic than in other regions; average change in the 1990s, relative to the 1980s, was negative (–0.2 mm), whereas the change in precipitation, relative to the 1980s, in the 2000s and 2010s was positive (5.67 mm and 7.86 mm, respectively). The wet season in Kaolack has seen considerably more average rain throughout the course of the study period; changes in the 1990s, relative to the 1980s, were moderate, but still positive (0.06 mm), whereas changes in the 2000s and 2010s were significantly higher (38.85 and 33.61 mm, respectively). The dry season has not seen much variation in the change in average precipitation across each decade, increasing from 0.00 mm in the 1990s, relative to the 1980s, to 0.05 and 0.04 in the 2000s and 2010s, respectively, relative to average precipitation levels in the 1980s.

3.7 Kaffrine

Located between Kaolack and Tambacounda, Kaffrine is one of the most vulnerable regions in the country, as it has a short rainy season (July and September) and long dry season. The region has suffered from a series of droughts and storms, which has negatively affected farmers' ability to cope with various climate challenges in maintaining their agricultural fields. Agriculture is the most important economic activity in the region, employing at least 80% of the population, and accounts for a majority of the region's GDP.[80]

Kaffrine hosts both a pure tropical and semiarid tropic climate. Similar to its neighboring regions (Kaolack and Kolda), Kaffrine has experienced amongst the highest changes in temperature increases during the study period. Indeed, the region saw an average increase in temperature of 0.4 C in the 1990s, relative to average temperature levels in the 1980s, and again increase in the 2000s and 2010s by 0.62 and 0.71, respectively, relative to average temperature levels in the 1980s. Average, yearly precipitation in Kaffrine has also been erratic. Average precipitation in the 1990s fell by 0.48 mm, while average precipitation values rose by 4.47 mm and 6.46 mm in the 2000s

[78] Senegal. (2015). Kaolack Region—SENEGEL - Senegalese Next Generation of Leaders.

[79] Climate Chance. (2022). AVS-Green Agriculture Senegal.

[80] World Bank. (2019). Senegal | Data.

and 2010s, respectively, relative to the 1980s. Likewise, wet-season precipitation changes were erratic; on average, precipitation fell by 3.05 mm in the 1990s, relative to the 1980s, whereas these values significantly rose to 30.73 and 27.71 in the 2000s and the 2010s, respectively, relative to average, wet season precipitation values in the 1980s. Kaffrine's dry season has seen consistent, though marginal, decreases in average precipitation change, relative to average precipitation in the 1980s; indeed, the region saw a loss of 0.06 mm in the 1990s, followed by a loss of 0.03 mm in the 2000s, and a loss of 0.02 mm in the 2010s. These trends confirm a dryer, dry season, and a wetter, wet season, which poses a significant threat to farmers who will struggle to plan for both droughts and floods in a single, growing season.

Extreme events combined with changes in temperature and precipitation have a significant influence on agriculture as a result of: i) heat and water stress that leads to yield losses in both plants and animals; ii) ecosystem disruptions that can affect production through the development of pathogens, proliferation of invasive species, etc.; and iii) direct (increased temperatures, floods and droughts) and indirect (reduced availability of water and fodder, spread of infectious diseases) impacts on animal health and welfare.[81] Indeed, according to a survey on the perception of climate change in Kaffrine, the main perceived threats in the region are: drought/high heat resulting in food insufficiency and lower productivity, an upsurge in diseases, a gradual disappearance of forests and biodiversity, a shortening and shifting of the rainy season, more irregular and intense rainfall, and a drop in the water table.[82] Other challenges, such as strong winds, are also noted, leading to the spread of fires, the spread of diseases, and the increase in the diseases, increased wind erosion, displacement of topsoil causing impoverishment. Floods in Kaffrine have been largely responsible for causing losses of arable land, water erosion, development and spread of diseases and swelling of valleys.[83]

3.8. Ziguinchor

Ziguinchor is located in the southwestern part of the country, bordering Guinea-Bissau. The region benefits from its Atlantic coastline, as well as its access to the Casamance River. The Casamance River is an important source of water for irrigation; however farmers in the region are still very reliant on rainfed, agricultural techniques.[84] Indeed, the correlations between rainfall and grain production are among the highest in the country (R=0.56).[85] Despite such an important reliance on agriculture, the region suffers from some of the lowest rates of diet diversity and food insecurity.[86] Ziguinchor is a tropical region, hosting a transitional and pure tropical climate, with access to the Senegalese coastline, and an important river system, the Casamance river, on which the region's farmers are highly dependent for their irrigation. The historical analysis reveals that Ziguinchor is also the region that experienced the greatest amount of change in terms of temperature increase across the entire country. Indeed, the change in average temperature in the 1990, relative to 1980,

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[81] Ouédraogo, M., Fall, M., & Chabi, A. (2020). Activity report: Monitoring Outcome of Climate-Smart Agriculture in Kaffrine ClimateSmart Village, Senegal [Report].

[82] Ibid

[83] Ibid

[84] Senegalese National Agency for Civil Aviation and Meteorology, World Food Programme, & IRI. (2013). Climate risk and food security in Senegal: Analysis of climate impacts on food security and livelihoods.

[85] Ibid

[86] Ibid

was 0.43 C (national average: 0.36 C), followed by 0.67 C in the 2000s (national average: 0.61 C), and 0.75 C in the 2010s (national average: 0.70 C), all relative to the 1980s. Likewise, the region saw the highest increases in precipitation change; the 1990s saw a rise in precipitation of 7.64 mm (national average: 2.11), relative to the 1980s, while the 2000s and 2010s, respectively, saw a 15.22 mm (national average: 7.49 mm) and 19.25 mm change, relative to the 1980s. The wet season in Ziguinchor was also among the highest increases in the change in average precipitation; the region saw an increase of 14.73 mm in the 1990s, relative to the 1980s, followed by a substantial increase of 69.33 mm and 64.41 mm in the 2000s and 2010s, respectively, relative to the 1980s. The dry season, however, has seen a loss in the average precipitation across the study period; the change in average precipitation values initially increased by 0.13 mm in the 1990s, relative to the 1980s, while the 2000s and 2010s both saw a decline in average precipitation of 0.01 mm, relative to the 1980s.

The climatic data in Section 1 suggests that traditional farming systems in Lower Casamance has changed, or is undergoing profound change, because of the new rainfall regime demonstrated in the historical analysis. Participatory research conducted by ANIDA, the executing entity of this project identified five major climatic risks noted in the zone: i) rainfall deficit, ii) flooding, iii) rising temperatures, vi) proliferation of crop pests, and v) strong winds. In addition, further non-climatic risks have been identified to be salinization, acidification and silting of valleys and deforestation throughout the region. These different risks affect the northern part of the region and all the valleys more than any other, resulting in a reduction in cultivable areas due to soil degradation and, consequently, a decrease in agricultural yields.

In short, this climate rationale has provided a comprehensive review of the ways, and extent, to which climate change is heavily threatening Senegal’s agricultural sector. The analysis clearly demonstrates the regions that need to most attention to mitigate and adapt to the impacts of climate change; they will be able to better address their diverging threats to the sector through a tailored approach that the Naatangue farm model will provide.

SECTION II: BASELINE ASSESSMENT

The Baseline Assessment builds upon the Climate Rationale and provides a comprehensive overview of the current situation in the project area and includes a deeper focus on non-climate vulnerabilities. The Baseline includes a review of the social, economic, and environmental conditions, as well as an assessment of the existing agricultural practices, and how different project activities will help address them.

Together, the Climate Rationale and BA provide the evidential basis for the Upscaling Naatangué farms GCF SAP project to address climate change challenges and promote sustainable agriculture practices in the project area.

1. Introduction

The Baseline Assessment (BA), together with the Climate Rationale provides the evidential justification for proceeding with “Upscaling "Naatangué". It serves as the foundation for measuring the impact and effectiveness of the proposed project interventions.

With respect to each project location the BA will:

- Identify and describe the core problem that the project seeks to address;
- Identify key climate and non-climate, barriers/drivers;
- Propose options that will have greatest likelihood of success given the financial, environmental, social limitations of the region;
- Assess baseline situation in the project areas, such as existing agricultural cooperatives status.
- Comparison between baseline use of agricultural inputs and practices vs. with-the-project use of inputs and practices, to clearly show the differences between the baseline and project scenario.

An accurate BA will facilitate effective monitoring and evaluation of activities, their impact, and the effectiveness of GCF funding support. This will allow for a clear demonstration of the additionality of GCF funding and the project's contribution towards achieving transformative change.

The project “Upscaling "Naatangué" integrated family and village farms for a resilient agriculture” aims to increase the resilience of Senegal’s agricultural sector, particularly small-scale producers, to impacts of climate change. The project is principally focused in 8 areas with high agricultural potential and facing large impacts from climate change and climate hazards, as identified in the Climate Rationale document. The regions include: Thiès, Saint-Louis, Louga, Tambacounda, Kolda, Kaolack, Kaffrine and Ziguinchor.

In addition to the evidence presented under Climate Rationale for the selection of the sites, project implementation partners have leveraged knowledge and experience from previously donor funded projects (see Table 7). These projects have successfully tested and implemented the "Naatangué" farm model in the target regions, providing a solid foundation for scaling up this climate smart integrated farming system with the support of concessional finance from the GCF.

The project is structured around three interconnected components that aim to:

1. To promote sustainable agriculture and improve food security through the establishment of resilient village and family farms.
2. To diversify and improve production and income for farmers by integrating resilient agroforestry practices into existing Naatangué farms.
3. To empower farmer entrepreneurship through market integration and acceleration of new agricultural markets, leading to increased economic opportunities and improved livelihoods for farmers.

By climate-proofing, diversifying, and modernizing agricultural systems, the project will deliver both mitigation and adaptation benefits to the target regions and beneficiaries.

2. Overview of the agriculture sector in Senegal and baseline context for the proposed project

2.1 National Context

2.1.1 Greenhouse Gas Emissions

According to the 2020 Nationally Determined Contribution of Senegal, the country's total GHG emissions in 2010, the reference year of the latest national communication, were estimated at 16752000 metric tons CO2eq ($MTCO_2$), of which agriculture represented 43.8% (7354000 $MTCO_2$) of emissions (see Table 6). The emissions in the agriculture sector are projected to increase to increase steadily from 9903400 $MTCO_2$ in 2025 to 10 600 000 $MTCO_2$ in 2030[87]. Senegal has set ambitious greenhouse gas (GHG) emissions reduction targets in its Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change. The country aims to reduce its GHG emissions by 5% (unconditionally) to 23.7% (conditionally) by 2025 and 7% (unconditionally) to 29.5% (conditionally) by 2030 compared to baseline projections. The conditional targets are dependent on international support and finance, which would enable the country to implement more ambitious measures to reduce emissions.

According to Climate Watch, Senegal emitted 33.6 million tonnes of CO2 equivalent representing 0.07% of global emissions. Over this last decade, agriculture continued to be the primary sector contributing to GHG emissions in Senegal (See Figure 6), and it remains a key sector for Senegal's economy, with a significant contribution to employment and GDP, as will be explored later on.

Table 6. Breakdown of greenhouse gas (GHG) emissions by sector in the base year in Senegal.

Sector	Co2 Emissions levels in Gg	Percentage
Energy	6165	36,8
Agriculture	7354	43,8
Waste	1820,8	10,8
Industrial Processes and Product Use	1412	8
Total	**16 752**	**100**

[87] Republic of Senegal. (2020). “Nationally Determined Contribution of Senegal”

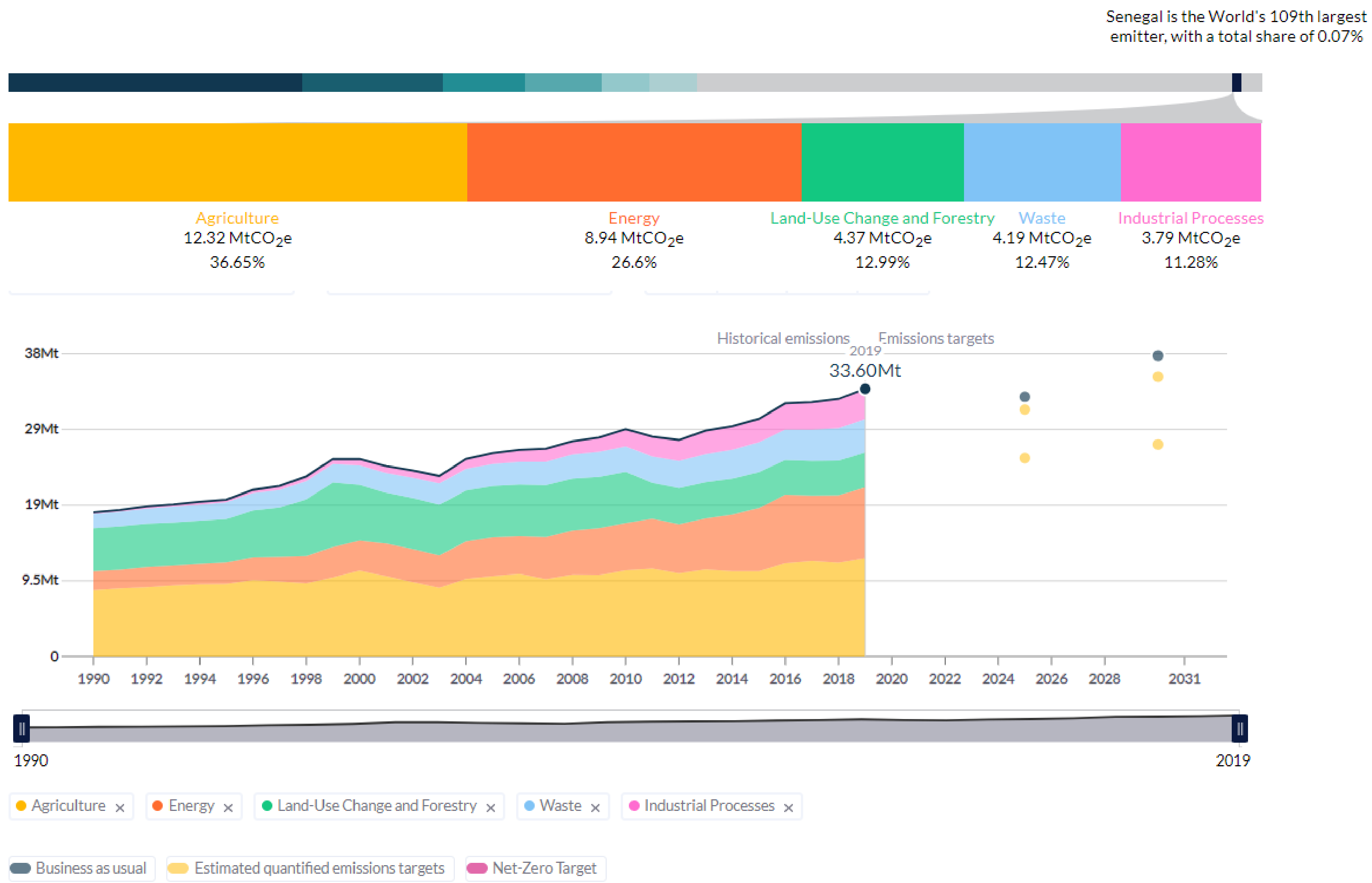

Figure 6. Senegal's greenhouse gas emissions and emissions targets[88]

[88]CLIMATEWATCH (2019). Senegal Climate Change Data | Emissions and Policies.

2.1.2 Contribution to GDP

According to Agency for the Promotion of Investments and Major Works (APIX-SA[89]), the Senegalese agricultural sector employs more than 60% of the active population, and accounts for around 17% of the country's gross domestic product (GDP)[90]. Although the sector provides livelihoods and incomes for a large section of the population, its contribution to economic growth is declining. Since 1980; the share of GDP expansion derived from agriculture fell from 10% between 1997 and 2001, to just over 7% between 2007 and 2011. This declining trend has also been seen as compared to the overall performance of the Senegalese economy. For example, the overall economy in 2021 grew by 6.1% but the growth of the agriculture sector was 4.6% in the same year. These indicators suggest that the Senegalese agricultural sector is experiencing a decline in terms of its productive capacity to the national economy.

2.1.3 Contribution to food security

These tendencies may also be driving Senegal's increasing reliance on foreign food imports. Senegal currently relies on imports to meet approximately 70% of its food needs.[91] Rice is the primary staple crop and yet imports accounted for 65% of rice consumed annually a decade ago.[92] The annual production output of rice production was estimated at 1,346,000 tons in 2021.[93] Senegal is the third largest importer of rice in Africa, behind Nigeria and Côte d'Ivoire. Since 2014, the quantities imported have been stable between 960,000 and 997,000 t per year. In 2022, the State of Senegal decided to subsidize local rice up to 3.2 billion FCfa as a way to increase national production.[94] Figure 7 below shows that in 2019 the value of imported foods for the main staple crops is almost 7 times higher than Senegal's export value of staple crops.

The impacts of climate change on the sector, as detailed in the Climate Rationale report, will likely continue to deepen the dependency on imports, which increases the vulnerability of the population to external shocks. For example, Senegal's heavy reliance on food imports has stressed household incomes in recent years due to agricultural commodity price shocks, such as at the advent of the COVID-19 pandemic, which saw inflation in food prices rise to ~115%. A decade of sluggish sales of groundnut products and a deepening crisis in the fisheries sector have also reduced the contributions of the traditional agricultural export sector to Senegal's GDP.

Despite these challenges, horticulture has ranked as the greatest hope for the future of Senegalese agriculture since the early 1990s, as a recent surge in foreign direct investment in the export-oriented horticultural sector shows[95].

[89] FAO. (2016). FAOSTAT Senegal.

[90] World Bank Open Data. (2016). World Development Indicators. World Bank Open Data.

[91] International Trade Administration (2023). Senegal—Agricultural Sector.

[92] Colen, L., M. Demont, and J. Swinnen (2013). Smallholder participation in value chains: The case of domestic rice in Senegal, In: Rebuilding West Africa's Food Potential, A. Elbehri (ed.), FAO/IFAD.

[93] Agrisen. (2021). Evolution de la production et des importations de riz au Sénégal. Agrisenegal.

[94] Diouf, P. O. (2022). Sénégal: Subvention annoncée du riz paddy - Optimisme chez les acteurs de la chaine de valeur locale. Le Soleil.

[95] Matsumoto-Izadifar, Y. (2023). Senegal – Challenges of Diversification and Food Security.

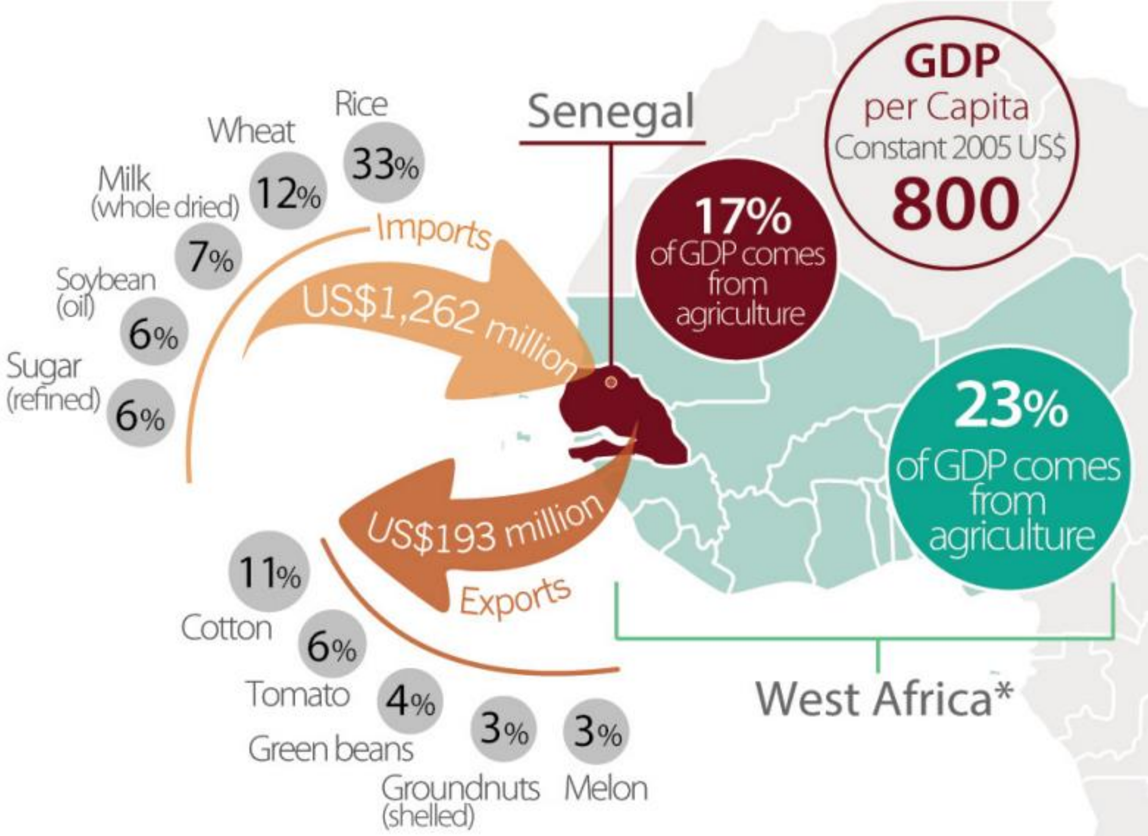

Figure 7. Economic Relevance of Agriculture in Senegal[96]

2.1.4 Land area under cultivation and major crops[97]

Agricultural activities in Senegal covers approximately 46% of the country. Figure 8 below shows the land use of the country. Agriculture is a crucial sector for Senegal's economy, with around 46% of the country's total land area dedicated to agricultural activities[98]. However, despite this large share of land, the area under production has remained relatively stable at approximately 2.5 million hectares, which is just 13% of the country's surface area[99]. Furthermore, the combination of a growing population and land intensification has led to overexploitation of natural resources and land degradation, negatively impacting agricultural productivity and ecosystem services. This degradation is particularly concerning in the context of the country's forests, which are declining at a rate of around 45,000 hectares per year, posing a threat to biodiversity and exacerbating climate change by reducing carbon sequestration[100].

[96] Feed the Future (2019). *Climate-Smart Agriculture in Senegal.* WorldBank

[97] The Climate Rationale section includes references to Senegal's current land use and status on land degradation, and thus not included here.

[98] FAO. (2016). FAOSTAT Senegal.

[99] CSE (2010). Annuaire sur l'Environnement et les Ressources Naturelles du Sénégal. Centre de Suivi Ecologique

[100] CSE (2010). Rapport sur l'État de l'Environnement (REE) du Sénégal. Centre de Suivi Ecologique

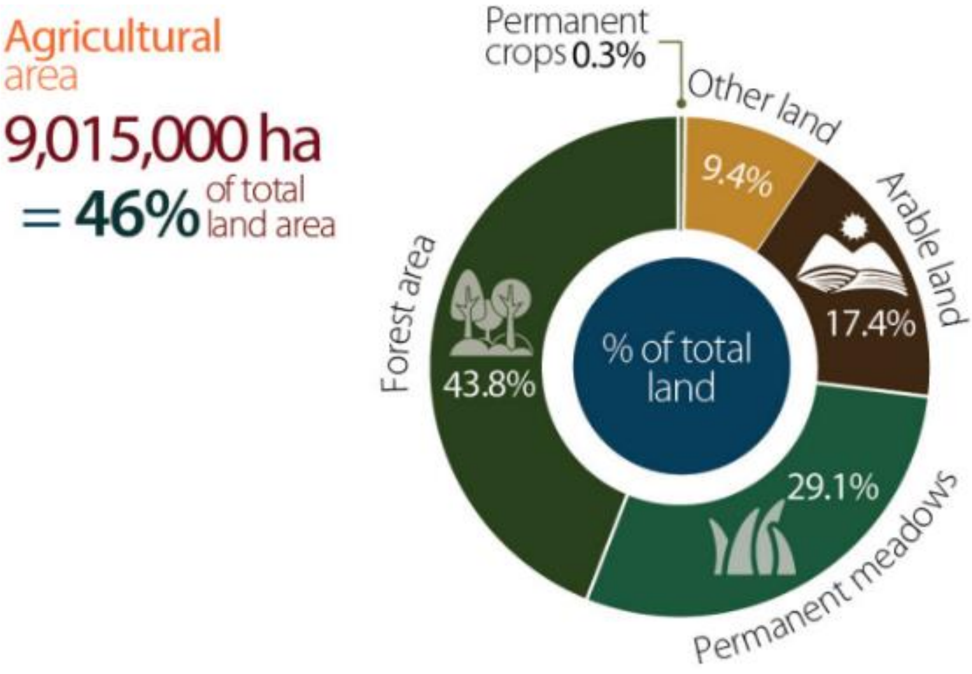

Figure 8. Total land use Senegal[101]

The agricultural economy of Senegal is dominated by smallholder farmers cultivating millet, maize, sorghum and rice.[102] However, the main cash crops are groundnut and cotton. Figure 9 below shows main production yields from crops and livestock.[103]

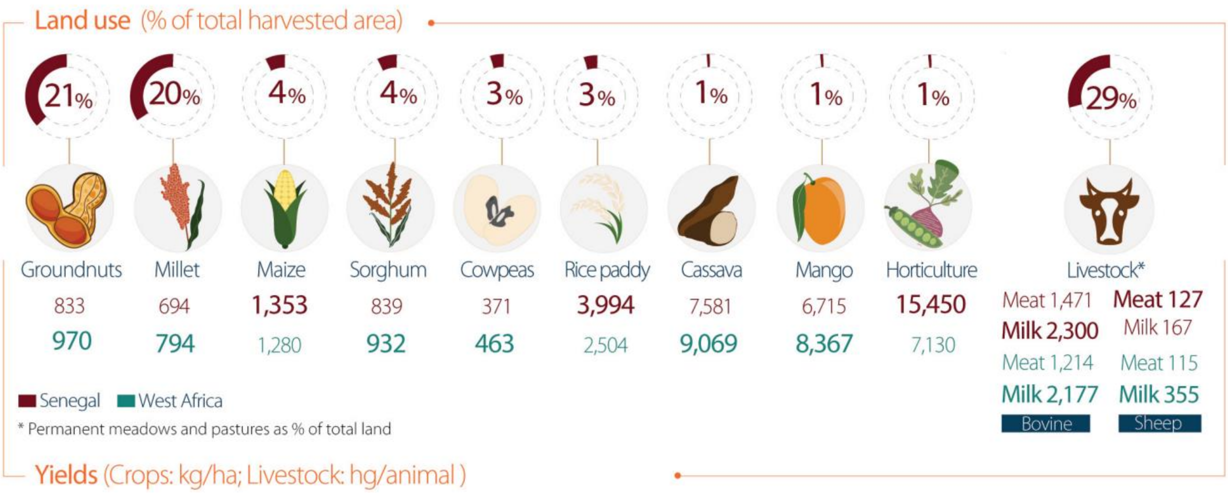

Figure 9. Land use and yields of Crops and Livestock production Senegal.[104]

Across the range of staple crops and livestock options, agricultural activities are unevenly distributed in eco-geographical zones across the country[105].

[101] Feed the Future (2019). Climate-Smart Agriculture in Senegal. WorldBank

[102] Ibid

[103] Ibid

[104] Ibid

[105] Diouf, S., Diallo, I., Woldeyes, A., (2020). L'avenir de l'agriculture au Sénégal : 2030-2063

- The Niayes, encompassing the regions of Dakar, Thiès, Louga and Saint-Louis, are home to producers, crop and fruit growers who produce more than 80% of exports and modern farms in production of meat, milk and eggs.
- The groundnut basin in the regions of Kaolack, Fatick, Thiès, Louga and Diourbel which, in addition to groundnuts and millet, sees the emergence maize, watermelon and cowpea crops.
- Dominated by livestock activities is the sylvo-pastoral zone, also called the Ferlo. This zone is mainly covered by the regions of Louga and of Matam.
- Irrigated rice cultivation, market gardening and corn are dominating the Senegal River Valley.
- In Eastern Senegal and Upper Casamance, covering the regions of Tambacounda and Kolda, rain-fed agriculture predominates, including cotton, livestock and forestry.
- Lower and Middle Casamance are essentially areas of forest, lowland rice crops, millet, corn and peanuts, but also livestock.

Despite its significant contribution to the economy and employment barriers to improving the climate resilience and productivity of the sector include poor soil and weather conditions, limited access by farmers to quality seeds and fertilizers, and a lack of infrastructure. 95% of agricultural production is rainfall dependent during the rainy season. For example, typically, crops are only cultivated during the wet season, with some exceptions in irrigated areas where two to three growing seasons are possible within a year[106].

2.1.5 Industrial organization of the sector

Small-scale and family-based farms occupy 90% of Senegal's agricultural lands, with commercial agriculture accounting for only 5% of the land under production in the early 2000s.[107] However, commercial agriculture has been steadily growing and accounted for 10.7% of the land under production in 2013. Farmers typically hold multiple plots of land, with plot sizes ranging from 1 to 5 ha. Typically, crops are only cultivated during the wet season, with some exceptions in irrigated areas. Furthermore, according to a 2011 survey, poverty is particularly widespread among independent small-scale farmers, affecting 61.1% of farming households compared to the 46.7% national poverty rate[108].

In Senegal, farming cooperatives provide a vital infrastructure for rural communities to meet, pool their financial and capital resources (equipment), exchange information, and become more resilient bodies by acting collectively in pursuit of improving their agricultural production models. Farming cooperatives are typically within farming villages, with farmers pooling their funds based on their needs and capacity to contribute to the cooperative. These cooperatives are key for small-holder farmers who would otherwise struggle to access information and financial resources for their farm. The first Senegalese cooperatives were created mainly in rural areas with the aim of cleaning up the peanut production and marketing circuits, dismantling the trading economy, putting an end to the usurious indebtedness of peasants.[109] Initially organized on a national scale and operating according to democratic principles, the agricultural cooperatives brought together a group of several villages whose cooperators elected a management team which acted as the guarantor of the supervisory

[106] GGGI. (2020), Landscape Analysis Report to scale up the installation of solar irrigation businesses in Senegal.

[107] Ibid

[108] Ibid

[109] RESOPP (n.d.) Coopératives au Sénégal. https://www.resopp-sn.org/Cooperatives-au-Senegal

organizations and State services.[110] However, the financial and political stakes represented by the cooperative system led to its appropriation by the executives of the supervisory organizations, by the large producers holding large farms and this reform did not provide suitable answers to the problems of rural cooperatives that were too dependent on declining groundnut cultivation.
The Senegalese cooperative movement lost traction and was replaced by other forms of organizations such as the Economic Interest Groupings (EIG). However, since the early 2000s, there has been a renewed interest in cooperatives[111]. In Senegal, no less than fourteen interprofessional organizations have emerged in the agricultural sector since 1990; in these organizations, public authorities are very present, either as organizers or in as associate members, or even as organizers of the framework of consultation. [112] The functions carried out by these interprofessional organizations are often limited, and focus on advocacy, and, to a lesser extent, on the definition of marketing rules[113].
There are various organizations which are distributed according to the sector of activity for crops such as groundnut, rice, tomato, and onion, some of which include:

- **National Union of Agricultural Cooperatives in Senegal (UNCAS)** was created in 1974 to carry its claims in favor of the continuation of the modernization of the small family exploitation by the means of the intensification of the production. UNCAS is the largest peasant organization of mainly groundnut producers. Composed of 800,000 members, it had a pyramidal structure in 2008 of 4,500 village sections, 338 cooperatives, 90 local unions, 30 departmental unions and 10 regional unions.[114]

- **Peanut Producers Consultation Framework (PPCF)** was created in 2001. The PPCF is a farmers' organization of producers which brings together 61 inter-village groups of peanut producers (IGPP) for more than 36,000 members. Its activities are essentially based on the production of seeds, marketing and processing. The IGPP brings together producer organizations from the regions of Kaolack, Fatick, Kaffrine, Tambacounda and Kédougou. The IGPPs are the backbone of the PPCF and are made up of around 150 family farms. The main function of IGPPs is groundnut marketing, seed production and groundnut processing.[115]

- **Supply, production, marketing, and agricultural advisory company for the agreements of associated groups in Senegal (SAPCA-EGAS):** Has more than 11,500 members spread over eight regions of Senegal[116].

In the project areas, farmers are organized differently between family farms and village farms. At the level of family farms, there is only one cooperative, which operates in the Ziguinchor region. It is the cooperative of Naatangué family farms (FFN) that was established with previous support under the Naatangué project. It has about fifty members and has a WhatsApp group. Through this cooperative, the members deal with the problems they encounter, give each other advice, make announcements of sales or purchase needs and others but they do not yet carry out certain flagship activities of cooperatives such as group purchases, joint sales, etc. It is the only cooperative that is actively operating and performing well currently. In the other localities, cooperatives are at the stage

[110] Ibid

[111] RESOPP (n.d.) Coopératives au Sénégal.

[112] Duteurtre, G. and Dieye, P.N. 2008) Les organisations interprofessionnelles agricoles au Sénégal. ISRA.

[113] Ibid.

[114] Les organisations de producteurs | Portail agroalimentaire du Sénégal. (2023).

[115] Les organisations de producteurs | Portail agroalimentaire du Sénégal. (2023).

[116] Les organisations de producteurs | Portail agroalimentaire du Sénégal. (2023).

of establishing first contacts.

At the level of village farms, there are no cooperatives that are currently operating; instead, village farms benefit from Economic Interest Groups (GIE, in French). Each GIE is composed of about twenty members, and is led by an office which is composed of the following actors: President, Vice President, Treasurer and Assistant, Secretary General and Assistant. Each GIE has a control team, which is independent from the office, and is made up of 3 auditors. The GIEs intervene throughout the agricultural supply chain, from cultivation to sale, though are not involved in processing. EIGs have a formal, legal status and have all the documents required for an organization to be legally recognized. ANIDA has provided welcomed support for the creation of GIEs through administrative procedures to accelerate impact by avoiding errors or delays.

The main objective of each GIE is to support the management of the consolidated village operations. Depending on the demands, size and operational focus of village farm members, it has been possible to create and successfully operate several GIEs, and group them together in a union. Each union of GIEs has an office. The decisions taken at the level of the union of the GIEs are reported to the members of the GIEs by the presidents of the GIEs. The administrative documents of GIE Keur Gallo are attached, providing details on the following procedures: minutes of constitution and appointment, delegation of power, rules of procedure, role of the group, role of members, admission of members, financing of the group, etc. The use of GIE has been successful in previously consolidated and integrated village farms, as membership numbers can be managed successfully to have active participation and the network enables local farmers to collaborate and conduct business more efficiently; and therefore this project aims to continue supporting this operating model.

The main challenges with the creation and operationalization of GIEs concern the administrative procedures under which it operates. The level of knowledge of the rural communities is not always sufficient to enable them to prepare the necessary documentation and to carry out the process at the level of the administrative services. As a government agency, ANIDA is well placed to collaborate with other government entities involved in the creation of GIEs. This avoids delays and saves resources and farmers' frustrations which may arise during the formalization of operations. At the level of family farms, alongside the aforementioned challenges, the creation of cooperatives can present difficulties due to the requirement of consolidating families that are not directly involved in the same agricultural operation, thus introducing a granularity factor. This requires more energy and resources to organize meetings, agree on operating rules, mobilize members, manage the cooperative and carry out follow-up sessions on agreed-upon measures. However, once set up, the cooperative will facilitate the management of Naatangué farms and make the use of resources more efficiently. Instead of managing dozens of farms individually, the cooperative will allow ANIDA to interact with the cooperative office which will relay decisions and information to the member level. In return, member information can be forwarded to ANIDA through the cooperative office.

Currently, ANIDA is undertaking appropriate monitoring of village farms with the help of GIEs. Monitoring family farms is not yet done correctly because of the lack of resources to monitor each farm. The resources of the GCF will help family farms to organize themselves into cooperatives in order to facilitate the efficient functioning of each farm. This will allow different family farms to have easier access to resources through the cooperative. Other notable advantages include the potential for collaboration, mutual assistance, and knowledge-sharing among cooperative members. Cooperatives will also offer increased collective bargaining power, and improve their ability to negotiate with various stakeholders as a unified group.

As it stands, farming cooperatives lack the institutional support to effectively group their resources together. This project will bridge that gap through the community-based savings fund (further discussed in this document later on), by offering a formal mechanism for collective investment and inclusion of financial institutions in a forum that will allow for these actors to exchange vital information and access critical financial advice on investment risk mitigation. Given the current climate vulnerabilities (see Climate Rationale), as well as the socio-economic pressures small-holder farmers face in Senegal (discussed further in this section), there is a need to scale-up and formalize farming cooperatives so as to ensure farmers can collectively leverage their resources to ensure the long-term success of the Naatangue model.

2.2 Demographic Breakdown

2.2.1 Income

The agricultural sector is a key employer of a large proportion of the national workforce. Between 30-40% of employment in Senegal is in the food economy (food production and/or processing). There is, however, strong evidence to suggest that the percentage of workers depended on the sector for employment has continuously fallen, from 49% in 1991 to 30% in 2019.[117,118]

Incomes vary across regions and annual net revenues in the agricultural sector in each region vary according to a range of factors including crops, commodity prices and regional weather impacts. Figure 10 below, illustrates incomes and revenues in 2021. The lowest revenues, highlighted in red, below, are found in Diourbel, Kaolack, Louga, and Matam.

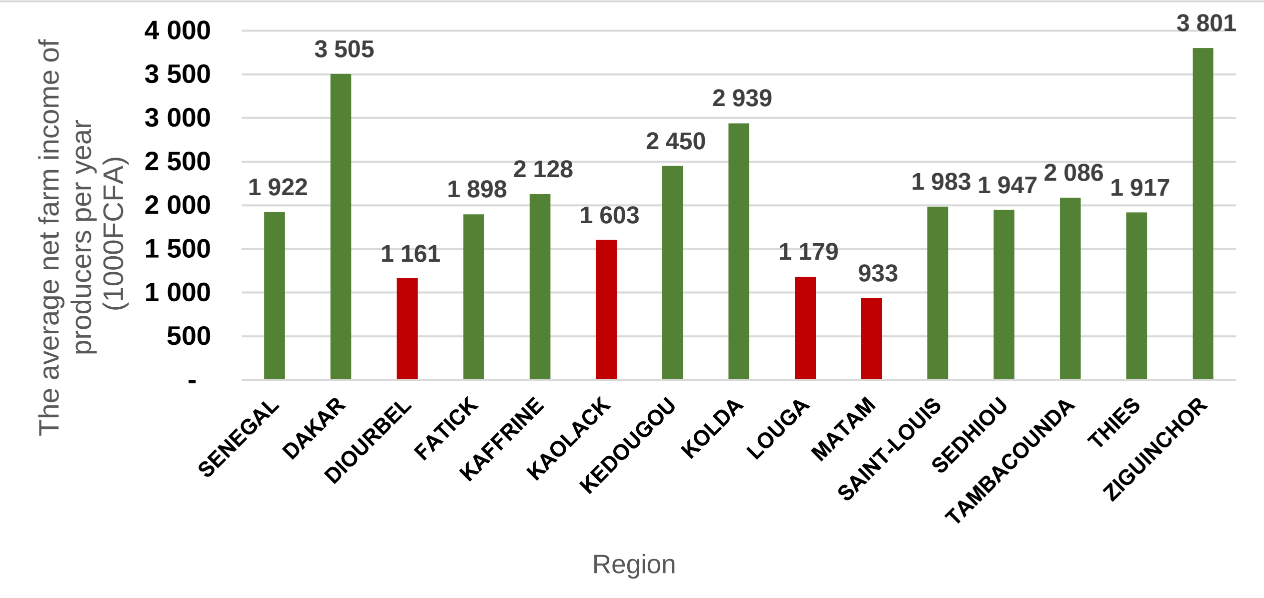

Figure 10. Net farm income across regions[119]

Agriculture losses due to disasters and exogenous price shocks can lead to serious economic and financial impacts over time. For example, between 1980-2012, the agricultural (representing 12 main crops), experienced a loss of 4.82 million metric tons (MT), which has an estimated value of

[117] World Bank (2019). Emplois dans l'agriculture (% du total des emplois) - Senegal

[118] Matsumoto-Izadifar, Y. (2023). Senegal – Challenges of Diversification and Food Security.

[119] ANSD (2021). Coûts et revenus agricoles des ménages selon la région et le type de producteur—Senegal Data Portal.

US1.40 billion, otherwise representing 3.9% of annual, agricultural GDP.[120] These losses were due to different natural disasters and climate-related stressors (locusts, erratic rainfall/drought, flooding…etc.). The same analysis found that agricultural losses in Senegal exceed 10% of their gross production value every 5-6 years due to climate-related stressors.[121]

Senegalese farmers grow both subsistence crops, such as millet and sorghum, as well as cash crops, such as groundnuts. Ground nuts play a key role in supporting incomes for Senegalese farmers. 40% of cultivated land in Senegal grows groundnuts, and the cultivation of groundnuts employs 1 million people. [122] Groundnuts are particularly sensitive to changes in precipitation and elevated temperatures; some models project a 5-25% decrease in groundnut yields as a result of climatic changes; both groundnuts and subsistence crops are rainfed (87% of all crops are rainfed), which renders the entire agricultural sector, both in terms of its subsistence and economic production, highly susceptible to climatic changes.[123] This poses a considerable risk for farmers to support their families and finance the inputs and labor in their farms.

2.2.2 Population living in poverty

A majority of Senegalese farmer's incomes range from 933,000 to 3,801,000 FCFA. This means farmers and especially those in rural areas suffer from the highest poverty rates in the country. In Senegal, the average income was 100215 CFA/Month (168.558 USD/Month) and the national poverty line was set at 469.5 in CFA franc (2011) or US$1.90 (2011 PPP) per day per capita.[124] [125] . Compared to urbanized zones such as Dakar where 26.1% of the population live below the poverty line, regions with the highest poverty rates are Kolda (71.3%), Sédhiou (68.3%), Fatick (67.8%) and Ziguinchor (66.8%).[126] These poverty rates are comparable to other analyses of poverty in Senegal, which found that 80% of people residing in Kaffrine, Kolda and Sedhiou find themselves in the bottom 40% in income distribution, followed by Kedougou and Tambacounda.[127] The operating model of farmers also impacts poverty rates, and according to a 2011 survey, poverty is particularly most widespread among independent farmers, affecting 61.1% of farming households compared to a 46.7% national poverty rate[128]. Interestingly, the areas in which irrigation is most prominent (Niayes in the Dakar region, and in the Vallée du Fleuve in Saint-Louis), poverty rates are the lowest.[129]

[120] D'Alessandro, S., Fall, A. A., Grey G., Simpkin, S. & Wan, A. (2015). AGRICULTURAL SECTOR RISK ASSESSMENT.

[121] Ibid

[122] Gro Intelligence. *Polishing Peanuts: The Senegalese Groundnut Story*. (2015, February 20). https://www.gro-intelligence.com/insights/polishing-peanuts-the-senegalese-groundnut-story

[123] GGI. (2020), Landscape Analysis Report to scale up the installation of solar irrigation businesses in Senegal.

[124] Take-profit.org (2023). Senegal Wages 2023 | Minimum & Average.

[125] World Bank (2020). *Poverty & Equity Brief, Senegal.*

[126] Deuxième Enquête de Suivi de la Pauvreté au Sénégal

[127] ANSD et ICF. 2018. Sénégal- Enquête Démographique et de Santé Continu (EDS-Continu) 2017. The DHS Program ICF. Rockville, Maryland, USA : ANSD et ICF. Septembre 2018

[128] GET.INVEST, 2019

[129] IFAD (2019). Republic of Senegal Country Strategic Opportunities Programme 2019-2024.

2.2.3 Gender and age group

Women play a dominant role in agriculture in Senegal. Women contribute to 80% of the agriculture production workforce in Senegal[130]. They comprise 70% of those engaged in subsistence agriculture (compared to 30% of men).[131] Despite playing an important role, demographic studies in the Senegalese agriculture reveal that the probability of participating in the agricultural sector for single women is lower when compared to other demographic groups.[132] With regard to access to strategic resources, women are often discriminated in the distribution of exploitable land at the expense of men. Studies by The Direction of Agricultural Statistics (DAPSA) show that, in 2012, only 9.8% of land ownerships were held by women against 90.2% of men,

The issue of women's land ownership in Senegal is complicated by various barriers. Customary laws that govern inheritance often result in women receiving a disproportionately small share of the land. Moreover, authorities responsible for allocating land, such as rural councils, tend to prioritize men as heads of households, granting them the majority of cultivable plots. This structural barrier is compounded by religious and cultural norms that place men as the guardians of familial authority, leaving women responsible for childcare, asset maintenance, and household tasks. The combination of these factors limits women's access to and control over land in Senegal forcing women to constantly seek alternative strategies such as renting and crop sharing resulting in higher production costs. In 2012, nearly 66.7% of women accessed land through rental as opposed to 33.3% men[133].

Furthermore, women play a particularly important role in rice cultivation in certain regions though, with as many as 65% of rice fields being owned and operated by women. This means that female farmers are at much higher risk of agricultural losses because of salinization.[134] In part because of the high rate of women engaged in subsistence agriculture, women and youth are most impacted. In the aforementioned poorest regions of Senegal, women and youth-led (under 40 years of age) households make up the vast majority of those impacted by food insecurity.[135] Furthermore, as climate impacts threaten agricultural incomes already vulnerable women farmers and labourers are made even more vulnerable and face additional barriers to men in accessing financial loans or other support.

2.3 Access to finance

2.3.1 Public sector finance

Senegal has set ambitious targets to increase agricultural production and achieve food security. The government's strategy focuses on increasing crop yields, expanding the use of modern agricultural technologies, promoting irrigation, and improving land use practices. To achieve this, the Government of Senegal has set production targets for the 2020/21 agricultural season, which include

[130] Supporting women in agriculture in Senegal (2022). ICR Facility.

[131] IFAD (2019). Republic of Senegal Country Strategic Opportunities Programme 2019-2024.

[132] Hathie, I., & Wade, I. (2015). Emploi des Jeunes et Migration en Afrique de l'Ouest (EJMAO) / Youth Employment and Migration in West Africa. Africa Portal; Initiative Prospective Agricole et Rurale (IPAR).

[133] World Food Programme and USAID (2017) *Gender, Markets and Agricultural Organisations in Senegal", VAM Gender and Markets Study #6 2016-2017.* https://docs.wfp.org/api/documents/WFP-0000022438/download/

[134] Thiam, S., Villamor, G. B., Kyei-Baffour, N., & Matty, F. (2019). Soil salinity assessment and coping strategies in the coastal agricultural landscape in Djilor district, Senegal. Land Use Policy, 88, 104191. https://doi.org/10.1016/j.landusepol.2019.104191

[135] Hathie, I., Seydi, B., Samaké, L. et Sakho-Jimbira, S. (2017). *Reducing economic and environmental vulnerability to achieve food and nutrition security in Senegal. Ending Rural Hunger- Senegal Policy Brief*

an aim to increase rice production to 1.5 million metric tons (MT) annually, peanut production to 1.5 million MT, and corn production to 630,000 MT.[136]

The Government of Senegal has historically provided support to agricultural producers across Senegal for key crops, including peanuts, rice, millet, corn, and sorghum. This annual support primarily consists of facilitating producer's access to inputs (i.e. fertilizers, seeds, phytosanitary products) and agricultural equipment through subsidies as well as providing technical and marketing support. The budget proposed for the agricultural campaign by the State of Senegal has been on an increasing trend since 2020. It rose from 40 billion FCFA to 60 billion FCFA in 2021 then to 80 billion FCFA in 2022, before reaching 100 billion FCFA in 2023[137]. A non-comprehensive list of available agricultural subsidies is included here:[138]

- The GOS has allocated 23.7 billion CFA francs ($39.5 million), or about 40 percent of the entire Agricultural Program 2020/21 budget, to subsidize 150,000 MT of fertilizer, up 25 percent from the previous season. These fertilizer subsidies are not tied to specific crops.
- The GOS funds research and development of foundation seeds through the Senegalese Agricultural Research Institute (ISRA). The foundation seeds are sold to private seed multipliers who sell to farmers mainly through cooperatives.
- The government also buys seeds from multipliers and selected farmers and traders for subsidized distribution depending on targets set out in the Agricultural Program for that year.
- The GOS has allocated 30 billion CFA francs ($50 million) or about half of the entire Agricultural Program 2020/21 budget to seed subsidies for priority crops such as peanut, cowpea, rice, potato, and corn.
- Although a much smaller portion of the 2020/21 Agricultural Program, rudimentary farm equipment will also be provided to small-scale farmers. The GOS has allocated 4.9 billion CFA francs ($8.2 million) or about 8 percent of the 2020/21 Agricultural Program budget to purchase seeders, hoes, plows, and carts.

In addition to the Government of Senegal's budget towards agriculture, there are also contributions from other donors, subsidies from various entities, and investments from concessional finance such as:

- The African Development Bank Group extended a loan of €63.6 million to Senegal to implement the Agropole-Centre agro-industrial processing zone project.[139]
- The Senegalese Banque Agricole has provided over FCFA 7 billion in credit to assist rice producers in Saint-Louis and Matam to assist producers with the challenges of rice cultivation in the dry season.[140]

2.3.2 Climate finance

In addition to the state, climate finance is also playing a crucial role in funding agriculture in Senegal. International organizations and developed countries are providing financial support through climate funds to help Senegal adapt to the adverse effects of climate change, including the

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[136] Osinski, J. and Wright, R. (2020). Senegal Agricultural Program 2020-21

[137] Dieng, D. (2023) *Senegal: Un budget exceptionnel de 100 milliards FCFA pour la campagne agricole 2023-2024.*

[138]Osinski, J. and Wright, R. (2020). Senegal Agricultural Program 2020-21

[139] Bank, A. D. (2022). Producers increase agricultural yields in southern Senegal thanks to the African Development Bank. African Development Bank - Building Today, a Better Africa Tomorrow; African Development Bank Group.

[140] *La Banque Agricole*. (n.d.). Financement De La Campagne Contre Saison Chaude Riz 2022: La Banque Agricole (LBA) Débloque Plus De 7 Milliards De FCFA Pour Accompagner Les Producteurs De La Vallée Du Fleuve Sénégal. https://www.labanqueagricole.sn/mediatheque/actualites/financement-de-la-campagne-contre-saison-chaude-riz-2022-la-banque-agricole

promotion of sustainable and climate-resilient agricultural practices. Moreover, private sector investors are increasingly recognizing the potential of climate-resilient agriculture and investing in sustainable agriculture projects in the country.

The national strategy for mobilizing climate finance is part of a logical approach aimed at strengthening the country's capacities in dealing with the impacts of climate change. A major constraint indeed remains the issue of financing, which is still difficult to mobilize due to the complexity of the mechanisms for accessing external resources and the lack of initiatives at the internal level of the country. This strategy is built on the priorities and needs of the country which are identified in the national policy and strategy documents relating to the fight against climate change. These are in particular the "Nationally Determined Contribution" (NDC)[141] which defines the projects to be carried out in the areas of mitigation and adaptation, on the one hand; but also, the Country Program of the Green Climate Fund as well as other initiatives in favor of the fight against climate change, on the other hand. The purpose of the national strategy for mobilizing climate finance, through the NDC in particular, is to contribute to the mobilization of a financial amount of 13 billion US dollars distributed between: 8.7 billion for mitigation projects and 4 US$.3 billion for adaptation; including USD 4.8 billion in unconditional financing and USD 8.2 billion in conditional financing. As for the Country Program[142], the funding needs are estimated at 6,403,183,636 USD divided into two phases: 2,956,145,136 USD for the 2018-2025 phase and 3,447,038,500 USD for the 2026-2030 phase. Climate finance comes from cooperation with developed countries in accordance with the principles and commitments made within the framework of the various COPs. Thus, multiple sources of funding have developed, but access to them still remains complex in the eyes of several national actors.

[141] Btb, P. lamine D. (n.d). REPUBLIQUE DU SENEGAL.

[142] Green Climate Fund and Republic of Senegal (2018) Programme pays 2018 – 2030.

3. Barriers and drivers of vulnerability in the agriculture sector

3.1 Climate drivers

As detailed in the Climate Rationale document, the main climatic vulnerabilities to the agriculture sector in Senegal are related to: i) temperature increase; ii) rainfall availability and variability. Average temperature across the country during the 2021-2040 period is projected to be 28.9 C - 29 C, whereas temperatures are projected to reach an average of 29.7 C - 30.1 C during the 2041-2060 period, representing a 0.8 C – 1.1 C average temperature increase. Increase in the frequency of extreme heat waves by 40-60% by 2035 is expected, particularly for the Senegalese coastal zone[143]. This will exacerbate water stress and evapotranspiration, intensification of water erosion, salinization of land and loss of fertility. Drier conditions will lead to the drying of crop fields and wildfires, which might encourage farmers to abandon their fields, contributing to long-term land degradation.

Projected rainfall is an equally important indicator for the Senegalese agricultural sector as the vast majority of crops in Senegal are rain fed. Overall, the projected trend finds that precipitation will increase across the country, though the Southern regions are more likely to experience notable increases in precipitation compared to the Northern regions, which, in certain emission scenarios (Ssp370) may even experience losses in precipitation. While some regions are projected to experience higher precipitation, other regions may experience losses in precipitation. There is also a forecasted increase in climatic extreme events, such as a 20-30% increase in drought incidence by 2035 particularly for the northern and central parts of the country[144].

Concretely, climate change is affecting agriculture in Senegal by causing:

- floods and high uneven precipitation, which cause erosion, lead to significant crop losses, damage to agricultural infrastructure, clog fields and reduce yields;
- the shortening of the rainy season (prolongation of the dry season) and the late onset of the rainy season (leading to premature and poor seedbed preparation, planting and harvesting, resulting in a poor harvest or reduced yields);
- Increase in temperatures and drought conditions;
- significant loss and degradation of topsoil and thus increasing erosion;
- Climate change may increase frequency of locust infestations and incidences of disease for livestock, due particularly to flooding conditions that are conducive to vector development.

3.2 Non climate drivers

In addition to climate-related barriers, there are non-climate barriers that can have impacts on the project.

- The lack of knowledge and awareness of climate change in Senegal is a major obstacle to the implementation of climate-smart practices. A study conducted as part of the "Scientific Support Project for the National Adaptation Plan Process" project revealed that there has been little progress in identifying the impacts and risks of climate change in the medium and long term. The lack of in-depth impact chain studies on strategic sectors, such as water resources and agriculture, further exacerbates the issue. It is crucial to improve the level of knowledge among

[143] CSE (2020). Rapport sur l'État de l'Environnement

[144] Ibid

authorities and technicians responsible for supporting and sensitizing communities on climate change to ensure proper management of the issue, in addition to the farmers themselves. Weak capacity and organization of community actors to leverage information on climate impacts, implement climate-resilient practices, access markets, and develop a viable value chain is a reflection of this lack of knowledge and awareness.

- Over-dependence on financing from agricultural campaigns leading to decreased participation and income if any delays occur: At the farmers' side, some gaps in production are justified by the difficulties in mobilizing credit financing from campaigns for certain farms, forcing producers to sow within the limits of their financial possibility with the risk of delay in the establishment of cultures. The financing of the campaigns of the farms may depend on the financial institutions which, often do not grant the amounts of credits requested or do not do so on time noted. This causes delays in the establishment of crops and/or reductions in sown areas[145].

- Access to adequate financing is a critical challenge for the agricultural sector in Senegal. This is due in part to a lack of knowledge and understanding of the risks associated with the sector, which makes financial institutions reluctant to invest. Additionally, financial product terms are often mismatched with the needs of agricultural producers. For instance, the long-term nature of climate smart agricultural investments often clashes with the short-term nature of financial products. The low level of control over certain risks, such as crop failure in a changing climate, also increases the perceived risk for lenders. To address this challenge, financial institutions in Senegal must develop a better understanding of the agricultural sector and the associated risks, while also developing financial products and terms that are better suited to the needs of agricultural producers. Additionally, greater collaboration between financial institutions and agricultural stakeholders can help to identify and address financing gaps, as well as to develop innovative financing mechanisms that better support the needs of the sector.

- The marketing of agricultural products in Senegal is largely informal and lacks regulation, leading to disorganization and inefficiencies. This is due to the absence of formal markets and the dominance of small-scale farmers who have limited access to information, transportation, and communication technologies. As a result, farmers often struggle to find buyers, negotiate prices, and secure fair market access, leading to low profitability and limited opportunities for growth. To address this issue, there is a need to develop formal market structures, improve infrastructure and logistics, and provide better access to information and financial services to support the marketing of agricultural products in the country. Farmers in Senegal also face a lack of awareness and availability of developed value streams, which limits their ability to capture the full economic potential of their products.

- Rural populations have further exposure stemming from general poverty, low education levels, limited access to markets, high operating costs (some farms had as high as 40% income spent on diesel fuel costs alone), low adaptive capacity, their reliance on rainfed agriculture (~80% dependence) and limited availability of social services.

3.3 Impacts of barriers and pressures on the agriculture sector and target regions

The agricultural sector in Senegal is currently facing significant challenges related to limited economic activity, low yields, and comparatively low productivity. These challenges are primarily attributed to several climatic and non-climatic barriers, including inadequate water control, weak technical and organizational capacities of actors, and insufficient access to funding. The result of

[145] CSE (2020). Rapport sur l'État de l'Environnement

these challenges is a situation in which agricultural producers are able to engage in economic activity for only a few months of the year, leading to significant limitations on overall agricultural productivity. These impacts have reduced agricultural productivity at the national level with 5-25% reduction in crop quality and yields, particularly for rained maize, sorghum, millet and groundnuts. This has led to a high vulnerability of small agricultural producers to climate hazards. In particular, rural populations are exposed to poverty because of their great dependence on rain-fed agriculture, which is why more people are leaving their villages to seek better living conditions in the cities. For example, the droughts in 1982, 2011 and 2014 affected 1.2 million, 850 000 and 640 000 people respectively. Revenue loss for the 2000 drought stood at over 74% of groundnuts and 60% for millet and sorghum.[146]

Climate change is negatively affecting agricultural production in different regions in Senegal. The rainfall season has gone from 3 months to 2 months or even less in some localities. Late start or early end of the rainy season does not allow crops to complete their cycle in good water supply conditions. As a result, farmers have less time to cultivate their crops leading to a decrease in production.

This situation is visible in most of the regions in Senegal, for example:

In Tambacounda, we note a decrease in vegetable production (particularly forage production and agricultural yields) and a decrease in animal production (milk, meat, eggs, etc.). Whereas in Kolda the impacts are more pronounced on the value chains of rice and maize, particularly a significant decrease in yields across production areas.
Louga is the region that hosts majority of the country's groundnut production, which are among the most valued cash crops in Senegal[147] and the climate trends are particularly threatening to the farmers.

In addition, future projections have proven that Senegalese farmers will experience losses as high as 100% by the 2080s.[148]s

The declining productivity of the agricultural sector in Senegal has resulted in an increased migration of rural populations to urban areas. This has led to an increase in the proportion of the urban population, which rose from 34% in 1976 to 46.9% in 2019. The rate of urbanization varies across regions, with the Thiès region having the highest level of urbanization at 52.2%, followed by Saint-Louis at 49.3%, and Kaffrine, Fatick, and Diourbel having comparatively lower levels of urbanization at 18.2%, 17.3%, and 16.2%, respectively[149]. This migration trend exacerbates the vulnerability of intra country displaced populations, as they become more reliant on external food sources and lose their ability to subsist on their own agricultural production. Furthermore, the increasing urbanization of Senegal puts pressure on already limited urban resources and infrastructure, as well as making it difficult to ensure food security for the growing urban population.

Furthermore, the cost of inputs for Senegalese farmers has been on the rise in recent years, resulting in reduced margins for producers. According to the World Bank, the cost of inputs, such as seeds, fertilizers, and pesticides, has increased by 30% since 2012 while the price of agricultural products

[146] Ayugi, B., Eresanya, E., Onyango, A.O. *et al.* Review of Meteorological Drought in Africa: Historical Trends, Impacts, Mitigation Measures, and Prospects. *Pure Appl. Geophys.* **179**, 1365–1386 (2022). https://doi.org/10.1007/s00024-022-02988-z

[147] Ibid

[148] Climate Risk and Adaptation Country Profile: Vulnerability, Risk Reduction, and Adaptation to Climate Change - Senegal. (2011, May 4).

[149] Ibid

has remained relatively stable[150]. The costing challenge is particularly evident in Sub-Saharan Africa where fertilizer prices have tripled since early 2020 and remain volatile. This has put significant pressure on smallholder farmers, who make up 95% of all farms in Senegal. The lack of access to affordable credit exacerbates this problem, as it limits farmers' ability to purchase inputs and modernize their operations. As a result, farmers are increasingly facing lower profit margins, making it difficult for them to sustain their livelihoods and re-invest in their farms.
Different regions in Senegal present unique challenges and barriers to the development of the agriculture sector. For example, while arable land covers 39.3% of land in Senegal, the Niayes region only covers 2.9% of the arable land in Senegal. There is a concentration of arable land in the Peanut basin (42.1%). The other regions have much lower agricultural land: Casamance has 7.9%, Eastern Senegal 3.3%, Silvo-pastoral zone 34.9% and Senegal River 8.9%.[151] In addition to different land coverages, other varying factors across regions include farming types, limited access to training and extension services, weak farming structures such as cooperatives and producer organizations, and inadequate market infrastructure.

To overcome these differences, there is a need for tailored interventions that address the specific needs of farmers in different regions, including improved access to training and extension services, support for the establishment of effective farmer organizations, and investment in market infrastructure. To assess the potential impact of the project, it is crucial to understand regional data to allow for an evaluation of the effectiveness of diversification and improved activities on each location. The project is set to be implemented in eight regions of Senegal, namely Thiès, Louga, Saint Louis, Kaolack, Kaffrine, Tambacounda, Kolda, and Ziguinchor. In addition to the information here, data on temperature and precipitation, available in the Climate Rationale report, also provides valuable insights into the potential challenges and opportunities presented by each region, and demonstrates the tailored design of the interventions to meet the specific needs of each region and local context.

The Niayes region: Thiès, Louga and Saint-Louis
Social and economic baseline

The Niayes region is one of the country’s most important eco-regions for agriculture, tourism and economic development. Benefiting from both the coastline and a complex network of freshwater resources (lagoons, wetlands), the region has high potential for further agricultural development. However, despite hosting an optimal environment for farmers to thrive in the agricultural sector, the Niayes region faces considerable social and economic vulnerabilities. Wealth inequality across the Niayes region (expressed as a GINI coefficient) ranges from 0.12 (Thies) and 0.28 to 0.30 (Louga and Saint-Louis, respectively).[152] Given that the national average wealth inequality index is at 0.23, the Niayes region presents considerable variation in the terms of wealth inequality dynamics.

In Louga, for instance, more than 65% of the region's population live below the poverty line.[153] The ability of people in Louga to overcome such a high poverty rate is hindered by their limited access to education and critical social services, which are especially restricted for women and girls.[154] Saint-Louis also suffers from a high poverty rate of 40.1%, and residents of the region likewise have limited access to educational and professional development opportunities that would allow them to

[150] World Bank (2022) *A transformed fertilizer market is needed in response to the food crisis in*.

[151] CSE (2020). Rapport sur l’état de l’environnement.

[152] Gini coefficient wealth inequality—Area Database—Table—Global Data Lab. (2021)

[153] Daraint. (2013). Senegal.

[154] Ibid

overcome poverty (42% of residents have not had access to formal education, and only 43% of the population is literate).[155] In Thies, one vulnerability analysis found that women, the elderly, and youth populations working in the agricultural sector are particularly vulnerable as they are less likely to have access to information or means of accessing information (phones, internet) on climate projections and their impact on agriculture. For this reason, it's particularly difficult for these vulnerable groups to use agriculture as a means of lifting themselves out of poverty.[156]

Despite such high social and vulnerability rates across the Niayes region agriculture still has considerable potential in lifting populations out of poverty, as there is an existing and growing food production and processing industry across the Niayes region. Indeed, in Saint-Louis, the agricultural industry plays a key role in driving the goods and services industry on which it relies for the processing, packaging, and shipping of products. However, the ability for populations to realize the benefits of these existing infrastructures and economic sectors is limited by a range of social vulnerabilities, such as disease and malnutrition, which is coupled by the limited access to health services.[157]

Agricultural Baseline

The Niayes region is known as the agricultural lifeline of Senegal; the region produces over 80% of the country's national food production.[158] By combining the irrigation system and the area of the agricultural farm, the four main types of farms can be classified across the region are[159]:

- Small farms which are characterized by an area not exceeding 0.5 ha and whose irrigation system is based on sumps or traditional wells;
- Small farms (1 to 2 ha) equipped with improved wells;
- Medium-sized farms covering an area of 3 to 10 ha and whose water supply is provided by the national water company Sen'Eau and by improved wells;
- Large farms with several tens and hundreds of hectares, equipped with boreholes.

Saint-Louis produces 12.8% of national cereal production, and most farms produce rice, millet, sorghum, maize, onion, sugar cane, and tomatoes.[160] However, the production of cereals is highly vulnerable to increases in temperature and natural disasters[161], both of which have seen increases in

[155] Saint-louis. (n.d.). Agence Nationale de la Statistique et de la Démographie (ANSD) du Sénégal

[156] Sall, A., Toure, A., Kane, A., & Fall, A. N. (n.d.). Vulnérabilité des agriculteurs de la région de Thiès (Sénégal) dans un contexte de changement climatique. J.Anim.Plant Sci., 1.

[157] PNA (2022) Études de vulnérabilités approfondies aux changements climatiques dans les régions de Kaffrine, Kédougou, Matam, Saint-Louis et Ziguinchor: Rapport d'analyse de la vulnérabilité approfondie aux changements climatiques de la région de Saint-Louis. Livrable 03C

[158] Faye, A., Tounkara, A., Ciss, P. N., Ngom, M., & Camara, I. (2022). Évaluation de la vulnérabilité du secteur agricole aux changements climatiques et identification d'options d'adaptation pour la région de Kolda au Sénégal: Rapport produit dans le cadre du projet Sécurité alimentaire: une agriculture adaptée (SAGA). FAO. https://doi.org/10.4060/cc0571fr

[159] Touré, O., & Seck, SM (2005). *Family farms and agricultural enterprises in the Niayes area in Senegal* . International Institute for Environment and Development.

[160] PNA (2022) Études de vulnérabilités approfondies aux changements climatiques dans les régions de Kaffrine, Kédougou, Matam, Saint-Louis et Ziguinchor: Rapport d'analyse de la vulnérabilité approfondie aux changements climatiques de la région de Saint-Louis. Livrable 03C

[161] Ibid

the Niayes region, as highlighted in the climate rationale. Louga's Sahelian climate is becoming drier as the region experiences longer spells of drought events, caused by lack of rain and rising temperatures.

The main vulnerabilities in the region are drought, locust infestation, soil erosion and desertification of agricultural areas.[162] These vulnerabilities particularly threaten the cultivation of ground nuts, which are the primary cash crops in Louga.[163] The 2014 growing season was relatively poor due to longer drought periods, and was particularly challenging for groundnut farmers in Louga, who saw their yield decline by up to 50% of the average yield, which lead to the price of groundnut seeds rise by 36%; this led farmers to abandon growing groundnut, which is the primary source of income for many farmers.[164] The farmers moved from ground nuts to crops that provide lower, but more immediate, financial returns, such as cowpea and millet.[165]

This may have been a contributing factor to the poverty rate rising within the last few years. Urban sprawl has also threatened the viability of agriculture due to the displacement and loss of arable soil for urban development; indeed, between 2009 and 2014, the region saw a loss of 556 ha of arable agricultural land to urban development projects.[166] The impact of the loss of agriculture has further stressed the existing food security issues in the Niayes region[167], which further renders social and economically vulnerable populations less resilient to the current and forthcoming impacts of climate change.

The Groundnut Basin: Kaffrine, Kaolack

Social and economic baseline in region

In Kaffrine, as of 2019 the poverty rate is 53%, which is among the highest poverty rates in the country (Senegal's national average poverty rate is 37.8%). [168] Floods in Kaffrine are particularly damaging to the socio-economic well-being of its residents. [169] This damage leads to the destabilization of already vulnerable infrastructures in the region. People who already face malnutrition and disease are further exposed to flood-driven diseases, such as malaria and schistosomiasis. [170] Women are particularly exposed to socio-economic vulnerabilities in the farming sector of Kaffrine. One study in a municipality of the region found that there is unequal access to farming extension and advisory services to female agricultural workers.[171]

[162] Daraint. (2013). Senegal.

[163] Daraint. (2013). Senegal.

[164] Poor start to the agropastoral season in central and northern areas | FEWS NET. (2015).

[165] Ibid

[166] Diack, M., Loum, M., Diop, C., & Holloway, A. (2017). Quantitative risk analysis using vulnerability indicators to assess food insecurity in the Niayes agricultural region of West Senegal. Jàmbá: Journal of Disaster Risk Studies, 9. https://doi.org/10.4102/jamba.v9i1.379

[167] Ibid

[168] Kaffrine. (n.d.). Agence Nationale de la Statistique et de la Démographie (ANSD) du Sénégal.

[169] PNA – FEM, "Études de vulnérabilités approfondies aux changements climatiques dans les régions de Kaffrine, Kédougou, Matam, Saint-Louis et Ziguinchor", Avril 2022).

[170] Ibid

[171] Climate Change, Agriculture and Food Security (CCAFS) Village Baseline Study – Site Analysis Report for Kaffrine . (2012).

Kaolack is also threatened by poverty; the region has one of the lowest International Wealth Index (IWI) scores in the country (53.5, compared to the national average of 60.3).[172] This indicates that fewer residents of Kaolack have access to capital, which is a severely limiting factor in economic life, generally, but especially in agriculture, which is a capital-intensive endeavor. Income inequality in Kaolack is on par with the national average of 0.23.[173]

Agricultural Baseline

In Kaffrine, agriculture is the dominant economic activity, employing 75% of the population.[174] Agriculture is rain-fed and extensive (rice, maize, sorghum, cassava, fonio, and peanuts). Agricultural production is concentrated around cereal production, though horticulture (fruits, vegetables) and cash crops (ground nuts) are also commonly produced throughout the region.[175] The region's agricultural production is particularly under stress due to the prolonging of droughts and consecutive days without rain during the dry season (5 to 10 days). [176]

Kaolack is one of the areas that is most vulnerable to climatic hazards. For instance, in the Saloum islands, salinization has gained ground both at the level of wells and in the fields.[177] Salinization of the soil leads to the loss of productivity, which drives farmers to abandon non-productive fields, leading to land degradation and the loss of arable soil.

The Casamance region: Kolda, Ziguinchor
Social and economic baseline

The Casamance region is one of the most productive agricultural regions in the country; as explained in the climate rationale. The region benefits from higher rates of precipitation and relatively lower temperatures, allowing for the production of a variety of crops.
However, Kolda has one of the highest levels of poverty in the country; in 2011, it had a poverty rate of 76%[178], and in 2019, the percentage of poor households exceeded 91%. The region also has the lowest IWI score in the country (39.6), compared to the national average (60.3).[179] These poverty rates are exacerbated by a relatively high degree of wealth inequality; the region had a GINI coefficient score of 0.27 in 2019, and it is projected to increase to 0.29 in 2021.[180] Malnutrition is also considerably higher in Kolda relative to other regions.[181]

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[172] Global Data Lab. (2021) Mean International Wealth Index (IWI) score of region—Area

[173] Ibid

[174] PNA (2022)Study on vulnerabilities to climate change in the regions of Kaffrine, Kédougou, Matam, Saint-Louis and Ziguinchor: Analysis report on the vulnerabiltiies to climate change in the Kaffrine region.

French titel: Études de vulnérabilités approfondies aux changements climatiques dans les régions de Kaffrine, Kédougou, Matam, Saint-Louis et Ziguinchor: Rapport d'analyse de la vulnérabilité approfondie aux changements climatiques de la région de Kaffrine

[175] Ibid

[176] Ibid

[177] CNCR and IPAR (2020) Les ménages agricoles dans un contexte de changement climatique. https://www.africaportal.org/documents/20292/7_ieme_debat_dexperts_paysans_sur_les_impacts_du_covid-19.pdf

[178] Diop, O. B. (2018). *Social Protection and Poverty Reduction in Senegal.*

[179]Global Data Lab. (2021) % poor households Senegal —Table—Global Data Lab.

[180] Ibid

[181] Watch Us Work: How the Women of Rural Senegal are Fighting Drought, Hunger and Inequality. (2020). Heifer International.

There are also considerable, structural challenges that render it difficult for the population to lift itself out of poverty. Kolda has one of the highest school drop-out rates in the country, and this rate is even higher for women and girls, only 30% of which complete their secondary education.[182] The lack of educational opportunities acts as a key socio-economic barrier to people in Kolda, and the added stress of gender disparity in the access to basic, public services further adds to these pressures.

Ziguinchor's IWI indicates a below-average level of wealth (55.3), when compared to the national average IWI (60.3).[183] Wealth inequality is also relatively low (GINI:0.20) when compared to the national average (GINI: 0.27). This does not mean that there is considerable wealth that is relatively evenly distributed among the population; rather this more likely indicates that there is relatively even distribution of poverty in the region (as evidenced by the region's IWI score). Further, despite having a high potential for agricultural production, 37% of households in the region face food shortages each year, compared to the national average of 14% across all of Senegal's regions.[184]

Agricultural Baseline

Despite significant socio-economic challenges, the Kolda region hosts the natural infrastructure necessary for the region to become a high-producing region. There are considerable and accessible freshwater and groundwater resources through the Niandouba and Anambé dams, as well as the surface aquifers, which are 50m to 150m deep. This allows existing farmers to benefit from a plentiful water supply and will allow future Naatangue farmers considerable access to water resources to feed their crops. The region also has considerable access to agricultural fields, with nearly 14,000 km² of arable land. Rainfed agriculture remains the main field crop practiced in the region. Market gardening is practiced by 12.2% of agricultural households and fruit cultivation by 3.1% of agricultural households.[185] Irrigated crops excluding market gardening are practiced by 799 households. Almost all farms practice rain-fed agriculture (97%), with irrigated agriculture (excluding market gardening) during the dry season representing only 1.8%, ahead of flood recession crops of around 1.2%.[186] Farms in the Kolda region are essentially family-run. Most family farms (75%) have an average useful agricultural area (UAA) which varies between 1 and 5 ha. [187]

In Ziguinchor, agriculture is an important economic activity, and has the potential to scale-up its production due to its rich soil and favorable climate conditions for the production of various crops throughout the region. However, despite benefiting from ideal rainfall, soil and topographic conditions, rainfed agriculture is characterized by low yields, salinization and acidification of soils and groundwater, in addition to experiencing enormous organizational difficulties and access to

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[182] A programme of the Fundació Guné places gender parity in education at the centre of the Senegalese society. (2022). Nonprofit

[183] Global Data Lab. (2021) Mean International Wealth index (WI score of region—Table

[184] Malgré son potentiel, la Casamance fait face à des pénuries. (2014). The New Humanitarian.

[185] Tounkara, A., Ciss, PN, Ngom, M. and Camara, I. 2022. *Assessment of the vulnerability of the agricultural sector to climate change and identification of adaptation options for the Kolda region in Senegal. Report produced as part of the Food Security: Adapted Agriculture (SAGA) project.* Rome, FAO.

[186] Ibid

[187] ANSD (2014). RAPPORT DEFINITIF RGPHAE 2013

financing.[188] Due to the abandonment of agricultural fields due to political conflicts in the region throughout the last three decades, experts have not been able to quantify the number of agricultural fields that have been lost to salinization; further, agricultural development is stifled by a particularly important lack of access to basic farming equipment and agricultural inputs (fertilizer).[189]

Oriental region: Tambacounda
Social and economic baseline

The region's population is small relative to its size (640,000), with the majority of the population living in rural areas. Farmers in Tambacounda produce the country's main cash crops: peanuts and groundnuts. Despite being a major cash crop producer, the region suffers from a poverty rate of 61.4%.[190] Indeed, this high poverty rate is coupled with a high degree of food insecurity; national surveys have estimated that about 21% of households in Tambacounda face food insecurity.[191] The region also suffers from a relatively high degree of wealth inequality (GINI:0.30), and a relatively lower IWI score of 55.3 (compared to the national average of 60.3).[192]

Agricultural Baseline

Like most regions that will benefit from this project, agriculture the main economic activity in Tambacounda, with relatively diverse crops; the dominant crops being millet, sorghum and maize, while the cash crops tend to be limited to cotton and groundnuts.[193] The region benefits from access to the Gambia River and Falémé River systems, which can provide ample freshwater resources for irrigated agriculture. Recent projects funded by the African Development Bank in many regions, including Tambacounda, have contributed to improved livelihoods through the development of milk processing plants and diversification of income through agroforestry practices. This has allowed populations to increase their real income, and will also facilitate the introduction of the Naatangue model to a population that has already seen the success of similar interventions.[194]

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[188] ANSD (2018). *Service Régional de la Statistique et de la Démographie de Ziguincho* https://www.ansd.sn/sites/default/files/2022-12/SES-Ziguinchor-2015.pdf

[189] Malgré son potentiel, la Casamance fait face à des pénuries. (2014). The New Humanitarian

[190] *"Un centre d'excellence dans un système statistique national fort"* (1970) *Agence Nationale de la Statistique et de la Démographie (ANSD) du Sénégal*. Available at: https://www.ansd.sn/?option=com_ansd&view=titrepublication&id=40#:~:text=En%20ce%20qui%20concerne%20le,%25)%20sont%20les%20plus%20touch%C3%A9es (Accessed: April 30, 2023).

[191] National Agency for Civil Aviation and Meteorology of Senegal (ANACIM) (2013). WFP's Office for Climate Change, Environment and Disaster Risk Reduction, WFP's Food Security Analysis Service, Columbia University's International Research Institute for Climate and Society, and WFP Country Office in Senegal. Climate Risk and Food Security in Senegal: Analysis of Climate Impacts on Food Security and Livelihoods.

[192] Global Data Lab. (2021) Mean International Wealth Index (IWI) score of region—Area Database—Table.

[193] Sustainsahel—Area 3: Tambacounda. (n.d)

[194] Bank, A. D. (2022). Producers increase agricultural yields in southern Senegal thanks to the African Development Bank. African Development Bank - Building Today, a Better Africa Tomorrow; African Development Bank Group.

4. Addressing agriculture barriers: the Naatangué farm model

4.1. Overview of the Naatangué farm model

As previously mentioned, the Naatangué farm model can be applied at two different scales:

1. The family farm level

The Naatangué family farms (FFN) are a cross between the “Tôkkoor” (a Senegalese agricultural tradition) and the Brazilian experience of Integrated and Sustainable Agro-Ecological Production (ISAEP) farms. In the history of the agrarian system in Senegal, the "Tookkoor" which is a diminutive of the Wolof words "Took kër" which means "stay at home" represented small plots for off-season production around concessions or near a perennial water source (lake, river, backwater, etc.). These "Tookkoor" were important for food security with productions such as cassava and small livestock (farmyard birds, small ruminants), and served as a storage place for rainy season production (granaries). Naatangué family farms often cover an area of 1 to 2 ha and have individual ownership. The model is located on a 1 to 2 hectares expandable area, consisting of a well equipped with a pump using solar energy; a market garden on a 0.5 ha area; a fishpond of 280 m3; a chicken coop of 12 m²; a small barn; a raised water tank (1 to 5 m3); and a house allowing the farmer to live in the farm. They have an integrated character due to the diversity of the types of productions they offer (horticultural, dairy, poultry, fish, etc).

[]

2. The village level

Naatangué village farms (NVF) are modern farms of 5 to 100 ha with water control equipment adopting new technologies (drip, sprinkling etc.) and oriented towards horticultural and animal production. Having no baseline at the start, ANIDA has tested different village farm sizes to help determine the most manageable size for crop production farms and which also translates as an appropriate social size in terms of joint management and level of rural solidarity. A standard farm often occupies circa 15 ha and have 4 to 5 activities such as market gardening, arboriculture, fish farming, dairy production, chicken farming. These farms are built according to a standard model including a fence, a water point (borehole, filtering point, etc.), electricity equipment (electric pump, generator or SENELEC network, control cabinet), a cabin of pumping, an irrigation network (structuring network, fertigation station, surface network). Then producers from villages located within a radius of 3 to 5 km from the farm are “consolidated” into a farming unit delivering farming benefits for all village participants.
In the past and with support from donors 497 Naatangué farms (family (285) and community farms (212)) have improved agricultural practices in target areas by:

- Implementing efficient solar drip irrigation systems for off-season and winter crops, along with integrated plant and animal production. The availability of water throughout the year is also crucial for the development of fruit agroforestry.

- Promoting climate-smart agricultural practices that encourage the complementarity between animal and plant production, while promoting the rational use of by-products as organic fertilizer inputs.

- Improving farmers' living conditions by developing housing on the farm, which provides better access to water and solar energy.

- Diversifying agricultural production to enhance food and nutrition in rural areas, particularly for women and children. For example, cultivating an average of 18 crops per agricultural year, including onions, potatoes, tomatoes, peppers, green beans, okra, and melons.

- Focusing on the production of fruits, vegetables, and cereals in "Naatangué" farms and emerging agricultural areas, with an emphasis on export markets for higher valuation, such as green beans, melons, sweet corn, and butternut.

- Creating permanent and seasonal jobs for young people and women and providing them with training and development support to reap maximum benefits. []

The State of Senegal, has implemented major programs to improve, strengthen and modernize the agricultural production base through the policies defined in the Emerging Senegal Plan (ESP), in its component Program for Accelerating the Pace of Senegalese Agriculture (PAPSA). The Government of Senegal has chosen to prioritize highly strategic products for Senegal affecting the entire rural world, namely rice, onions, groundnuts and off-season fruits and vegetables. The strategic thrusts of the PAPSA include:

- Modernizing family farms and promoting sustainable management of natural resources.
- Encouraging the emergence of agricultural and rural entrepreneurship.
- Adopting an inclusive value chain approach through contract farming.
- Providing a diverse set of technical, economic, commercial, and organizational support services aimed at facilitating links between different actors in the value chains.
- Building resilience for populations vulnerable to climate change.

Since 2014, the National Agency for Agricultural Integration and Development (ANIDA), has contributed to achieving the objectives of the PAPSA, which constitutes the operational version of the agricultural component of the ESP. The year 2016 marks the start of the implementation of the performance contract that the Agency signed with the state of Senegal. Over the years, ANIDA has worked with national and international partners to promote the modernization of agriculture, the diversification of practices and the sustainable use of water resources, while delivering remunerative jobs for young people.

Despite budgetary difficulties experienced in recent years which have led to the termination of several work contracts and the reduction of operational programs, ANIDA still continues to fulfill its mission of supporting and advising farm producers. ANIDA remains as the co-Executing Entity in the realization of innovative, efficient, and environmentally friendly farm models in Senegal. For example, the Agency played a pivotal role in developing and implementing climate-resilient farming models, such as the Naatangué farm systems, throughout the country. As such, ANIDA has been chosen as a key design and executing partner to CSE to scale-up their successful climate-smart farming systems: Upscaling Naatangué farms.

The Naatangué farm model aims to modernize agriculture in Senegal by introducing advanced irrigation techniques and expanding agricultural areas, all while taking into account the challenges posed by climate change. The program provides farmers with comprehensive agricultural advisory services to facilitate diversified and integrated farm development, and offers guidance on climate-smart agriculture practices to promote sustainable farming and help build resilience to climate-related shocks. The Naatangué farm program is designed to be adaptable to two different settings: village and individual/family farm levels, while maintaining key commonalities across the implementation levels such as a focus on developing more resilient farming models that can better adapt to the challenges posed by climate change through diversification, focusing on increasing the productivity by modernizing irrigation techniques, practices and mechanization, and providing effective advisory and financial services.

Depending on the regional and local needs, the exact farming models are tailored to the specific challenges and barriers (including climatic and non-climatic), based on pre-feasibility assessments and learnings from previous tests to ensure their effectiveness. The criteria for selecting farms are the potential of the area, accessibility to water, and the local knowledge ANIDA's advisors have in the regions.

Since its creation as part of the Government's Programme for Accelerating the Pace of Senegalese Agriculture, ANIDA with the support of funding, has successfully established hundreds of "Naatangué" village and family farms with the aim of modernizing production and providing year-round alternative income for small producers. Table 7 below captures the successful testing and implementation of Naatangué related programs implemented in Senegal, and which serve as proof of concept, ready to be scaled up with further concessional finance.

Table 7. Naatangué projects and source of funding

Funding	Program	Funding value (CFA)	Farming villages Naatangué	Family farms Naatangué	TOTAL realizations
Consolidated Investment Budget (Republic of Senegal)	CIB	11,143,961,852	53	10	63
Morocco	Morocco	596,46,443	1	-	1
Spanish Cooperation	Spanish Project	6,000,000,000	10	-	10
	PAPEFI	1,312,000,000	-	105	105
Global Agriculture and Food Security Program (GAFSP)	PASA LOUMAKAF	4,600,000,000	46		46
African Development Bank (BAD)	PAPEJF	5,780,000,000	7	-	7
Italian Cooperation	PAPSEN	9,181,500,000	7		7
	PAIS			10	10
	P2RS		2	--	2
Brazilian Cooperation	PAÏS	300,000,000	-	10	10
The World Bank	PARIIS	1,325,000,000	12	-	12
	PPDC	1,330,380,000	27	-	27
European Union (EU)	PACERSEN	6,121,000,000	47	150	197
Total		**36009526443**	**212**	**285**	**497**

ANIDA had already developed 497 "Naatangué" farms resulting in sustainable subsistence and export agriculture, over 30,500 direct and seasonal jobs, and a strong demand for replication (ANIDA Performance Report, 2019).[195]

Despite the strong political will and support for upscaling the model, as well as producer's demand for support to move to the diversified and integrated system, demand for expansion has risen to a level that can't be met by ANIDA or the government with available resources. As of June 2019, the total number of farm applications received by the Agency since 2008 was 2,664 (an average of 266 requests per year). Even with the various programmes implemented with funding from different partners, the Agency was only able to reach 860 native farms by 2020, or only 32% of the total applications. Sometimes ANIDA can only provide advisory services from its team of agricultural advisers. This, combined with the high initial investment costs in equipment and training, and a private sector that is reluctant to finance agriculture because of perceived risks and slow return on investment, creates a financial gap that needs to be closed to support long-term climate resilience in the sector/regions. To meet the remaining demands and applications for Naatangué farms, various efforts are being made, including showcasing success of the Naatangué farm model and seeking for additional investment from both the government and donors.

Additional grant investment from the GCF can help bridge the previously mentioned gaps and provide critical support and scaling for this innovative model through an alternative pathway that can facilitate creating additional investor confidence for the private sector over time. Further, investment and coordination and training support offered through experienced partners, such as ANIDA, can help scale up this approach to climate resilient agriculture and support its integration into other projects, programs, and policies by playing a convening role and driving a paradigm shift in the Senegalese agriculture sector.

4.2. The value proposition of Naatangué farms and paradigm shift

The value proposition of the Naatangué farm model in Senegal compared to traditional Senegalese farming practices lies in its systematic use of localized irrigation, diversification and integrated approaches and capacity building procedures adapted to the economic and financial environment. The Naatangué farm model promotes sustainable agriculture practices that focus on improving soil fertility, water management, and crop yields for smallholder farmers. The use of localized irrigation enables farmers to access groundwater through renewable energy sources, which allows them to work all year round and mitigate the effects of climate change. In addition, the adoption of high-yield technical itineraries helps to increase production, while management procedures adapted to the economic and financial environment ensure the sustainability of the project in the long term. High-yield technical itineraries are designed to maximize yields and promote sustainable agriculture practices. These itineraries are specific to each crop and consider factors such as soil type, climate, and water availability, thus making the approach adaptable to achieve the maximum likelihood of success.

Compared to traditional-type farms, which typically focus on rain-fed crops for a short period of time and have limited water control (usually 4 months), the Naatangué farm model offers a more sustainable and diversified approach to farming. The model enables farmers to cultivate a variety of crops, including cereals, vegetables, and fruits, which provides a good way to adapt to the effects of climate change affecting the agricultural sector, compared to the traditional farms which tend to focus on cereal or cash crops such as groundnuts and cotton, thus having higher exposure to climate hazards. Additionally, Naatangué farms provide opportunities for rural communities to improve their incomes and livelihoods by participating in a range of value-added activities, such as

[195] ANIDA (2020) Rapport d'Activités 2019.

processing and marketing their products.
The development of the Naatangué farms has had several positive impacts. Naatangué farms contribute to the resilience of the agricultural sector to climate change by diversifying crops and increasing overall production, making them a source of wealth creation in the primary sector. Horticultural production is increasing year by year and is spreading to all regions of the country. It is increasingly a source of wealth creation in the primary sector with an increasing diversity of cultivated speculations. This diversification provides a good way to adapt to the effects of climate change affecting the agricultural sector. Fruit arboriculture is also becoming increasingly established on farms, contributing to income diversity. Green bean production is practiced on many farms, particularly in the western zone, where every year hundreds of tons are transported to European markets.[196]

Naatangue farms are also innovative approach to agriculture that can lead to reduced costs due to synergies across activities and utilization of by-products. These farms integrate multiple crops and livestock activities, allowing for efficient use of resources and the use of organic fertilizers, which are often more cost-effective than synthetic fertilizers. This is particularly important as the prices of synthetic fertilizers remain high and volatile, making them a significant expense for farmers (see Figure 11 below). By using organic fertilizers, Naatangue farms can reduce costs while also improving soil health and reducing the environmental impact of agriculture.

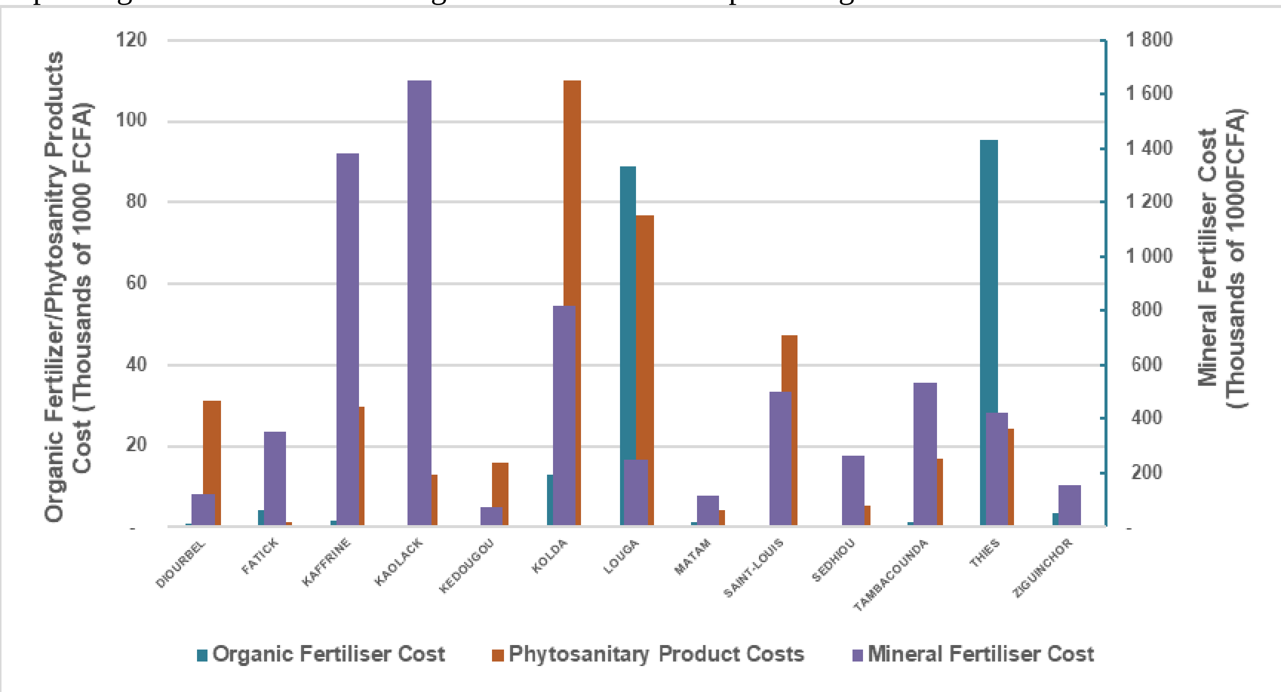

Figure 11.Comparison of input costs in Senegalese farms across project intervention regions[197]

Lastly, a novel element of the Naatangue farms is its emphasis on the mobilisation, consolidation and pooling of resources at the community and project level. This promotes collaboration and locally led adaptation actions to foster trust and social cohesion, reduce risks, and increase resilience, especially for smallholder farmers. Once involved in Naatangué farms, farmers are empowered, trained and capacitated to organize themselves to form economic interest groups and cooperatives, and manage the farms and value chains. For example, by consolidating individual farms into larger plots managed collectively as a village farm, the project promotes the implementation of sustainable

[196] ANIDA (2020) Rapport d'Activités 2019.

[197] Archivage national des données du Sénégal (ANSD). (2023), Enquête Agricole Annuelle (2021-2022) Senegal, 2021-2022. https://anads.ansd.sn/index.php/catalog/?page=1&sk=engrais&collection%5B%5D=AGR&ps=15

agricultural practices, such as agroforestry and intercropping, and facilitates access to markets, inputs, and financing. Similarly, the community-based savings fund allows farmers to pool their resources, reducing the risks associated with individual farming operations and enabling them to benefit from shared resources.

The Naatangue farm model offers an unconventional, successfully tested sustainable and inclusive approach to small-scale agriculture in that promotes diversified production, climate-smart practices, and community-based financial sustainability compared to other farming models available across the country.

Figure 12. Data used in determining water availability on Naatangué farms[198]

[198] Extract from the National directory of hydraulic structures

The comparison of the different options in the Technical Assessment shows that irrigation using solar energy has more advantages and less disadvantages. Diesel-Powered Irrigation and Grid-Powered Irrigation use fossil fuel sources which contribute to GHG emissions. Even if their initial investment is lower than that of solar irrigation, the latter has lower operating costs. The expenditure on fuel or electricity, accounting for as much as 40% of operational expenses, coupled with the potential for power outages and fuel scarcity leading to operational disruptions, highlights the increasing significance of rising fossil fuel costs in light of the declining prices of renewable energy sources. Therefore, solar irrigation is more profitable in the long run. These options make it possible to grow crops all year round and increase income. Rainfed Agriculture does not allow crops to be grown all year round and is very exposed to uncertainties related to water availability. If the financial resources are available to overcome the high investment costs solar drip irrigation will offer high replication capacity and is easy to implement with the technical assistance of ANIDA. The co-benefits are also important because farmers can use solar energy in their homes and in their other activities: lighting of habitats, poultry houses and dairy farms, kiosks, powering refrigerators and solar tricycles. This option allows an increase in production and income.

4.4. Eligibility Criteria

In this subsection, we aim to clarify the process and criteria used for the selection of beneficiaries in order to ensure an equitable and effective allocation of resources. Eligibility criteria vary between the typology of farms:

- For family farms, the selection of beneficiaries is demand-driven. A request is sent to ANIDA by the person who wishes to benefit from this type of farm. The person must have land and have already started their activities. This ensures that the beneficiary has a clear idea of what he wants to do and that the resources granted will be used well. The selection proves will favor young people (up to 50 years old) and women. However, other segments of the population are not excluded. The beneficiary must provide a clear description of the planned activities. The availability and quality of water in the locality are also taken into account as previously mentioned, as well as equitable geographical distribution. Given the previously success of the Naatangue family farm model and the active number of requests for support, the implementing organization is confident that there will be a strong pipeline of family farms requesting support to become integrated as Naatangue practices.

- For village farms, a request is sent to ANIDA by a local authority: mayor, village chief, etc. The land for the realization of the project must be allocated to the State through ANIDA. Land allocation is carried out by the town hall, which is a key player. If a village chief makes a request, he will have to approach the town hall. The equipment that will be put on the farms remains under the property of the state. ANIDA can transfer the equipment to the communities on condition that the activities continue. If the activities cease, the equipment reverts to the State (ANIDA). The communities take care of the maintenance. Another selection criterion is the composition of the farms in the village and demographics such as availability of young people and women who agree to be active in the project. The availability and quality of water in the locality are also taken into account. Given all these constraints, the implementation agency already has identified and pre-selected the beneficiary village farms (please see Annex 2h for more details such as the geographical distribution, number of active members in the village farms, and gender breakdown).

5. Project activities and baseline indicators

5.1. Overview of project components and project-wide indicators

This project seeks to reduce the vulnerability of small producers and family farms to climate change through the modernization and intensification of production systems, as well as through the better integration of opportunities for Naatangue's agro-silvo-pastoral system into small farms. Specifically, the project aims to:

- Establishing resilient village and family farms for sustainable agriculture (Component 1);
- Diversifying and improving production and income through integration of resilient agroforestry (Component 2);
- Empowering farmer entrepreneurship through market integration and accelerating new agricultural markets (Component 3).

Each of these of these components are interlinked with one another. Components 1 aim to provide the equipment and infrastructure needed for farmers to adopt the Naatangue model. Component 2 aims to shift practices towards climate smart agriculture through the incorporation of trees on farms. Component 3 serves to render Components 1 and 2 completely operational by lending both technical training and marketing support to ensure that what farmers produce is successfully and easily sold onto markets. The project aims to increase the resilience of Senegal's agricultural sector, particularly small-scale producers, to the impacts of climate change (ex: droughts, flooding and loss of arable land). The project will be implemented in areas with high agricultural potential located in the regions of Thiès, Saint-Louis, Louga, Tambacounda, Kolda, Kaolack, Kaffrine and Ziguinchor. In total, the project is expected to impact 46,940 direct beneficiaries.

Key project level indicators: Baseline and overall impact

Specifically, the project aims to achieve the following:

- The project aims to establish 100 new Naatangué family farms. ANIDA has already developed 285 family farms over many years, with the support of other, international donors (Spanish Agency for International Development Cooperation/*Agencia Española de Cooperación Internacional para el Desarrollo*). Previously funded projects demonstrated the success of the Naatangue model, which is why ANIDA, through CSE as accredited entity and with support from GCF, now seek to scale-up the Naatangue model.
- The project also aims to climate proof 40 Naatangué village farms, from already established individual farming units. For five identified village farms that have existing cattle operations, the project will support the development of milk processing units to improve existing farm operations. Both poultry and cattle operations supported by the project will also be accompanied by waste recovery and organic fertilizer activities to unlock additional value streams and minimize environmental externalities from project activities. These activities will be implemented on 536 ha of farmland. The overall goal of these activities will be to reinforce the financial independence of existing village farms, which will not only help to improve livelihoods and income, but will also enable the advisors/trainers currently supporting these farms to expand their engagement, and further-scale up the Naatangue model to others.

- Regarding job creation, the target in 2019 was the creation of 40 000 direct and indirect jobs through 214 Naatangué farms. Women represented 40% of the workforce selected on farms in 2019.[199] This project also aims to create jobs, and ensure that at least 50% of the direct beneficiaries are women.

- Quantity of GHG emissions avoided: Agriculture is responsible for 45% of GHG emissions in Senegal. Quantity of GHG emissions avoided: Projections show that Greenhouse Gas emissions from agriculture will increase from 2010 to 2030 (Table 6). However, this increase in emissions can be mitigated should local investments in emission-reduction measures be made that would allow for a paradigm shift in the way in which energy is sourced and used in the small-scale agricultural sector. Investment in component 1, which is one the larger investments of the project, would allow for the integration of solar-powered irrigation pumps in villages and family farms. The activity would provide immediate carbon mitigation benefits by providing the necessary equipment, expertise and training for the replacement of diesel-powered pumps on farms with solar-powered systems. This will deliver immediate carbon mitigation benefits by avoiding emissions in the future, while also providing co-benefits to farmers through the avoided cost of fuel, which is expected to increase over time. The baseline scenario of having farms continue to use fossil-fuels to power pumps and other farming equipment will lead to greater greenhouse gas emissions, and reduce the real income of farmers in the long-run. While national plans (such as the country's NDC and National Adaptation Plan) will provide the legal framework and targets to achieve mitigation and adaptation objectives, GCF financing would provide the technology and training farmers will need to reach the country's ambitious climate commitments. There are also sequestration benefits expected from Component 2 activities, but those are minor compared to the switch to solar water pumps.

Table 8. Projection of emissions in the agriculture sector in Senegal until 2030 (Gg CO2e)[200]

Year	2010	2015	2020	2025	2030
GHG Emissions	7,354	8,323.9	9,110.7	9,903.4	10,600

[199] ANIDA (2019). Rapport de Performance

[200] Diouf SARR, M. (2020). NATIONAL DETERMINED CONTRIBUTION ON CLIMATE CHANGE OF SENEGAL.

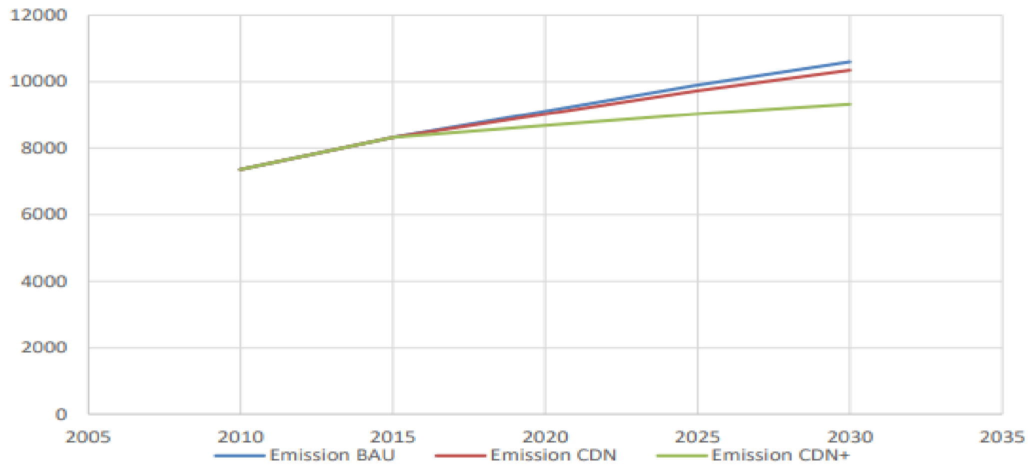

Figure 13. Projections of emissions in the agriculture sector until 2030 in a business-as-usual scenario (blue) compared to scenarios with national investments (red) and international investments (green)[201]

5.2. Breakdown of activities and their expected impact

This section provides an overview of the proposed activities, and their expected impact against identified barriers (see Table 9 for a general summary). Further details on each activity are included in the Technical Assessment.

5.2.1. Component 1- Establishing Naatangué farm models for sustainable agriculture in 8 regions

Village farms

The project includes several activities aimed at improving productivity and sustainability by consolidating and pooling individuals into integrated village farms. A total expected 40 village farms will be established across the country. As part of the consolidation exercise, the proposed project will acquire and install solar equipment for drip irrigation for the village farms, including preparing tender documents, carrying out technical analysis for testing water availability, and awarding contracts for the acquisition of a solar pumping system, and 4,622 solar panels of 260 watts each for 40 farms to be established. The equipment will be installed, and beneficiaries will be trained in its use and maintenance. Deploying solar energy on farms can result in significant energy and cost savings by avoiding diesel costs, thereby improving farmers' resilience and adaptive potential, while providing a greenhouse gas mitigation benefit through diesel combustion The second activity involves integrating poultry farming into six consolidated village farms. This includes constructing a 200 m² capacity chicken house, purchasing equipment and accessories, and buying 2000 broilers and 60W lighting lamps. Producers will be trained on good practices, including the use of poultry waste in market garden plots, to increase income and improve sustainability. A complementary activity involves establishing chicken processing units, which will include a refrigerator, feather remover machine, cutting material, and biodegradable packaging bags, and tricycle for transport. Introducing henhouses on consolidated farms diversifies productive activities, leading to increased income for producers, albeit with a greater time

[201] Republique Du Senegal. (2022). CONTRIBUTION DÉTERMINÉE AU NIVEAU NATIONAL DU SENEGAL. https://unfccc.int/sites/default/files/NDC/2022-06/CDNSenegal%20approuv%C3%A9e-pdf-.pdf

commitment. Strengthening the value chain through training in good practices, particularly in the valuation of poultry waste for use in market garden plots, helps to reduce conservation challenges that drive down product prices. The processing of these products further increases producer income, benefiting a larger population.

The fourth activity is the establishment of solar-powered milk processing units for three dairy farms. This will involve the acquisition of solar panels, cooling systems, refrigerators, packaging machines, and training on dairy processing. The processing units will improve the income and resilience of producers and help to avoid health contamination and quality problems in already established dairy farms.

The last activity proposed under the integration of village farms involves the establishment of compost pits for waste management and recovery of organic fertilizer. This includes the construction of three pits per farm with 4 m² and a depth of 0.5 m, collection of biodegradable waste for filling, and training of producers on composting techniques. The composting techniques will improve soil productivity on farms and protect the environment from degradation.

Family farms

The project's first activity is to select 100 family farms, using data from ANIDA's database of submitted application. A selection committee will evaluate the requests against pre-defined criteria, including age (youth favoured), gender, land ownership, and legal formalization. Upon receipt of the files, the project will define the specific elements required for the beneficiaries' farm activities, such as market gardening, arboriculture, or animal production. This activity aims to ensure that the beneficiaries meet the criteria and have access to the necessary resources for a successful farm.

The next activity proposed aims to create and support Naatangue family farms in the intervention areas, providing beneficiaries with necessary resources to increase productivity and income. The project will accomplish the following tasks after selecting sites and establishing contracts/technical files:

- Build a wire fence on one hectare with a living hedge
- Install drip irrigation on 0.5 ha area with 400 micron ducts, 2 litres per hour flow rate, and 1 bar pressure
- Build storage room, caretaker's room, and toilets
- Build water points with wells up to 30m deep
- Install solar equipment including a 1.5 KW photovoltaic station and 1 solar pump (45m3/day) with 6 solar panels
- Undertake tasks for livestock production based on identified needs, such as building a 12 sqm chicken house with 120 broilers or 60 layers, procuring livestock equipment and accessories, and developing a 280 m3 fish pond filled from well water with initial purchase of fry and feed.

For each new farm created, farmers will be asked to enter into a Public-private Partnership to contribute to a community-based savings fund. The self-funded scheme will provide financial support to small-scale farmers for farm modernization, equipment acquisition, maintenance, and crop treatment. The scheme's investments will also contribute to providing a guarantee for traditional financial institutions and will be used to finance the operation for the beneficiaries, including supporting with maintenance cost of farm equipment, thereby generating long-term sustainability for the initial investments. This activity will provide a sustainable financial system for small-scale farmers, enabling them to maintain and expand their farms. GCF funding will be used to help establish the structures of the scheme, but no GCF funds will contribute to the scheme.

Lastly there is an activity planned focused on monitoring and controlling the different productive farm elements introduced by the project, including the small solar irrigation pumps for improved water control to overcome learning curves and unexpected vulnerabilities. A joint ANIDA team, including a rural engineering engineer, an agronomist, an environmentalist, and other specialists, if necessary, will be deployed to ensure quality work and compliance with environmental clauses.

5.2.2. Component 2 - Strengthening the capacity of agricultural advisors and smallholder farms

Under Component 2, agroforestry techniques and waste management are proposed to strengthen and diversify productive bases for rural farmers through the introduction of climate-smart practices. This activity aims to improve production and income for farmers while promoting the use of natural fertilizer and reversing the tendency of agriculture to reduce forest areas in favor of extending agricultural land. Additionally, agroforestry techniques have the potential to contribute to climate sequestration, making them an important tool for greening the agriculture sector.

Under this component, the project aims to develop activities to strengthen the capacities of ANIDA agricultural advisors by providing training on domesticating high-value forest fruit trees, agroforestry resilient practices, and climate-resilient agroforestry technological packages. This will enable the advisors to train producers and facilitate decision-making based on local climate data, thereby improving resiliency, increasing productivity, and reducing greenhouse gases. Another activity is the training of producers on climate-smart technologies and practices, such as integrated land, water, pest, and nutrient management, as well as the PICSA approach and farms of the future. This will help producers make informed decisions and reduce the risks associated with climate change. The project also aims to promote resilient agroforestry practices, such as windbreaks/hedgerows, alley farming, improvement of soil fertility, and diversification and integration of production, to enhance the productivity, diversity, and resilience of Naatangue farms. Finally, the production of seedlings of priority forest fruit trees and the introduction of resilient agroforestry technologies through the Farmer Field School approach will contribute to increasing the diversity and productivity of Naatangue farms, creating new economic opportunities for producers and promoting knowledge-sharing in local communities. Overall, these activities aim to build capacity for resilience and adaptation to climate change, thereby improving the sustainability of agricultural systems in the region.

5.2.3. Component 3: Empowering farmer entrepreneurship through market integration and accelerating new agricultural markets

Component 3 have a suite of activities aimed at successfully enabling the previous activities by investing in capacity building, support, opening new market opportunities, and formalising industrial organisation structures in the sector.

One activity relates to the training of agricultural advisors on value chains (NTFPs, vegetable products, etc.), organizational dynamics, and marketing. The objective of this activity is to provide training to 40 agricultural advisors on various aspects of agricultural value chains. This training will equip the advisors with the necessary knowledge and skills to properly implement the training modules, which will focus on different aspects such as poultry production, dairy, market gardening, farm maintenance, and maintenance of solar and agro-equipment, good practices (composting, safe use of pesticides), and water management for irrigation. The targeted trainers are the agricultural advisors who are deployed in each of the village farms. Once trained, the advisors will be able to redeploy these trainings to the industry associations of the farms (in particular 80 economic interest groups). The training modules and material provided will enable the advisors to effectively transfer the knowledge to the farmers, which will ultimately lead to an improvement in their production techniques and increase their income.

Another activity is aimed at building in Organizational Development and Entrepreneurship. The main objective of this activity is to address the organizational limitations of producer organizations, which have weak management, especially financial management, and an inability to sustainably use the investments made available to them. The activity will design trainings for organizational development, financial education, farm maintenance, maintenance of agricultural equipment and infrastructure, adoption of good practices, and value chain development. The training plan will be developed based on the needs of each farm and will be implemented by ANIDA with the support of internal and external experts. The training will be evaluated twice to ensure that the practices taught are being utilized by the farmers.

Establishment of cooperatives is another core element of Component 3, with the goal of establishing farm cooperatives in specific coordination/aggregation areas to reduce the burden on individual farmers by facilitating group sales and purchases, joint management of equipment, and the search for financing. The activity will involve elaborating terms of reference and a concept note, holding information and exchange meetings at the farm level, drafting statutes and internal regulations, and creating a committee through voting amongst the representatives. The establishment of agricultural cooperatives will result in the information and sensitization of producers, as well as training and preparation on the labelling of their products. The establishment of cooperatives will lead to better market access, fair prices for their products, and reduced production costs, ultimately leading to an increase in the farmers' income.

Finally, marketing support for farmers will include monitoring food prices, directing production towards better selling products with controlled production pathways, and partnering with wholesalers, retailers, and processors. The support aims to increase profitability and reduce risks by facilitating sales, promoting standardization of practices, and defining a long-term strategy for sustainable development. Core elements include monitoring food prices, connecting with markets, organizing leases, supporting processing and sales, and creating innovation platforms.

Table 9 Summary of Barriers and activities

Need	Barriers	Solutions	Activity	Baseline	Impacts
Reinforcement of institutional and private actors in the agricultural sector	Lack of engagement of potential beneficiaries in a collective finance system due to the absence of the instrument and lack of involvement of financial institutions in the management and hosting of a common agricultural fund for small-scale farmers Farmer's over-dependence on financing from agricultural campaigns	Community-based savings fund Cooperatives Financial agreements Formalizing and structuring existing processes Forums for dialogue between farming cooperatives and national, financial institutions to provide advice on risk mitigation for farm-level investments	Activity 1.1.3. Establishment of revolving savings funds Activity 3.1.3. Establishment of cooperatives	Excess demand from private actors (farmers) to join the Naatangue farm model Lack of financial instruments to provide financial and technical support to farmers	Savings Fund will allow future farmers to join the Naatangue farm model and existing farmers Farmers will benefit from a self-sustaining fund that will not be reliant on future public expenditure
Affordable and renewable energy sources for agricultural production	Inadequate access to affordable, productive equipment and training on PV systems	Provision of solar PV systems will reduce the long-term operating costs and GCF funding will provide the necessary start-up capital for the installation and use of PV systems in irrigation	Activity 1.2.1. Acquisition and installation of solar equipment (solar pumping system, fences, 4,622 solar panels, company to ensure the delivery of related works)	Farmers continuing to use costly energy sources which limits their income to diversify their farms, procure food for subsistence needs and access public services (health, education)	Carbon emissions will be mitigated Farmers will have greater disposable income Water use will be more efficient through drip irrigation compared to manual watering or hosing of crops (achieving climate adaptation goals)
Diversification of Incomes	High dependency on vulnerable production methods (monocropping), and are highly exposed to climate and non-climate shocks. Lack of access to affordable, high-quality equipment and training on improving current operations of existing milk	Provision of equipment and training on modernized poultry farming, dairy production practices, and fish farms.	Activity 1.2.2. Establishment and integration of poultry farming (acquisition of chickens, construction of the building, acquisition of equipment, accessories and inputs, fishponds) Activity 1.2.3. Establishing of chicken processing units Activity 1.2.4. Establishment of milk processing units (3)	Farmers generally have one source of income (monocropping) that are highly specialized, which will make them more vulnerable to climate change as temperatures rise and as rain becomes more erratic (see climate rationale) Farmers may be reticent towards systemic change	Farmers will diversify their existing operations and improve on the quality and quantity of their existing production

	and poultry production practices			without financial support and training	
Organic Waste Management and Recycling	Inadequate access to organic waste treatment and recycling equipment and training on techniques for recapturing and repurposing organic waste	Provision of organic waste recycling equipment and training on their use (composting, biodigesters…etc.)	Activity 1.1.4. Monitoring/control of productive works Activity 1.2.5. Establishment of compost pits for the management and recovery of waste and sale of organic fertilizer	Farmers will continue to emit GHG gases (methane, nitrous oxide) from poor waste management. Farmers will not be able to utilize recaptured waste to improve their agricultural production	Farmers will improve the overall functioning of their farm by supplying an additional, cost-effective alternative to synthetic fertilizers that will support crop production
Adaptation to climate change/ Reinforcing resilience for farmers	Lack of knowledge and initial capital to improve farming models through the integration of agroforestry	Provision of equipment, natural capital and technical assistance (training and site-visits) on agroforestry techniques in the form of fruit trees and hedgerows	Activity 2.1.3. Promotion of resilient agroforestry practices Activity 2.1.4. Domestication of priority forest fruit trees Activity 3.1.2. Organizational analysis of producer associations and capacity Building in Organizational Development and Entrepreneurship	Agroforestry systems have worked in the past, but access to training and marketing services is not widely available Without funding, farmers would be reticent to risk the financial commitment of adopting agroforestry techniques Farmers are more exposed to natural disasters, droughts and floods without natural barriers and inputs to improve the resilience of the farm	Farmers benefit from reinforced farming models (Naatangue) that allow for adaptation to worsening climate conditions (rising temperatures) and the increasing incidence of natural disasters (flooding, droughts, storms…etc.) Farmers benefit from a tailored approach from agricultural advisers on the best combination of Naatangue activities with the constraints of a specific farm's specificities
Formalize and improve the organizational capacity of farmers and of public and private institutions	Weak capacity and organization of community actors to leverage information on climate impacts, implement climate resilient practices, access markets, and develop a viable value chain Lack of capacity on marketing of agricultural products	Provision of agricultural extension services through site-visits, workshops, training manuals and monitoring/evaluation follow-up visits on farm sites Create infrastructure and organization of cooperatives to allow farmers to leverage a stronger, collective position that will allow for improved engagement between farmers and financial institutions	Activity 3.1.3. Establishment of cooperatives Activity 3.1.4. Marketing support	Farmers may be reticent towards systemic change without financial support and training	Farmers benefit from access to new social and economic structures that allow for them to engage with the private sector more efficiently and formally Farmers gain access to information on prices and climate forecasts, and to marketing/selling points for their goods

		Marketing support in the form of training and online resources on improved farming practices, price of raw goods, and access to points of sale			

5.2.4. Addressing localized needs and opportunities

The Naatangue model will be implemented on selected farms, depending on their infrastructure and specific needs. Some farms will receive most of the outlined activities, while others may only receive a subset. The selection criteria for beneficiaries will depend on the type of activity and the availability of physical and natural capital, such as equipment or water resources. The Technical Assessment provides more information about the feasibility of each activity.

Annex 2 provides a detailed breakdown of the identified village farms that will be consolidated, along with a mapping of activities for each location and region. This annex also includes information on the typology of beneficiaries.

5.3. Project management risks

The Naatangué farm model, despite its previous successful testing and high demand for its continuation, still has potential project management risks that could affect the implementation of the project. One such risk is the possibility of equipment and contractor failures, which can lead to delays in completing the work requested within the specified timeframe. For example, in 2016, six out of 43 planned farms were not carried out due to failures of the companies in charge of developing irrigation networks and boreholes. Budgetary constraints for ANIDA and farmers also pose a significant risk, as ANIDA may lack control over state allocations for the agency and has given up feasible activities due to insufficient budgets. Farmers may face difficulties in mobilizing credit financing and may have to sow within the limits of their financial possibilities, leading to delays in the establishment of crops.

ANIDA has learned to prevent and manage these risks over time and will choose the most reliable equipment and companies for an adequate implementation of the project. Their experience allows them to select the most reliable equipment and companies for an adequate implementation of the projects and have technical experts on the ground. In addition, CSE will oversee the implementation of the project and will make sure the GCF requirements and expectations will be met.

SECTION III: TECHNICAL ASSESSMENT

The goal of this document is to provide a technical assessment of the different activities outlined in the project proposal. The technical assessment document is a critical component of the GCF funding proposal, which provides a comprehensive analysis of the proposed project's technical aspects. This technical assessment compares each of the respective activities with viable alternatives to the activities (selected based on current practices or alternatives used elsewhere), as well as the feasibility of implementing said activity in Senegal, with respect to multiple criteria such as cost, scalability, ease of up-take/ implementation, impact on agriculture production, co-benefits, impact for climate adaptation an mitigation, and whether the activity is future-proof for future climate change.

The primary focus of the technical assessment is to explore the different modalities under which the proposed activities take shape. The technical assessment also analyzes whether the proposed options are feasible, affordable and whether they can deliver maximum impact for farmers in terms of production potential and provide a resilient farming structure that will allow them to adapt to and mitigate climate change.
Various sources from national, climate analysis to international case studies of the proposed activity and its alternatives were used to inform this analysis. This analysis also uses the information that emerges from the climate rationale and baseline assessment to assess the extent to which the proposed activity should be implemented across the targeted regions, or in a selection of the targeted regions. Ultimately, this document will provide the necessary information to understand the impact, need and feasibility of implementing the various activities in Senegal, as well as what can be done to address implementation challenges.

This section provides a comprehensive assessment of various water harvesting and saving options for agriculture, including a justification for the selection of solar-powered irrigation systems in Naatangue farms. This assessment should be read in conjunction with the Climate Rationale and Baseline assessment document, which covers an evaluation of the irrigation's impact on water balance availability to ensure sufficient freshwater resources resulting from the project's activities. This section focuses on activities diversifying farms to enhance production through integrated farm systems and includes a technical assessment of proposed activities, such as poultry houses, milk production units, and fishponds. Section 4 explores the incorporation of trees on farms through forestry, inclusion of fruit trees and agroforestry techniques. Finally, Section 5 centers on supporting producers technically and financially to promote farm-level entrepreneurship and train them on best practices to maximize the benefits of the Naatangue model. It outlines the establishment of a community-based savings fund, and marketing support and training activities[202].

[202] Marketing support and training activities are evaluated to a lesser extend due to being outside the scope of work. However, due to their importance and complementarity with other activities, they are briefly mentioned in Section 5.

1. Water harvesting and solar irrigation assessment

1.1 Solar-Powered Drip Irrigation

1.1.1. Description

Solar-powered drip irrigation is encompassed within the following activities of the logical framework of this project: 1.1.2, 1.1.4, and 1.2.1. Solar-powered drip irrigation is a tried and tested pillar of Naatangue farms that has not only been successful in supplying farmers with an adequate supply of water for their crops, but also in reducing farm-level operating costs and using water more efficiently. In the context of this project, the goal of implementing this activity is both to mitigate emissions from current practices that use diesel-operated pumps, as well as to create additional income opportunities for farmers from the avoided costs of manual pumping, fuel-sourcing, as well as other costly farming practices without project intervention. The activity also aims to ensure that water is used efficiently, especially in water-stressed areas that may see less rain in the coming in the decades (see Climate Rationale).

This activity is composed of two parts which play distinct roles in helping farmers improve their supply of water, save costs, and reduce emissions. The first component is comprised of solar panels, which use solar energy to pump water from underground resources. The second component is the drip irrigation system, which conservatively uses water to meet the needs of the crops and soil in which they grow and mitigate the loss of water from run-off and evapotranspiration. Together, solar panels capture the sun's energy, and convert it into electrical power to run a pump that moves water from a reservoir to the irrigation system. The water is then delivered through a network of tubes that deliver water directly to the plants' roots. By combining drip irrigation with solar energy, farmers benefit from a reliable and cost-effective way to water their crops, improve their yields, and reduce their fixed and operating costs, all the while delivering carbon mitigation benefits.

Sources of energy to pump water for drip irrigation come in different forms, both in terms of how the electrical system is set up and in the way in which water is distributed to crops. The delivery of solar energy can be battery-operated, sourced directly from solar panels to the pump, or rely on grid-based solar energy. Depending on the type of Naatangue farm, (family or village), these systems can have different advantages; in the context of this project, however, energy will be directly sourced from solar panels, without the use of grids or costly energy storage (battery) systems.

Farm-level assessments are critical in determining the appropriate water delivery systems required for specific farms. ANIDA's local experts possess the technical expertise to conduct these assessments and identify the correct configuration based on a farm's layout, such as linear or non-linear rows, varying slopes...etc. With their extensive experience in this area, having conducted similar assessments in other donor programs[203], ANIDA's local experts are equipped to identify optimal solutions for farms. It is important to note that regardless of the type of solar-powered drip irrigation system selected, the benefits remain consistent; this technology provides a sustainable way to source water for crop production, minimize groundwater waste, improve

[203] Agencia Española de Cooperación Internacional para el Desarrollo (AECID). (2020). Anexo I: Descripción de la acción. PACERSEN. Agencia Española de Cooperación Internacional para el Desarrollo (AECID)

efficient water use and farm yield, and deliver carbon benefits by replacing existing diesel-pump systems (further discussed below). This system will also be in line with the other activities outlined in this project; solar panels will also be used for milk production and chicken processing units, increasing operational and cost efficiency. In the context of this project, the installation of solar-powered drip irrigation will have the following specification, shown in Table 10 below.

Table 10. Specifications of the project-level equipment needed for solar-powered drip irrigation

Designation	Cost	Technical specification
Example of the solar pump system of the village farm of Tivaouane Peulh		Total photovoltaic area of the farm of Tivaoune peulh = 7,800KW NB: Tivaouane peulh has 300w (26 panels) **Example of the design for the farm of Tivaouane Peulh**: **Pump**: voltage = 380volts; Amperage: I = 17A; **Variator**: VOC = 750 volts; Amperage: I =17A; **Panel**: VMPPT =31,39 ; IMP = 9 Ampere 2 rows of 13 panel alongside **Depth (HMT)** = 50m; **Flow of the pump** = 30m^3/h; **Power of the pump** = 7,5 Kw; **Surface area** = 5ha
Solar pumping system for a village farm with a drilling depth higher than 50 meters	**40,665$** for one farm **1,626,600$** for the 40 farms that need to be consolidated through the project	The power of the photovoltaïc area depends on the power of the solar pumping. For example: for a pump of 18,5 KW the power needed for the photovoltaic area is 23,4KW Example of design: 1. Pump: - Voltage = 390 to 400 Watts - Amperage = 38 Ampere = 2. Variator: - VOC = 620 to 750 Volts; - Amperage = 38 Ampere 3. Panel: - VMPPT = 31 volts IMPPT = 8 Ampere To have 38 Ampere and a VOC of 750 Volts, we need 18 rows of solar panel. In detail it will be 18 panel and 5 rows alongside. **Depth** = higher than 50m ; **Flow of the pump** = between 30 and 60m^3/h ; **Power of the pump**= between 7,5 and 18,5 Kw ; **Surface area** = between 5 and 15ha
Solar pumping system in the family farm with a depth not more than 50 meters	**800,000$** for the 100 family farms	Purchase of water pumping system with a photovoltaic station and a solar pumping: **10 solar panel of 260w**; **1 solar pump =** 40m^3/day); **Flow** = 5m^3/h; **Power** = 1,5Kw: **Surface** = 0,25ha; **Depth less than** 50m^3

1.1.2 Technical assessment of the activity and its alternatives

In conducting the technical assessment of proposed irrigation systems, different technologies and designs are evaluated and compared including the expected impact of the proposed technology and their alternatives. This evaluation was aimed at identifying the optimal irrigation system that would maximize water efficiency and ensure sustainable practices. We considered factors such as the potential impact of each technology and design on crop yields and the environment, as well as the associated costs and feasibility of implementation. Through this process, we aimed to identify the irrigation system that would best align with project objectives, meet technical and financial requirements, and ensure the greatest possible impact.

Expected impact on agriculture and future-proofing production capacity

Solar-powered irrigation has the potential to be highly effective for Senegalese agriculture, especially as rain patters becoming more erratic per the historical analysis of the climate rationale. Irrigation allows for crops to have a constant flow of water no matter how dry the conditions become throughout the growing cycle, allowing farmers to mitigate the risks of droughts.

A pilot-study in which solar-powered drip irrigation systems were retrofitted onto diesel-powered pumps in the Dakar region found that farmers were able to increase their water supply to crops, and, in turn, earn higher incomes because they avoided the cost of purchasing irrigated water from other areas.[204] The additional water also allows farmers to use said water to clean the crops before their transport to national markets, which facilitates the sale of the crops.[205]

Solar panels also have an indirect, potential benefit of improving the environment in which crops grow. For instance, farmers can adopt agrovoltaic farming, whereby solar panels are installed on raised mounts, above crop rows to provide plants with the exact amount of light and shade they need to grow. Traditionally, land has had to be cleared before the installation of solar panels; with agrovoltaic farming, farmers can avoid the environmental and financial costs of clearing land, all the while improving the environment in which their plants go. As temperatures increase, agrovoltaic farming provides the necessary shade during the hottest periods of the day to avoid the drying of crops. Conversely, raised solar panels can also mitigate soil erosion during heavy rains; this is because the raindrops do not impact the exposed soil with the same intensity, which would otherwise result in soil erosion.

These shade-providing solar panels can even extend the options farmers have in terms of the selection of cultivation sites and the type of crops they grow, thereby broadening the options that farmers have to increase their revenues, even as temperatures increase and as rain becomes more erratic. There are several examples of pilot studies that have adopted the use of PV systems in this manner, such as in Kenya, where farmers have been able to increase their revenues despite an equally warming climate.[206] Therefore, if farmers adopt solar-powered irrigation in a way that also provides shade to crops, they can provide additional co-benefits to the production of their crops.

[204] Noubondieu, S., Flammini, A., & Bracco, S. (2018). Costs and benefits of solar irrigation systems in Senegal. FAO.

[205] Ibid

[206] Randle-Boggis, R. (2021). Harvesting the sun twice.

Cost

The fixed and variable costs of using different energy sources for drip irrigation systems differ heavily. One cost assessment for the implementation of solar pumps in the region of Saint-Louis on 350 ha of land for melon cultivation compared the fixed and variable costs of diesel-based, electricity network, and solar-powered irrigation systems.[207] The analysis revealed that initial fixed costs for solar-powered systems are considerably higher than diesel pumping systems; however, the variable costs of diesel systems far outweigh the combined fixed and variable costs of solar PV systems over the project's lifetime (20 years). Table 11, below, provides an overview of these costs.

Table 11. Expected impact on agriculture and future-proofing production capacity.

	Fixed		
	Solar PV	Diesel	Electricity Network
Pump	€ 220 000	€ 60 000	€ 100,000
Solar Panel	€ 116 030	-	-
Electricity Supply	-	-	€ 19,173
Total	€ 336 030	€ 60 000	€ 119,173
	Variable (Yearly, over 20 years)		
	Solar PV	Diesel	Electricity Network
Use and Maintenance	€146,020	€120,000	€ 47,660
Fuel	-	€ 1,863,320	-
Electricity Supply	-	-	€ 945,940
Total	€146,020	€ 1,983,320	€ 993,600
	Fixed and Variable (over 20 years)		
	Solar PV	Diesel	Electricity Network
Total	**€ 482,050**	**€ 2,043,320**	**€1,112,773**

However, in the context of the Naatangue farms project, the fixed costs associated with implementing a solar-powered, drip irrigation system vary significantly depending on the depth at which the groundwater aquifer is available. This is because the costs of digging are greater, and deeper pumping systems require more power to pump water. For instance, the 40 village farms will require a solar pumping system that have installation costs estimated at $US 40,665 per farm, otherwise representing a cost of US$ 1,626,600 for all 40 village farms. Solar pumping systems for a family farm with a depth less than or equal to 50 meters is about $8,000 per family farm (or US$ 800,000).[208] Therefore, the fixed cost for solar PV systems may be higher than those outlined in Table 11 above as the information presented for PV systems in this scenario does not account for

[207] GetInvest. (2019). Senegal: Renewable Energy in Agricultural Value-Chains Case Study: Solar Powered Irrigation—Large-Scale Water Pumping at a Melon Farm (350 Hectares).

[208] ANIDA Calculations outlined in Project Prefeasibility Study

variations in groundwater depth. For this reason, GCF financing would provide the necessary resources to cover the initially high up-front cost. The long-term costs of diesel and electricity-powered systems remain significantly more expensive than PV systems; the estimates for diesel and electricity-powered systems are also optimistic as they assume the price of fossil-sourced energy will remain stable, which is unlikely as fossil energy prices have consistently risen and are projected to continue to rise in the coming years and decades.

Though the costs provided in the table above are approximations, the long-term costs of a solar-powered irrigation system are likely to be far more affordable than diesel-powered and electricity grid-powered irrigation systems in Naatangue farms. This is because there are no fuel related costs associated with PV systems. However, initial fixed costs are considerably higher in PV pump systems for drip irrigation, which may contribute to the difficulty of establishing these systems without financial support. For this reason, funding for this project would help alleviate the initial price challenge and facilitate the up-take of PV-powered, drip irrigation systems. Yet, there are maintenance costs associated with the up-keep and prolonged use of solar PV systems, but the training and guidance that ANIDA will provide to farmers in village and family farms (Component 3), along with the community-based savings fund, will provide the necessary skills and capital that will allow for farmers to continue their operations without needing further public funding.

Another benefit of PV-powered irrigation systems is that their costs decrease as the farm size increases. One cost assessment of different pump technologies in Senegal found that the levelized cost of electricity (LCoE) of solar PV pumping systems (in terms of EUR/kWh) decreases by 32% when the farm size increases from 50 ha to 250 ha, while the LCoE for Diesel as the farming surface area increases is only 9%.[209] Therefore, as farmers are able to improve their yields, and grow the size of their farms, their energy costs will decrease more significantly if they were to use PV-powered irrigation systems compared to diesel-based systems.

Ease of Up-Take and Implementation by Farmers

Solar-powered drip irrigation systems are relatively common techniques that are gaining more popularity and benefiting from increasing investments from various international and national institutions. Indeed, Senegalese farmers have had very positive experiences from investments in farms that have seen the successful implementation of solar-powered drip irrigation. The Cooperación Española (Spanish Cooperation), for instance, successfully introduced a programme that created 10 farms (50 ha per farm), which allowed for the introduction and extension of drip irrigation technology for milk production and other means.[210] Likewise, the Italian Cooperation, working with the National Program Investment in Agriculture in Senegal (PAPSEN), successfully introduced drip irrigation systems to 70 horticultural farms (450 ha), as well as to 4,000 ha of rice fields in the Casamance region.[211] The results of these investments have provided ample returns to

[209] GetInvest. (2019). Senegal: Renewable Energy in Agricultural Value-Chains Case Study: Solar Powered Irrigation—Large-Scale Water Pumping at a Melon Farm (350 Hectares).

[210] Agencia Española de Cooperación Internacional para el Desarrollo (AECID). (2020). Anexo I: Descripción de la acción. PACERSEN. Agencia Española de Cooperación Internacional para el Desarrollo (AECID). MINISTERIO DE ASUNTOS EXTERIORES UNIÓN EUROPEA Y COOPERACIÓN OFICINA DE INTERPRETACIÓN DE LENGUAS.

[211] Agencia Española de Cooperación Internacional para el Desarrollo (AECID). (2020). Anexo I: Descripción de la acción. PACERSEN. Agencia Española de Cooperación Internacional para el Desarrollo (AECID). MINISTERIO DE ASUNTOS EXTERIORES UNIÓN EUROPEA Y COOPERACIÓN OFICINA DE INTERPRETACIÓN DE LENGUAS.

farmers, who have been able to increase their incomes and create over 9,000 new jobs in the agricultural sector.[212]

International, African corporations, such as InfraCo Africa have also partnered with smaller organizations and companies in Senegal, such as BonEnergie Senegal, to deliver projects that introduce the commissioning, sale and installation of over 2,000 solar pumps and 500 drip irrigation systems to rural farmers between 2019 and 2022.[213] The successful implementation of these systems over the last few years has seen an increased investment of US$ 2.4 million in 2021 to further assist rural farmers in Senegal in accessing and using solar-powered drip irrigation technologies.[214] The GIZ has also heavily invested in solar-powered irrigation systems in the Saint-Louis, Thiès, Kolda, Fatick and Niayes regions, which provided 14.8 kW of power to 400 market gardeners, allowing for the daily delivery of 2,000 m3 of water.[215] The recent introduction of solar-powered drip irrigation systems has directly benefited Senegalese women in agriculture, through a 30-month project organized by the Agricultural and Rural Prospects Initiative; this program provided training and equipment to 20 women on the installation of autonomous solar systems, with regular follow-ups every 4 months.[216]

As a result, these practices are well established in Senegal, which has created a variety of funding initiatives and local companies that can facilitate the transition from diesel-operated systems to PV systems in Naatangue farms. Despite the existing, new infrastructure that will assist in the transition from diesel to solar-powered systems, the high, initial costs of capital remain a fundamental barrier to up-take, which is why support from the GCF will be critical in assuring the up-take of the technology. Just as in the GIZ-project, this project will also assure regular monitoring and evaluation missions from ANIDA professionals to ensure that the technology is functional and that farmers are using it correctly (further explored in Component 3 of this project).

1.1.3 Ensuring the feasibility and successful implementation of the Naatangue farm model: water assessment

Effective management of water resources is vital for successful implementation of the Naatangue farms, given the baseline water availability and climate pressures on water resources. The national socio-economic development plan (Plan Senegal Emergent - PSE) aims to mobilize "abundant, good quality water for all, everywhere and for all uses, in a healthy sustainable living environment, for an emerging Senegal" by 2035. The reliance on surface water irrigation presents a major hindrance to the realization of the full agricultural potential of farmers and exposes them to the negative impacts of climate change. Additionally, the dependence on groundwater pumping infrastructure poses a challenge, as it is often either unavailable or very expensive due to the high cost of diesel. Therefore, the modernization and diversification of farming systems necessitate well-managed and supported irrigation systems that ensure the availability of water throughout the year.

[212] Ibid

[213] InfraCo Africa. (2022). Senegal: Bonergie Irrigation I&II Expanding access to solar powered irrigation technology.

[214] Farmers Review Africa. (2021). Solar-powered irrigation systems to take off in Senegal. Farmers Review Africa.

[215] Shetty, S. (2022, April 12). Solar Pumping System Near Saint Louis in Senegal To Serve 400 Market Gardeners. SolarQuarter.

[216] Wansi, B.-I. (2022, June 20). SENEGAL/GUINEA: Project to install solar irrigation systems. Afrik 21.

Naatangué Farms is committed to using sustainable water sources to support its agricultural activities in Senegal. The availability and quality of water is a crucial factor in selecting suitable sites for Naatangué Farms. Research conducted in Senegal on the impact of climate change on groundwater resources is limited. For his thesis work, Dieng (2017) used a numerical model that uses the MODFLOW/GMS software for the simulation of the hydrodynamics of the Continental Terminal (CT) aquifer and to simulate the impact of IPCC scenarios in terms of climate change combined with increased pumping. The results obtained showed that the combined effect of climate change and abstraction would lead to a decrease in piezometric levels that could go up to 12 m in certain places compared to the current level simulated during periods of stress, with a dispersion of 2 to 5 m around the multi-model average. Thus, the increase in withdrawals with the aim of satisfying the water supply of the populations, combined with unfavourable climatic conditions for a good recharge of the water table, can contribute to average drawdowns of around 4 m and a degradation of the water quality due to saline intrusion[217].

To ensure the availability of groundwater in sufficient quantity and quality, ANIDA (National Agency for Agricultural Investments and Land Development) carries out the necessary studies and surveys to identify the best locations.

For village farms, a preliminary analysis is conducted using the national directory of hydraulic structures produced by the Directorate of Water Resources Management and Planning of the Ministry of Agriculture and Hydraulics, Republic of Senegal. This directory provides information on the characteristics of water resources in all localities of Senegal, such as geographical coordinates, type of aquifer, depth and thickness of the water table, fluorine content, state of hydraulic works in the locality, etc (Figure 12). ANIDA uses this information to determine if the preliminary analysis shows the availability of water in sufficient quantity and quality.

If the preliminary analysis shows that water is available in sufficient quantity and quality, ANIDA commissions a firm to carry out a more in-depth geophysical study (see Annex 1 for an example of the studies conducted in the past). The geophysical study uses the method of electrical soundings to determine the availability of fresh water in sufficient quantity and quality. In the report of the study, the results of the geophysical prospecting are presented, along with the main information relating to the aquifer levels and the projected technical characteristics of the planned works at the level of each locality.

For family farms, shallower groundwater than in village farms is sought, and the preliminary study is carried out using the wells available in the locality. If these observations show sufficient availability of water, a further assessment with a more in-depth geophysical study will determine whether or not the locality is suitable for a family farm, and this is an essential component as part of the screening of family farm applicants. For example, in one of the village farms located in Medina Gowé, Kaffrine, ANIDA conducted drilling of groundwater to supply water for the village farm. The table below shows the results of the activity which shows that the impact of drilling in groundwater is minimal and does not affect much on the water table.

Features	Results and specifications

[217] CSE, Rapport sur l'état de l'état de l'environnement au Senegal, 2020

Depth of investigation	105 m
Equipped Depth	103,6 m
Captured Aquifer	Continental Terminal
Aquifer Top Depth	71m
Capture from / to	81,82m/101,21m
Static/Ground Level	63,40 m
Medium Flow Long Duration	71,69m3/h
Drawdown	8,44m
Specific Flow	8,49m3/h/m

Figure: Results of the Medina Gowé drilling to assess the availability and quality of water

Based on the findings, the study concludes that the Medina Gowé borehole, tapping into the Oligo-Miocene aquifer, exhibits satisfactory productivity (Q= 71.69 m3/h). Moreover, the water quality analysis reveals a low dry residue of 229mg/l, indicating good water quality. Hence, the water sourced from this borehole is deemed suitable for meeting the population's water supply needs.
In addition to using a water source available all year round and ensuring the sufficient quantity and quality of water, Naatangué Farms contributes to the rational use of water through the drip irrigation technique. Solar-powered irrigation (SPI) can be an effective solution for water-scarce regions like Senegal, where climate change has increased the frequency and intensity of droughts. Drip irrigation systems are particularly well-suited for water-scarce environments, as they deliver water directly to the roots of crops, minimizing water loss through evaporation and runoff. These systems work by using solar panels to generate electricity, which powers a water pump that draws water from a well or surface source and distributes it through a drip irrigation system. The use of drip irrigation can help to reduce water consumption by up to 70% compared to traditional flood irrigation methods, while also improving crop yields and reducing soil erosion.

The use of SPI can also help to reduce greenhouse gas emissions associated with traditional diesel-powered pumps, aligning with the Green Climate Fund's investment criteria for reducing emissions and promoting low-carbon development. The low-cost and low-maintenance nature of SPI systems makes them accessible to smallholder farmers who may not have access to grid electricity or the resources to maintain more complex irrigation systems.

Naatangué Farms uses a combination of geophysical studies, electrical soundings, and preliminary analyses to ensure the availability and quality of water for their solar-powered irrigation systems. This allows them to contribute to the rational use of water while promoting sustainable agricultural practices in water-scarce regions like Senegal. In implementation of the Naatangué farms, ANIDA will ensure rational use of groundwater by strictly applying the threshold of 50 meters withdrawal and also ANIDA will monitor the groundwater table and always measure proportionate level of water before the withdrawal takes place.

- **<u>Quantitative analysis</u>**

According to the DGPRE[218] (2021), in Senegal, water reserves in the shallow aquifer system are estimated at between 50 and 75 billion m3. Over and above these reserves, this system represents a significant potential for seasonal renewal (notably through rainwater infiltration), estimated at 1.5 to 2 billion m3/year (5.5 million m3/d) in an average rainfall year.

The flows exploited in target regions with climate projections in the project are 150,000 m3/d and 55 million m3/year respectively.

In terms of the estimated balance available for extraction, we have a mobilizable potential of 628,000 m3 /d (average). Theoretically, a potential of 8,000 ha can be covered over the whole territory and the quantity used: 200,000 (m3 /).

The table below is repository of boreholes and their water availability. It is a decision making tool for site selection committee to select the Naatangue farms locations. It enables us to determine safe locations where boreholes can be created, as it provides depth and characteristics of boreholes and their hydric potential.

PROGRES **Répertoire national des ouvrages**

Localité	Numéro IRH	Longitude	Latitude	Entreprise	Type Ouvrage	Date Récept.	Aquifère	Prof. Totale (m)	Prof. Sup. Crép. (m)	Prof. Inf. Crép. (m)	Niv. Sta. (m)	Prof. Ch. (m)	Diam. Chamb. (mm)	Débit Essai (m³/h)	Rabat (m)	Résid. secs (mg/l)	Fluor (mg/l)	Etat Ouvrage	Usage Ouvrage
MERINA NDIOLE	05-7X-0095	-16°40'04"	15°17'28"	WVI	Forage	10/97	Quaternaire	64	55	62	30.7	55	178	49.8	6.0	89	0.10		A.E.P.
				Communauté Rurale		DIOKOUL NDIAWRIGNE													
THIENABA	05-5X-0051	-16°27'00"	15°25'05"	WVI	Forage	07/89	Quaternaire	58	45	55	39.5	58	203			132	0.25	Exploité	A.E.P.
NDIAWAGNE FALL	05-5X-0179	-16°34'30"	15°25'30"	GEOMECHANIQUE	Forage	02/04	Quaternaire	90	54	74	31.8	6	273	59.0	6.5			En service	A.E.P.
TAYBA MAR	05-5X-0175	-16°30'40"	15°22'50"	WVI	Forage	06/89	Eocene	50	39	48	33.4			25.0		172	-0.10		
KANENE KANE	05-5X-0077	-16°29'30"	15°24'30"	WVI	Forage	06/89	Quaternaire	51	44	49		44	203			180	-0.10	Exploité	A.E.P.
BAHDAR GUEYE	05-5X-0045	-16°30'25"	15°21'20"	WVI	Forage	07/89	Quaternaire	73	55	70	38.0	73	203			162	0.10	Exploité	A.E.P.
BAYTI NDIAYE	05-5X-0080	-16°33'50"	15°22'45"	WVI	Forage	06/89	Quaternaire	56	44	53		44	203			260	-0.10	Exploité	A.E.P.
CADE BRAMA	05-5X-0099	-16°24'54"	15°24'34"	SEHI	Forage	10/98	EOCENE	114			36.2	80	508					Abandonné	A.E.P.
DAKHAR DEMBA KODOU	05-5X-0178	-16°37'00"	15°25'00"	WVI	Forage	05/00	Quaternaire	55	45	52	35.3	54	152	19.0	6.7	118		Non exploité	A.E.P.
DARA ANDAL	05-5X-0056	-16°31'40"	15°24'50"	WVI	Forage	06/88	Quaternaire	50	43	48	34.3	50	203			180	0.10	Exploité	A.E.P.
DARA ANDAL	05-5X-0164	-16°32'07"	15°25'36"	WVI	Forage	11/97	Quaternaire	67	58	65	35.3	56	178	42.4	12.1	129	-0.10		A.E.P.
DIOKOUL	05-5X-0024	-16°31'00"	15°22'04"	SOBEA	Forage	06/86	Continental	97	75	93	40.8	95	203	33.8	3.7	360			A.E.P.
NGUER NGUER	05-5X-0017	-16°33'32"	15°23'08"	INTRAFOR	Piézomètre		Continental	111	67	73	34.2	73	64	4.8	0.9	160	-0.10	En service	A.E.P.
DIOKOUL NDIAYE	05-5X-0177	-16°32'47"	15°26'53"	WVI	Forage	05/00	Quaternaire	60	50	57	32.3	59	152	36.2	11.9	248		Non exploité	A.E.P.
TEUGUE NDOGUI I	05-5X-0095	-16°25'51"	15°23'41"	SEHI	Forage	01/99	EOCENE	130	79	121	40.7	79	406	53.0	36.5			Abandonné	A.E.P.
MERINA NDIEGUE I	05-5X-0014	-16°30'15"	15°24'45"	INTRAFOR	Piézomètre		Continental	95	49	55	36.6	55	64	1.1	0.3	710	8.00		
MERINA SECK	05-5X-0052	-16°31'00"	15°26'30"	WVI	Forage	06/89	Continental	51	44	49	34.7	50	203			236	0.10	Exploité	A.E.P.
NDIAKHA FALL	05-5X-0053	-16°28'40"	15°25'45"	WVI	Forage	06/89	Quaternaire	51	48	50	36.9	43	203			180	0.10	Exploité	A.E.P.
NDIAWAGNE FALL	05-5X-0119	-16°34'30"	15°25'30"	EOMECHANIK	Forage	02/04	Continental	90	54	74	31.8	54	254	59.0	6.5			Exploité	A.E.P.
NGUER NGUER	05-5X-0008	-16°33'50"	15°23'20"	INTRAFOR	Forage	03/74	Continental	111	61	82	34.4	61	273	165.0	10.9	112	-0.10		A.E.P.

Direction de la Gestion et de la Planification des Ressources en Eau
Ministère de l'Agriculture et de l'Hydraulique, République du Sénégal

PROGRES-Sénégal / ANTEA-BURGEAP
24-01-2007

Figure 14. Data used in determining water availability on Naatangué farms[219]

218 Direction de la Gestion et de la planification des ressources eaux

219 Extract from the National directory of hydraulic structures

1.1.4 Considerations for successful implementation of this technology

The ease of implementation of solar-powered, drip irrigation systems will depend on the technology that different farmers currently have in place, the availability of a water source on or near the farm (surface or groundwater), and the availability of training for the maintenance of the system. For instance, village farmers that already use an irrigation system, whether it is diesel or grid-powered, can more easily adopt solar-powered irrigation because they already use irrigation practices to water their crops. Farmers in the Niayes agricultural zone[220] could more easily adopt solar-powered irrigation as most farmers in this area already rely on diesel-powered irrigation from surface water (southern Niayes) and groundwater (northern Niayes).[221] This, however, is not the case for most Senegalese farmers, who almost entirely rely on rainfed agricultural practices.[222] The adoption of solar-powered irrigation will, therefore, require training and equipment (tubing, pump...etc.) and training on how to irrigate crops most efficiently. One study on the feasibility of installing solar-powered drip irrigation in the Niayes region found that installation of the irrigation system, without the pumping mechanism, can account for up to 67% of the cost of implementing a solar-powered irrigation system.[223] Training is also a key component in the up-take of this technology; thankfully, an enitre component of this project (Component 3) is dedicated to the training of advisors and, subsequently, producers on how to install and use this equipment effectively. Past projects that have successfully assisted the Senegalese agricultural sector improve *Waar Wi* (another farming model, similar to Naatangue) and Naatangue farms also had significant training activities for both family and village farms.[224]

The other key barrier to this technology is the availability of surface and/or ground water near the farm. Without access to an aquifer or surface water body (river, lake or pond), farmers cannot use this technology effectively. However, this is mitigated in the context of this project as ANIDA, the executing agency of this project with years of experience in implementing the Naatangue model, has selected implementation sites that have a sufficient and accessible water supply. Indeed, ANIDA and several international institutions (ex. USAID) have conducted water availability assessments of its groundwater resources, and these analyses demonstrate the availability and quality of groundwater resources for agricultural production. One USAID analysis of groundwater availability found that the deep Maastrichtian aquifer (part of the Senegalo-Mauritanian aquifer), covers 80% of Senegal, and accounts for 40% of

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[220] Ganie, Z. (2021, September 28). Upscaling solar-powered irrigation solutions in Senegal. ESI-Africa.Com.

[221] Sarr, A., Diop, L., Diatta, I., Wane, Y. D., Bodian, A., Seck, S. M., Lamaddalena, N., & Mateos, L. (2021). Technical and Economic Feasibility of Solar Pump Irrigation in the North-Niayes Region in Senegal. Engineering, 13(7), Article 7. https://doi.org/10.4236/eng.2021.137029

[222] Feed the Future. (2016). Climate-Smart Agriculture in Senegal. USAID.

[223] Sarr, A., Diop, L., Diatta, I., Wane, Y. D., Bodian, A., Seck, S. M., Lamaddalena, N., & Mateos, L. (2021). Technical and Economic Feasibility of Solar Pump Irrigation in the North-Niayes Region in Senegal. Engineering, 13(7), Article 7. https://doi.org/10.4236/eng.2021.137029

[224] Agencia Española de Cooperación Internacional para el Desarrollo (AECID). (2020). Anexo I: Descripción de la acción. PACERSEN. Agencia Española de Cooperación Internacional para el Desarrollo (AECID). MINISTERIO DE ASUNTOS EXTERIORES UNIÓN EUROPEA Y COOPERACIÓN OFICINA DE INTERPRETACIÓN DE LENGUAS.

groundwater flows.[225] The deep aquifer system has the highest productivity and greatest depths, reaching up to 400 meters (m), although variability can be significant depending on location.[226] In addition, an analysis conducted by ANIDA maintains that the groundwater extraction sites for the Naatangue farms only use non-fossil water from renewable aquifers, thereby assuring the long-term availability of water for agricultural production.[227] The Climate Rationale and the Baseline assessment have further information on the steps taken to ensure that enough water is available to meet the needs.

Any concerns of limited availability of groundwater can also be mitigated depending on how solar-powered irrigation is integrated in each farm. For example, farms do not need to completely abandon rainfed, agricultural practices; instead, farmers can continue to rely on rainfed agriculture for most of the year and use irrigation as a buffer technique to ensure an adequate amount of water during the dry season. Should a farm have inadequate access to an aquifer or well, rendering the sourcing of water for irrigation more challenging, they can also use water collection tanks that recharge during the rainy season.

Regions such as Thiès have plentiful and deep ground water resources; this may mean that certain areas will require more costly digging and more powerful pumping systems (submersible pumps).[228] Shallow aquifers, such as in the Kaolack region, will require different pumping systems (surface pumps).[229] The selection of sites will largely depend on the amount of water the county's major aquifers receive; for instance, the Senegal River Basin, which receives 20,000 million cubic meters each year and covers 37% of the country, is the largest water basin in the country, and is found in Thiès, Louga and Saint-Louis regions.[230] The Gambia River Basin, in the south of the country, covers 30% of the country and supplies 2,700 million cubic meters of water, annually, and is found across Kolda, Tambacounda and Kedougou.[231] For this reason, solar-powered irrigation could be successfully applied in these regions.

Maintenance will also be a key consideration to ensure the longevity of the project, and specifically the use of solar-drip irrigation. Component 3 of this project ensures the training of agricultural advisors on the maintenance of solar and agro-equipment, who can then provide the tools and knowledge on maintenance of these systems to producers. The community-based savings fund will also serve to ensure that there is a continuous pool of funds to finance the maintenance of equipment.

1.1.5 Overview of impact and co-benefits

[227] ANIDA (2023). Note sur l'Impact Environnemental des Forages Agricoles des Fermes Naatangue

[228] USAID. (2021). Senegal Water Resources Profile Overview

[229] Ibid

[230] Various reports conducted by ANIDA on groundwater availability.

[231] Ibid

Table 12 below shows a summary of how the proposed option in this activity (solar-powered drip irrigation) compares to the identified alternatives in terms of scalability, impact and co-benefits, and climate impact.

Table 12. Overview of Options for Solar-Powered Drip Irrigation

Options and Alternatives	Scalability			Impact and Co-Benefits		Climate	
	Cost	Scalability	Easy Up-take/ Implementation	Impact on agriculture production	Co-benefits	Impact for climate adaptation and mitigation	Future-proof for future climate
Solar-Powered Irrigation	Initially high, with low, long-term costs	High	Moderate (depending on whether farm uses irrigation)	High, Positive	Energy supply for other needs (powering storage, homes...)	Adaptation: allows for cover for crops to improve growth despite rising temperatures Mitigation: 915t CO2 eq/Y 18,314.16 tCO2 over 20 years in avoided emissions from Diesel use	Provides farmers with shade for crops and continuous access to water through dry season, with no projected increase in the cost of energy
Diesel-Powered Irrigation	Initially low, with high long-term costs	Low	High	Moderate, Positive	None	Adaptation: None Mitigation: 915t CO2 eq/Y 18,314.16 tCO2 over 20 years (per ANIDA calculations)	Price of diesel projected to rise
Grid-Powered Irrigation	High initial costs	Low	Low (inadequate access to electricity)	Moderate, Positive	None	Adaptation: None Mitigation: Indirect contribution to emissions through use of fossil-powered electricity	No benefits for future climatic events
Manually Pumped Irrigation	Low monetary costs, high labor, and opportunity costs	High	High	Low, Positive	None	Adaptation: No adaptation benefits Mitigation: No emissions	No benefits for future climate events
Rainfed Agriculture (BAU)	High (most of country uses rainfed)	High	High	Low, Negative	None	Adaptation: No adaptation benefits Mitigation: No emissions	Future climate will make rainfed agriculture less sustainable

2. Assessment of farm diversification systems

This section of the technical assessment provides an overview of the components of integrated crop-animal-farming for the Upscaling Naatangue Farms project in Senegal, with a focus on how these systems can contribute to delivering impact for the project. It assesses the suitability and feasibility of implementing diversification practices and technologies as part of the Upscaling Naatangue Farms project in Senegal. The success of these diversification activities relies on the availability of water harvesting and solar power supply. The use of solar energy will provide both lighting to buildings and power to equipment, which can improve product conservation and reduce losses. Furthermore, training activities will be provided for capacity building to learn how to implement new activities or improve existing practices. Waste generated from the activities can also be used in agroforestry and waste management activities to produce compost that can be used as fertilizer for crops and trees. The training and awareness-raising activities will enable farmers to learn techniques for producing superior quality products and minimizing production loss. The community-based savings fund can help prevent interruptions in production due to equipment failures. Additionally, marketing support will enable producers to increase their customer base and sell their products more easily, adding value to the Naatangue farm model.
The selection of farms for activities considers resources that already exist on the farm, as well as the availability of natural resources (water) and existing farm capital (chickens and cows), together with ANIDA's local knowledge and available product markets in the area.

2.1 Poultry Farming

2.1.1 Description

This activity consists of integrating poultry farming (acquisition of chickens, construction of micro-scale chicken houses, chicken processing units, acquisition of equipment, accessories, and inputs) into the agroforestry system of the Naatangue model. The objective of this activity is three-fold: diversification of income, provision of cheaper, alternative sources of fertilizer for crop production, and improvement of year-round food security and nutrition. This activity serves as both a way for producers to create a constant stream of income throughout the wet and dry season, thereby offering greater income security in the midst of [climate impacts], all the while providing an additional farming input that can help farmers improve the quality of their soil. Indeed, the waste that will be produced from chicken farming also provides co-benefits to other components of the project, such as in the agroforestry and organic waste-management activities described further in this document.

Poultry farming in Senegal is characterized by two distinct farming systems, which are: traditional poultry farming and modern semi-industrial poultry farming. Traditional poultry farming is generally practiced in rural areas, primarily for private consumption, and as a secondary source of income. Semi-industrial poultry farming is a larger economic activity that generates income and creates jobs by producing large volumes of poultry products and distributing them to a market.

This project will adopt the traditional poultry farming model, which is smaller in scale. Specifically, the following activities are planned for small-scale, chicken production units: capacity of 120 chickens or 60 hens in 12 m^2 is planned for the family farms and 1000 hens in 200 m^2 for the village farms. The density planned is 10 chickens per m^2. The first 12 poultry farms will be implemented in the regions of Thiès (8), Louga (2), Kaolack (1) and Kaffrine (1).

The poultry sector is already well established in Senegal; there are five major manufacturers that supply poultry feed to farms[232], and five major manufacturers that supply food to most farms, as well as a strong and established network hatchery operators that supply day-old chicks to producers.[233] In the Senegalese poultry sector, the following three distribution channels are mainly used: In-situ direct selling to customers, wholesaling to retailers, and direct selling in urban or weekly markets ("loumas")[234]. The activities related to poultry farming present a unique opportunity for farmers to utilize existing infrastructure and benefit from additional support services provided by ANIDA. With technical training on poultry raising and market support, farmers can tap into a well-established poultry sector and expand their operations with the help of GCF funding. The funding would provide support for initial costs and training, as well as marketing assistance, enabling project beneficiaries to fully leverage the potential of poultry farming in Senegal.

The logical framework provides details of poultry farming in the following activities: 1.1.2; 1.2.2; and 1.2.3; each of the following activity's' components are further described below:

<u>Activity 1.1.2:</u>

- Building a 12 square meter chicken house with strips of 120 broilers or 60 layers;

<u>Activity 1.2.2:</u>

- Construction of a 200 m² capacity chicken house with 2000 broilers or 1000 layers;
- Purchase of equipment and accessories (1st and 2nd age water troughs, feeders, 60W lighting lamps, small equipment (shovel, buckets, basin, wheelbarrow, etc.).
- Purchase of chicks and feed at startup

<u>Activity 1.2.3:</u>

- 1 refrigerator powered by 2 solar panels for the conservation of chicken;
- 1 feather remover machine to better ensure the hygiene of the product;
- Cutting material and biodegradable packaging bags;
- 1 tricycle for transport;
- Labelled kiosks

The design and size of the proposed poultry farming activity in the Naatangue model provides the optimum conditions for successful and continuous poultry production. In

[232] Organization names: SEDIMA, SENTENAC, NMA Sanders, AVISEN, PRODAS

[233] Organization names: SEDIMA, CAMAF, CAM, PRODAS, AVI-PROD, AVIVET, SENAV, SEDPA

[234] Oualy, M. (2022). Study on the average cost for the launch of a sustainable micro enterprise project in three key economic sectors.

ANIDA's yearly performance review of farming activities, they found that the same poultry farming system (which has a surface area of 200 m2) performed most efficiently and outperformed expected yearly production by almost double the target production quantity (expected: 15 tons, observed: 28 tons).[235] ANIDA found from experiences of farmers that this size and dimension of poultry farming unit has allowed for farmers to effectively manage their production, which limits the mortality rate to 12% per row of poultry.[236] The same assessment also found that these farms that employ a spatial distribution of 200 m2 were able to produce ~74% of the yearly target of eggs within a single semester. The assessment found that this value would have exceeded the yearly target for egg production had the project not been delayed; this project will avoid any possible delays by deploying the necessary training and marketing services, along with equipment and materials, to ensure the uptake and proper implementation of the activity.

2.1.2 Technical assessment of the activity and its alternatives

Cost

Most poultry equipment used in farming, such as bird feeders and waterers, are costly imports. Alternatives to this equipment have been developed by local artisans at relatively lower prices, though they do not always meet the required standards, prompting some farmers to continue buying costlier, imported equipment. Given that imported poultry equipment is expensive, and that locally-produced equipment has not always been sufficiently functional, this project provides the opportunity to fill the gap by financing the acquisition of quality poultry farming equipment. This will reduce the up-front costs that act as a barrier to entry in the poultry sector, and better assure the long-term viability of the activity through the provision of quality materials.

Table 12 and Table below show the cost of equipment and operations to run a poultry farm in the Niayes region, which covers part of the regions of Dakar, Thiès, Louga and Saint Louis; this project will implement the majority of its poultry farming activities in these regions, as well, which offers a more accurate comparison for the cost assessment. The tables below provide information on the equipment required to start a poultry farm and the working capital for the first operating flock of 1000 baby chicks. The tables provide the quantity needed for each piece of equipment, as well as its corresponding price. The tables below can be used to have more detailed costs related to raising chickens on Naatangué farms.

Table 14. Operating Equipment Cost (Source: ERRIN-OFII, 2022, page 15)[237]

[235] ANIDA. (2016). Rapport de Performance : Agriculture, le nouveau business !

[236] Ibid

[237] Oualy, M. (2022). Study on the average cost for the launch of a sustainable micro enterprise project in three key economic sectors.

Operating Equipment			
Equipment	**Quantity**	**Unit Price (CFA)**	**Amount (CFA)**
Feeders for baby chicks	10	2 100	21 000
Waterers for baby chicks	10	2 500	25 000
Feeders for grown chickens	20	9 000	18000
Waterers for grown chickens	20	11 000	220 000
Radiant heater	1	45 000	45 000
Freezers	1	450 000	450 000
Automatic de-feathering machine with a capacity of 5-6 chickens/2 minutes	1	375 000	375 000
Gas cylinder	4	15 500	62 000
Subtotal 1			1 378 000
			Small Equipment
Equipment	**Quantity**	**Unit Price (CFA)**	**Amount (CFA)**
Wheelbarrow	1	15 000	15 000
Buckets and basins (package)	1	15 000	15 000
Rakes, pitchforks, shovels (package)	1	15 000	15 000
Subtotal 2			**45 000**
Total Investment (CFA)			**1 423 000**
Total Investment (EUR)			**2 169**

Table 15: Summary of the minimum cost - Poultry farming in the Niayes area[238]

DESCRIPTION	Amounts (in CFA francs)	RELATIVE SHARE (IN %)
Initial investment (equipment + materials)	1,423,000	40%
Costs of the formalization of the enterprise	25,000	1%
Working capital (for a flock of 1000 baby chicks)	2,103,350	59%
Total in CFA francs	**3,551,350**	

This average cost of 3,551,350 CFA francs for the start-up of a poultry farming activity (2 flocks or 2000 subjects) remains valid for the regions of Dakar and Thiès where the data were collected and, in the case, where a reintegration operator offers assistance. Concerning the south-eastern regions (Tambacounda, Kédougou, Ziguinchor, Sédhiou and Kolda), the costs of working capital requirements (baby chicks and feed) are higher because of transport costs. However, prices are reviewed accordingly (3,500 to 4,000 francs per unit)[239]. The tables above can therefore be used as a complementary tool to

[238] Oualy, M. (2022). Study on the average cost for the launch of a sustainable micro enterprise project in three key economic sectors.

[239] Ibid

better estimate the cost of the Naatangué farms. The tables above also indicate that the costs of initial investments represent the vast majority of costs, which acts as a barrier to farmers adopting poultry farming. GCF funding would fill that gap by providing the funds to introduce the initial capital, and ANIDA would ensure the proper implementation and use of the equipment and capital.

The net benefits of poultry farming tend to be greater than that of cattle or small-ruminant (goat/oxen) raising, as well. Indeed, one cross-country analysis of sub-Saharan animal raising found that poultry farming provides the highest economic benefits to rural women in Senegal out of any country in the Western Saharan region. This is explained by the short-cycle production system of poultry as compared to other animals, as well as the additional production benefit of poultry's production of eggs, which can be used for subsistence (contributing to food security) and financial means.[240] The combination of having animals that are continuously productive (by producing eggs), have a short life cycle (reaching maturity more quickly than cattle and small ruminants), and provide a nitrogen-rich fertilizer renders it much more cost-effective than any other animal raising system, and provides a host of co-benefits to crop production.

Scalability

The poultry sector in Senegal has experienced a considerable scaling-up in the past few years. Large banks and financial institutions in Senegal, such as the Agricultural Bank (La Banque Agricole), have invested considerable resources in the poultry industry.[241,242]. Through the improvement of production models and the import of quality materials for poultry production, the Senegalese poultry sector has successfully increased its volume of production. Sedima, the country's largest producer of chicken and eggs, now also produces hatching eggs locally, which increases the possibilities for local small-scale producers to get involved in poultry farming. As a result of the scale-up in the wider poultry sector in Senegal, local farmers that have access to poultry-farming equipment have been able to achieve feed conversion rates that are in line with global norms[243].

The challenge, however, remains in the availability of equipment and adequate training of a large network of farmers. This is where GCF funding could fill the gap that would otherwise act as a barrier to entry for small-scale farmers. The infrastructure for scaled-up, poultry production is growing rapidly, and GCF funding would allow small-scale farmers to benefit from the country's existing infrastructure. Scaling-up poultry farming is also easier to undertake once the initial capital is supplied (in terms of equipment and live poultry), as poultry can be reproduced on the farm in the long-term, and new materials for future poultry houses can be more easily obtained from the new revenue that poultry producers will have gained after the activity is successfully implemented.

[240] OECD. (2008). Livestock and regional market in the Sahel and West Africa Potentials and challenges

[241] Traore, E. H. (2021). Poultry Farming, A Growth-Promoting Sector to be Promoted and Supported for the Employment of Young People and Women. Approaches in Poultry, Dairy & Veterinary Sciences, 8(4), 812–814

[242] La Banque Agricole. (2023). Filière aviculture.

[243] Arnoldus, M., Kyd, M., Chapusette, P., van der Pol, F., & Clausen, B. (2021). Senegal Value Chain Study—Poultry. RVO Netherlands Enterprise Agency.

Ease of up-take by farmers

The mobilization of ANIDA's agricultural advisors will ensure that poultry farming is established and properly implemented. For this reason, as part of this overall project, a specific Component (Component 3 in the proposed activities under the TOC), has been included to prioritize the training and marketing support to farmers. ANIDA has a strong record of hosting in-person workshops with farmers across different localities on highly specialized aspects of Naatangue farming; these training workshops vary between a few days to one week, during which advisors provide theoretical and practical training exercises to farmers.[244] ANIDA's annual performance review found that, following a workshop on poultry production and maintenance techniques, farmers were able to produce double of what was set as the production target for the 2016 cycle.[245] This training was provided to farmers in the same regions that will benefit from this project, so there is a local track-record, word of mouth influence and awareness of the success of ANIDA's training programs for poultry farming.

Impact on agriculture and future-proof production capacity

The main benefit that poultry farming will have for the Naatangue farm is that it will provide the farm with a more affordable, and richer source of fertilizer for crop production. Indeed, the poultry-farming and agroforestry activities of this project are symbiotic. Chicken droppings are rich in macro and micro-nutrients, allowing for farmers to improve their crop production while reducing costs from avoiding synthetic fertilizers; this is particularly the case in the production of maize and other cash crops in West Africa.[246] This increased supply of fertilizer can not only save farmers money on synthetic fertilizer, but also provide an additional income should they have a surplus (see Table 13, for more information). This could subsequently be used for farming or personal uses, such as sending children to school or accessing medical facilities, thereby creating a network of positive externalities.

This activity is not immune to the impacts of climate change; poultry production is, to an extent, conditional on the temperature and humidity conditions of their environment; hotter temperatures tend to slow production[247], which is a concern as the climate rationale projects temperature increases throughout the country. However, the impact of rising temperatures can be mitigated by integrating the poultry houses described in Activity 1.2.2 by integrating the construction within the agroforestry system underlined in Activities 2.1.1. and 2.1.3. Indeed, by situating poultry houses underneath fruit-trees, such as Tamarind trees (one of the tree species proposed for this project), the impact of temperature increase can be mitigated as these trees over substantial cover from directly sunlight, thereby lowering the temperature at ground-level. In addition, most of the poultry farming activities planned in this project will be along the coast of the Thiès region of the Niayes, bio-climate zone, which is known to have much cooler

[244] ANIDA. (2016).

[245] Ibid

[246] Payebo, C. O., & Ogidi, I. A. (2021, January 4). Evaluation of the Effect of Cow Dung and Poultry Dropping on Maize Kernel Yield

[247] Arnoldus, et al. (2021) Senegal Value Chain Study—Poultry.

temperatures, thereby mitigating the impact of high temperatures on poultry production.[248]

Lastly, poultry farming in the rural areas proposed for this project will not only reinforce the food security of the farmers, but also of nearby, remote villages and communities, who would otherwise need to travel long distances to access central markets selling poultry. Indeed, the cost of transport and time required to travel to and from distant markets act as important costs to local communities that would benefit from the sale of goods grown and raised in Naatangue farms. Indeed, the establishment of poultry projects in villages has shown an increase in poultry consumption due to better accessibility and lower prices[249].

2.1.3 Considerations for successful implementation of this technology

The poultry sector is gaining an important share of Senegalese agricultural production; however, small-scale producers that will adopt the Naatangue model face considerable challenges. On difficulty is the cost of production such as feed, the components of which (corn and other cereals, fishmeal, meal, etc.) are sold to high prices. Feed, in the form of imported maize and soybean, represents the majority of the input costs for small-scale poultry farmers.[250] The Naatangue farm project and model can offer solutions to structural barriers, such as high feed costs. For instance, the project will provide farmers with start-up feed to begin their production (Activity 1.2.2). Farmers can also rely on their new, diversified farming environment (production of various grains, fruits, nuts) to source poultry feed alternatives; indeed, the use of a range of chicken feed products from agroforestry production has not only shown itself to be a cheaper alternative to imported maize/soybean, but also resulted in more nutritious and healthy flocks of poultry.[251] Therefore, GCF investment would help farmers surpass the initial barriers to entry of poultry farming by providing feed to farmers, as well as a structural alternative to traditional feed by also investing in agroforestry systems that would allow farmers to cut production costs and potentially improve the quality of their production through alternative, locally-sourced feed. ANIDA advisors will be able to effectively advise farmers on how they can use household and farm-level waste to produce chicken feed, which is a tried-and-tested technique that eliminates food waste and reduces operational costs from the purchasing of chicken feed.[252]

Another difficulty that poses a risk to small-scale poultry production is the comparative advantage that large-scale producers in Senegal have over small-scale producers in terms of storage equipment. Indeed, as large-scale producers are much more likely to have access to refrigeration, which allows them to store killed poultry in refrigeration, while small-scale producers are less likely to have this equipment.[253] This obliges

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[248] Ba, K., Diouf, A. D., Ly, C., & Ba, M. (2022). Commercial Poultry Success Stories in Sub-Saharan Africa: Senegal Case Study.
[249] CREATE! (2019, October 25). Increasing Food Security with Poultry Raising Projects | Senegal. Create.
[250] Arnoldus, et al. (2021) Senegal Value Chain Study—Poultry.
[251] Salem, A. Z. M., Kunst, C. R., & Jose, S. (2020). Alternative animal feeds from agroforestry plants. Agroforestry Systems, 94(4), 1133–1138.
[252] Siddiqui, Z., Hagare, D., Jayasena, V., Swick, R., Rahman, M. M., Boyle, N., & Ghodrat, M. (2021). Recycling of food waste to produce chicken feed and liquid fertiliser. Waste Management, 131, 386–393. https://doi.org/10.1016/j.wasman.2021.06.016
[253] Arnoldus, et al. (2021) Senegal Value Chain Study—Poultry.

producers to make difficult choices between keeping their poultry flock alive, requiring additional spending on chicken feed, or losing their flock, altogether (cutting their losses).[254] Either way, small-scale farmers experience considerable losses. The Naatangue farm project, with GCF support, would allow small-scale farmers to compete with large-scale producers by offering them more security, through the provision of solar-powered cooling equipment, should there be delays in selling their poultry.

During the cold weather period from December to February, prices of meat tend to decrease, leading to lower benefit periods for poultry farmers. Under the Naatangue farm model, integrating poultry production with other agricultural activities, such as agroforestry or crop farming, can provide diversified income streams and further enhance the profitability of the sector. In addition, farmers will be able to conserve their poultry production during periods in which poultry fetches lower prices by the acquisition and use of solar-powered refrigeration.

2.1.4 Overview of impact and co-benefits

In the Senegalese poultry sector, it is essential for farmers to not only understand market trends, but also the benefits of integrating poultry farming with other agricultural activities. The Naatangue farm model is an example of this integration, which promotes the incorporation of poultry farming into a diversified farming system that includes crop production, agroforestry, and animal husbandry. This model allows for the recycling of poultry manure as fertilizer for crop production, creating a closed-loop system that maximizes the use of available resources.

The production of poultry has significant implications for food security and income among farmers. In many rural areas of Senegal, chicken is a delicacy that is typically reserved for holidays and other special occasions due to its relatively high cost in terms of both money and time. However, with the rise of poultry farming in rural areas, and added contribution to the sector through the Naatangue farms, many rural communities will now be able to enjoy poultry more frequently and generate additional income through the sale of excess poultry in local markets. This can also improve food security and help rural communities better reach dietary requirements for protein in-take, without having to spend additional income on the cost of travel to distant markets. As a result, chicken has emerged as a lucrative source of protein and income for families in these areas[255], and GCF funding for Naatangue farms can act as a further catalyst for reinforced food security in rural Senegal.

The poultry & eggs value chain is well developed in Senegal. A variety of indirect actors are involved in the supply chain as shown below. In addition to farmers, all components of the value chain will benefit from poultry farming. Traders (*baba banas*) play a critical role in getting produce from producers to the markets in Senegal. They purchase chickens and eggs at the farm level and then sell these to retailers in mostly open markets. They can also supply supermarkets. *Bana banas*, who mostly trade in live chickens, sell chicken and eggs to wholesalers or retailers in the markets. The bird is then slaughtered, and the customer has an option of hiring a *deplumeuse to* pluck and

[254] Ibid

[255] CREATE! (2019). Increasing Food Security with Poultry Raising Projects | Senegal. Create.

clean the chicken. In the Naatangué farms, the diversification of activities will increase the number of direct and indirect beneficiaries, and existing structures such as those described in the figure, above, will facilitate the adoption of poultry farming in Naatangue farms.

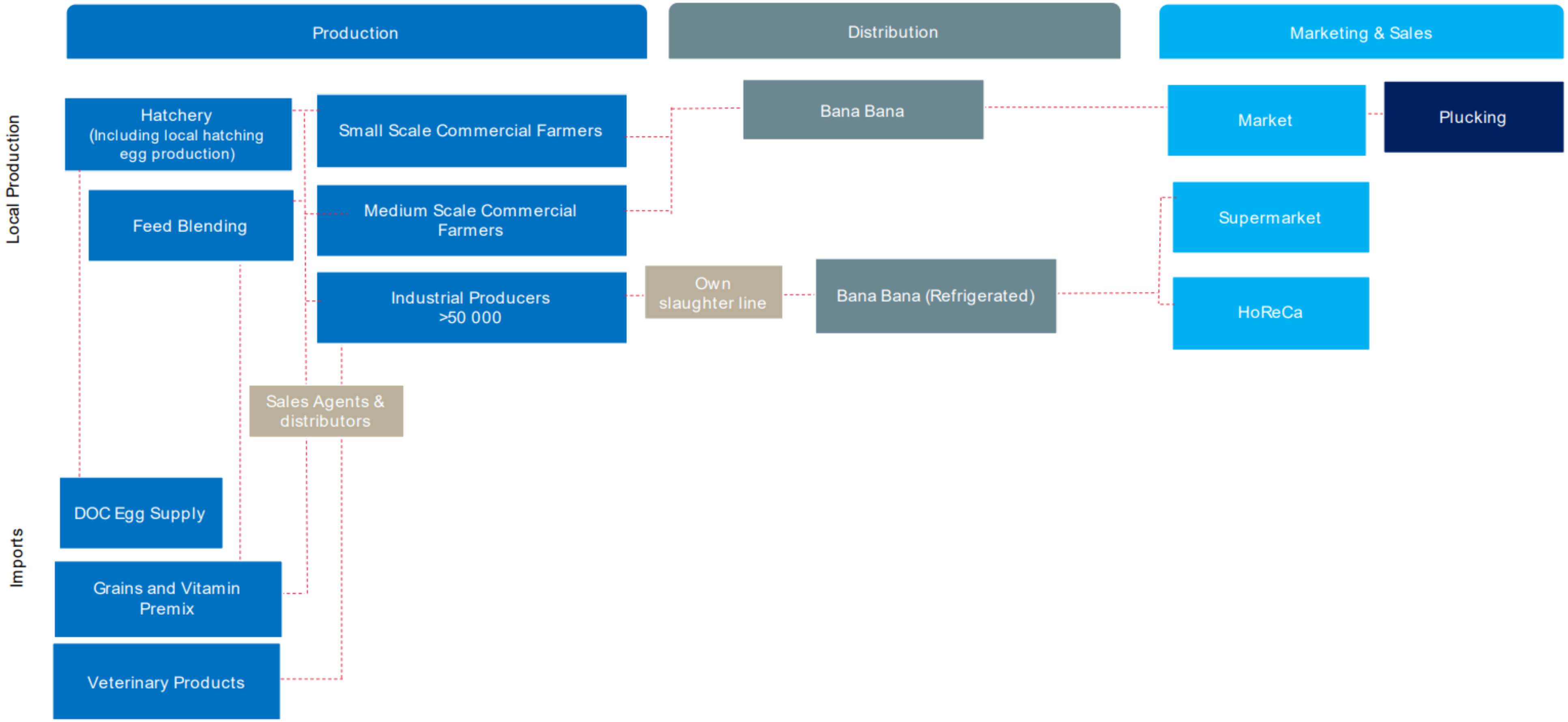

Figure 15.Structure of the Poultry Value Chain[256]

[256] Arnoldus, et al. (2021) Senegal Value Chain Study—Poultry.

Summary of Proposed Option and Alternatives

As previously mentioned, the goal of this activity to provide diversified income streams to farmers throughout the different cropping seasons, while also reinforcing food security for subsistence purposes, and providing organic substitutes to fertilizer for crops. There are, however, alternatives to poultry production that could meet the same goals. However, the findings of this analysis indicate that poultry production achieves these goals more efficiently than other means of animal production, which is why the Naatangue model is the most appropriate way forward for Senegalese farmers. A comparison of options is further explored below, whereby poultry farming is compared to cattle raising and fish production in terms of the economic and environmental benefits each of these options provide.

One of the key consideration's farmers have in animal production is the retail price their production will fetch in local markets. Figure 16, below, provides a break-down of the different retail prices of animals that are raised or fished in Senegal. The figure indicates that the production of eggs and chicken closely rivals beef and fetches a much higher price than tilapia. However, the retail price of the combined sale of eggs and chicken are lower than beef and Thiof (Senegal's national fish).

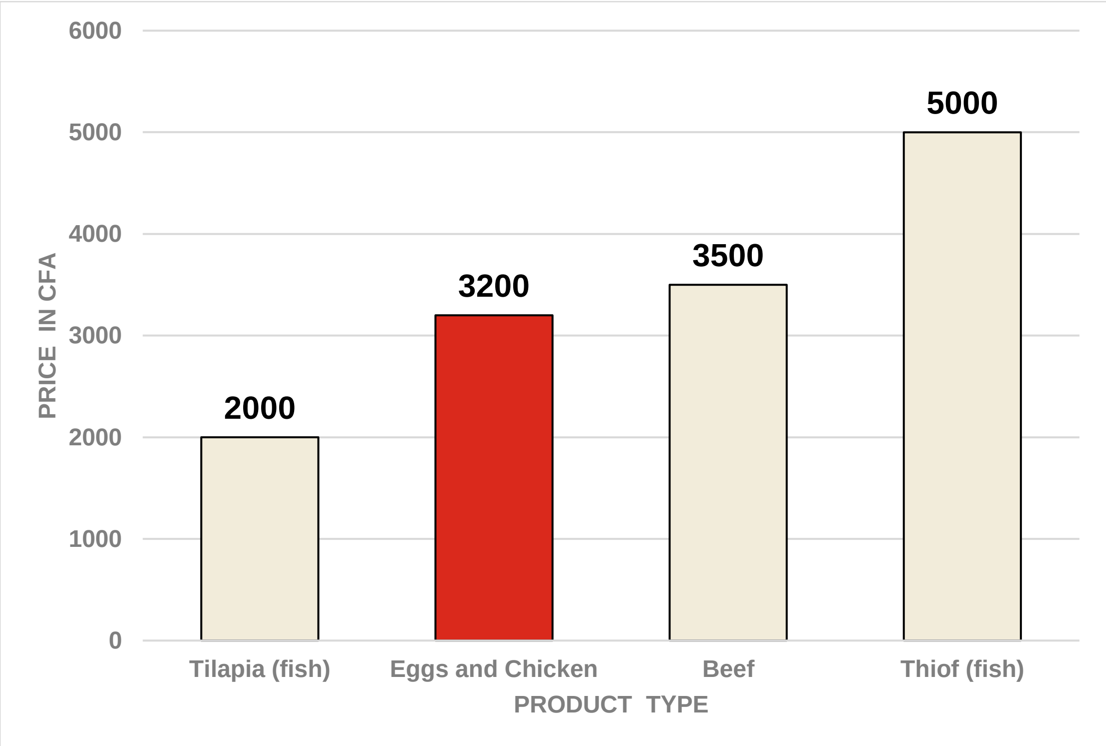

Figure 16. Retail prices (per kg in CFA) for animal products, 2020 [257].

Though beef and Thiof can fetch higher prices per kg, these higher prices are largely explained by considerably higher production and labor costs. Cattle require greater volumes of feed and water supply, which adds to the cost of production for a farmer Indeed, a cost analysis of cow production in Senegal found that the cost of cattle feed was most responsible for cattle raisers seeing lower returns in their production of cattle products. Though this is also the case for chicken feed (as discussed in the previous sub-section), chicken feed can be more easily replaced with substitute inputs sourced from agroforestry products than cattle-feed simply due to the much smaller dietary

[257] Arnoldus, et al. (2021) Senegal Value Chain Study—Poultry.

requirements (volume) of poultry. Cattle also requires significantly more surface area and time to mature before slaughter when compared to poultry (45 days), and poultry provides the added benefit of producing eggs, allowing for a continuous, additional source of income and means of subsistence not offered by cattle. As the Naatangue model operates on the basis of small farmers (~1 ha), poultry is most suitable due to surface-area constraints, cost of feed, and secondary production benefits (eggs). Thiof is, by far, the most expensive meat per kg in Senegal, though the production constraints are far more significant than in poultry production. Thiof is a grouper fish that lives in coastal waters, and is not suitable for inland aquaculture which is the main focus of this project.

Farmers can also more than double their income from selling poultry-based fertilizer (1,750 CFA/50kg bag) compared to livestock-based fertilizer (650 CFA/50 kg bag); this can serve as an additional income to farmers should they have a surplus in their waste-recycling of chicken droppings. Table 13 below, shows the price of fertilizers from different sources.

Table 13. Comparison of Cost of Various Fertilizers Available to Farmers[258]

Fertilizer type	Costs (CFA)
NPK (10kg bag)	1200
DAP (10kg bag)	1400
Poultry (50kg bag)	1750
Animal Livestock (50kg bag)	650
Compost (Casuarina tree) per wagon	2000

Poultry farming in Senegal is characterized by two distinct farming systems: traditional poultry farming, which uses local poultry breeds, and modern industrial poultry farming, which tends to favor imported broiler breeds.[259] The Naatangue farm model employs the traditional poultry farming technique, which is smaller in scale compared to the industrial system. Local breeds have the advantage of being more resistant to disease and are better adapted to the hotter climate of the country[260], and according to surveys, the local population prefers local varieties due to taste preferences, all the while fetching higher prices than broiler varieties. For this reason, GCF investment in the Naatangue farm model will reinforce a section of the poultry sector that is less likely to experience shocks, such as disease and fetch higher prices for small producers.

In short, the additionality of GCF investment will largely address the barriers to entry for farmers, who face high, up-front costs for the establishment of poultry-raising infrastructure (sheds, fences, feed) and working capital (chicks). The long-term, operational costs will be affordable for farmers with the support of ANIDA's agricultural advisors (see Component 3) as they will provide the necessary training that will maximize efficiency and mitigate production losses, as well as through the community-based savings fund. GCF investment in equipment will catalyze and mobilize local expertise from the agricultural advisors, which will be passed on to producers, hereby assuring the long-term functioning of poultry farming, and reducing the need for future public financing to

[258] Arnoldus, et al. (2021) Senegal Value Chain Study—Poultry.

[259] Traore, E. H. (2021). Poultry Farming, A Growth-Promoting Sector to be Promoted and Supported for the Employment of Young People and Women. Approaches in Poultry, Dairy & Veterinary Sciences, 8(4), 812–814

[260] Berkhout, N. (2020, January 6). Case study: Chicken remains a luxury in Senegal. Poultry World

support the activity. The success of this support in helping farmers sell products is demonstrated in the section on marketing support later in this document.

Summary of Proposed Option and Alternatives

Table 14 is a summary of the comparison between the selected option and the other alternatives. It shows that the informal backyard option can be implemented at low cost but its vulnerability to the impact of climate change is high, and no mitigation measures are available. The large commercial production option offers measures to adapt to the impacts of climate change, but its implementation cost is high. It may be difficult to implement and replicate because of the cost. The smaller commercial unit we have chosen has a moderate cost. It’s exposure to climate change impacts can be mitigated by the activities planned in the Naatangué farms project.

Table 14. Summary of the chosen option and alternatives

Options and Alternatives	Scalability			Impact and Co-Benefits		Climate		
	Cost	Scalability	Easy Up-take/ Implementation	Impact on agriculture production	Co-benefits	Impact for climate adaptation	Future-proof for future climate	Mitigation potential
Chosen Option: Smaller commercial units	Moderate	High	High	High: Possibility to produce poultry-based fertilizer. Possibilities of producing poultry feed	High: A variety of actors benefit directly or indirectly from the poultry sector	High: Diversification of sources of income, food security	High: Impact of changing climate conditions can be mitigated by integrating poultry farming within the agroforestry model of the farm	The barriers can be mitigated with closed shelters; refrigerators working with solar power
Alternative 1: Informal, backyard producers	Low	Low	High	Moderate	Moderate	Moderate: Diversification of sources of income, food security	Moderate	Moderate Impact
Alternative 2: Large commercial production	High	Moderate	Low	High: Possibility to produce poultry-based fertilizer; Possibilities of producing poultry feed	High: A variety of actors benefit directly or indirectly from the poultry sector	High: Diversification of sources of income, food security	Low: Use of air-conditioned sheds	Low impact (tend to contribute more to emissions)

2.2 Milk production units

2.2.1 Description

This activity consists of reinforcing the existing milk production facilities and operations in village farms. The activity will only assist village farms that already have milk-producing cows, on-site. The project will help improve the quality and quantity of milk production. As this activity does not consist of introducing a new technology or system, and rather focuses on reinforcing the climate-sensitivity and productive-nature of existing milk production facilities. As this activity is a minor component of the project only applicable in a subset of selected farms, this section will provide a proportionally less comprehensive overview of the activity.

The objective of this activity is the strenghtening and climate-proofing of current faming structures by diversification of the source of income and improvement of food security. Milk processing units correspond to activity 1.2.4 in the logical framework that list the equipment needed. The following tasks will be undertaken to establish solar-powered milk processing units:

- Solar panels
- 3 cooling systems
- 3 Refrigerators/pasteurizers;
- 3 Packaging machines;
- 6 Galvanized cans;
- 3 milking pots;
- 3 batches of milk quality control equipment;
- Acquisition of packaging;
- Training on dairy processing.

Historically, local milk production in Senegal has struggled to keep up with the demands of consumers, so there has been a heavy reliance on imported milk and milk products. [261]More recently, efforts have been made to improve local dairy production by establishing large, organized dairies that collect milk from rural production areas and developing small-scale processing units, such as mini dairies. The local dairy value chain in Senegal consists of (1) informal collection systems where farmers commonly deliver milk directly to dairies; (2) traditional and artisanal processing using simple equipment and techniques; and (3) short local marketing and sale circuits. [262] Most West African dairy sectors are dominated by raw, unpasteurized milk or traditional, spontaneously fermented milk products, such as “lait caillé” in Senegal, sold through small-scale channels without a cold chain, so the risk of food safety hazards may be increased.[263]

There is a need to educate milk producers, small-scale processors, and vendors on the importance of refrigerating milk immediately after milking as well as maintaining the cold chain until the milk is heat treated and, subsequently, until the milk is marketed to the

[261] Leone, C., Thippareddi, H., Ndiaye, C., Niang, I., Diallo, Y., & Singh, M. (2022). Safety and Quality of Milk and Milk Products in Senegal-A Review. Foods (Basel, Switzerland), 11(21), 3479

[262] Ibid

[263] Ibid

consumer. This activity will fill this gap by streamlining and improving the milk production process in order to raise farmer income, while mitigating risks of health-related contamination of the sites, in a way that mitigates the emission of carbon.

2.2.2 Technical assessment of the activity and its alternatives

Cost

Table 15, below, provides an overview of the main sources of income related to cattle production in Senegal, as well as the main drivers of the costs to raising cattle. The table indicates that the highest proportion of income from activities linked to cattle production are the sale of milk, followed by the sale of animal (meat). The table also indicates that the most important drivers of cost are linked to feed, followed by animal purchase, and labor.

The project aims to address these cost concerns by providing technological solutions that will not only drive the costs of production down, but also improve the quality and processing time of milk production. The activity will not require the purchase of more feed, milking cows or hired labor; rather, this activity, under the Naatangue model, is about providing the training and technology to the existing farmer capacity and physical infrastructure so as to create a paradigm shift in how farmers produce their milk. Therefore, the most important drivers of cost in milk production will be further added to by the activity's intervention.

Milk production requires significant energy for pumping, cooling systems and refrigeration; the fixed and operating capital for this equipment can be very costly, especially if they rely on fossil-fuels. The solar panels proposed in this activity will replace any existing technology that is reliant on fossil fuels (diesel/electricity network), thereby reducing the costs of the additional equipment planned for distribution by this activity. The costs of the refrigerators, pasteurizers, and cooling systems will be minimized by powering them with solar energy. Just as in the case of poultry production, the refrigeration units that will be provided under this activity will reduce the pressure farmers have to sell their fresh product. Pasteurization also allows for a much longer shelf-life of milk products, thereby providing the farmer with more storage and transportation options for the sale of their milk products. Finally, cooling systems will allow for an improved quality of the milk by reducing the likelihood of bacterial build-up, thereby meeting the country's dairy standards.

Table 15. Net returns and gross margin analysis (in US dollars) for milk production[264]

Variable	NR	GM	Per cow per annum				Per herd per annum			
			Mean	SD	Min	Max	Mean	SD	Min	Max
Income and benefit components										
Milk sale	•	•	172.2	178.6	1.4	910.7	1865.0	2794.5	12.5	20,962.9
Animal sale	•	•	120.3	192.5	0.0	1038.1	1002.8	1411.8	0.0	7896.1
Milk consumed	•		19.5	18.7	0.0	85.7	182.2	173.3	0.0	817.5
Animals gifted in	•		4.8	32.5	0.0	260.0	27.2	143.6	0.0	993.0
Animals given away	•		3.1	14.9	0.0	131.9	27.5	124.7	0.0	1062.6
Milk given away	•		2.5	6.6	0.0	39.2	30.0	85.5	0.0	713.1
Other incomes	•	•	0.4	4.6	0.0	48.5	3.1	31.1	0.0	329.9
Total income NR			**322.7**	**328.0**	**13.3**	**1562.6**	**3137.8**	**3935.4**	**160.9**	**30,817.2**
Total income GM			**292.9**	**302.5**	**13.3**	**1415.6**	**2870.8**	**3705.5**	**110.5**	**28,342.3**
Cost components										
Feed	•	•	146.4	194.3	0.0	1174.1	1393.1	2830.7	0.0	27,026.5
Animal purchase	•	•	62.8	119.7	0.0	679.6	831.1	1936.3	0.0	12,866.4
Hired labour	•	•	37.2	26.4	0.0	132.7	328.7	186.4	0.0	1064.4
Household labour	•		20.9	21.1	0.0	93.3	167.8	153.9	0.0	833.9
Housing	•	•	11.3	19.9	0.0	129.0	102.0	154.6	0.0	798.8
Reproduction	•	•	6.6	15.8	0.0	104.4	45.0	97.4	0.0	574.3
Health	•	•	4.5	5.0	0.0	23.4	46.6	54.5	0.0	273.5
Water	•	•	4.3	5.6	0.0	27.8	39.4	51.4	0.0	218.5
Animals given away	•		3.1	14.9	0.0	131.9	27.5	124.7	0.0	1062.6
Milk given away	•		2.5	6.6	0.0	39.2	30.0	85.5	0.0	713.1
Loan repayment	•	•	1.1	6.6	0.0	54.7	14.8	99.4	0.0	921.1
Other expenses	•	•	0.5	2.0	0.0	18.0	5.7	33.1	0.0	330.0
Total cost NR			**301.1**	**287.7**	**16.1**	**1612.3**	**3031.8**	**4267.5**	**166.0**	**37,113.3**
Total cost GM			**274.6**	**278.7**	**4.4**	**1528.7**	**2806.4**	**4168.0**	**30.4**	**35,188.7**
NR			**21.7**	**202.9**	**−639.1**	**807.4**	**106.1**	**1740.3**	**−6590.1**	**5416.0**
GM			**18.3**	**195.3**	**−602.6**	**806.0**	**64.4**	**1741.2**	**−6846.4**	**5158.3**

NR, net returns; *GM*, gross margin; *SD*, standard deviation; *Min*, minimum; *Max*, maximum

Scalability and Ease of Up-Take and Implementation by Farmers

The aim of this activity is specifically to scale-up existing dairy operations in certain village farms. As described above, the proposed interventions, both in terms of materials and training, are designed to streamline the milk production process in a way that mitigates losses (due to lack of refrigeration and cooling systems), as well increases the flexibility farmers have in deciding when it is most profitable to sell their dairy products.

There have been successful scaling-up activities related to dairy production for small-holder farmers in the Fatick region. These activities included providing marketing hubs for milk producers to sell their products, as well as training on how to improve milk collection and

[264] Malenje, E. M., Missohou, A., Tebug, S. F., König, E. Z., Jung'a, J. O., Bett, R. C., & Marshall, K. (2022). Economic analysis of smallholder dairy cattle enterprises in Senegal. Tropical Animal Health and Production, 54(4), 221.

storage practices.[265] The impact of this initiative, after 1.5 years of implementation, is that the project beneficiaries increased their production by 246% (from 12,900 liters to 44,670 liters).[266] In addition, average monthly income more than doubled from US$120.90 to US$253.20.[267] Other interventions have been particularly beneficial in terms of bridging the gender income gap in the dairy industry, such as the Ministry of Animal Husbandry's program that trained a group of female milk producers on alternative uses of milk (curdling, yoghurt, artisanal cheese), and how to market new dairy products.[268] This structural support from the Ministry allowed for the program, created in 2003, to scale up its membership to over 25,000 members by 2013.

As a result, there is local awareness among farmers in certain regions, such as Fatick (one of the project implementation regions), of the benefits of interventions from agricultural experts on milk production. The activity planned under the Naatangue model will go one step further, and not only provide the training and marketing support (component 3) to producers but will also introduce modern equipment that will assist farmers improve the pace at which milk is produced, as well as the ways in which milk is processed and stored. Therefore, the activity provides even greater benefits than past interventions, and farmers have already seen positive results from the provision of training and marketing support.

Impact on agriculture and future-proof production capacity

The cattle that will be used for dairy production also provide opportunities for recycling organic waste for crop production. Indeed, one of the complimentary activities of the Naatangue model to dairy production is the recycling of organic waste. Cow manure is rich in nutrients, and can provide farmers with a cheaper alternative to organic fertilizer for cash and subsistence crop production.

The availability of cattle feed and fodder crops is of particular relevance to the projected increase in temperature outlined in the Climate Rationale. As highlighted in the cost section of this activity, animal feed is one of the key constraints of cattle raising for milk production. This will likely become more difficult as warmer temperatures render the availability of crops used for fodder scarcer. However, as this activity will be embedded with agroforestry activities in the Naatangue model, farmers can benefit from a highly local, and cheap alternative to feed that will allow them to continue running their dairy operations, even as climate change becomes more pronounced.

2.2.3 Considerations for successful implementation of this technology

There are various climatic and structural challenges that may limit the effectiveness of the activity. For example, in the dry season, gross margins are negative due to high spending on food supplements and feed inputs. There is also an insufficient supply of fresh milk in the dry season, high transport fares due to long distances to the milk collectors, lack of storage facilities, insufficient extension support, poor road networks, and competition from imported

[265] Tetrapak. (n.d.). Linking local smallholders to the dairy industry in Senegal.

[266] Ibid

[267] Ibid

[268] Diagne, B. (2013). Le lait, valeur montante au Sénégal. ALIMENTERRE.

milk.[269] This activity will bridge this gap by not only supply the equipment and training necessary to improve the production of milk, but also the marketing of the milk so that milk producers have accurate and updated information on milk prices, as well as access to market vendors. The improved conservation and cooling of milk (through the provision of equipment and training on pasteurization) will allow for farmers to travel greater distances to sell their products by mitigating the risk of spoilage.

2.2.4 Overview of impact and co-benefits

Several stakeholders are involved in the livestock value chain. These include farmers, veterinary service providers, feed suppliers, other input suppliers to the livestock farms, crop farmers, other cattle owners and cattle traders, milk and meat processing companies, and consumers. Each of these actors can economically or personally benefit from the improvement in the milk production process, especially at the local level.[270] A variety of directly and indirectly-related jobs can be created in each at every stage of the supply chain should the production of milk be improved, such as: dairy farming, transport to the dairy, milk processing, milk packaging, milk transport to the "retail distributor", milk retailing and transport to the consumer and milk utilization.

This activity also provides an opportunity for farmers to diversify their sources of fertilizer by processing cattle waste; this demonstrates the synergy milk production has with the wider agroforestry system of Naatangue farms (further described in this document). The key is that farmers will have a wider range of choices in how they provide inputs to their farms, which will also allow them to save their income on expensive, synthetic (fossil-based) fertilizers. Despite ramping up milk production, the activity mitigates any additional carbon that will be produced from improving milk-production practices as solar panels will provide the energy necessary to extract and cool/store dairy products in these farms.

It is important to remember that this activity represents a small portion of the planned interventions of this project; the activity will only be implemented in a few family farms, in which dairy farms are already operational. However, it is worth considering the various co-benefits and low climate impact that this activity will have for both farmers and society, respectively.

[269] Gunarathne, A., & Boimah, M. (2022). Analysis of the milk value chains in Ghana and Senegal: What can we learn? Proceedings in Food System Dynamics, 0, Article 0.

[270] Leone, C., Thippareddi, H., Ndiaye, C., Niang, I., Diallo, Y., & Singh, M. (2022). Safety and Quality of Milk and Milk Products in Senegal-A Review. Foods (Basel, Switzerland), 11(21), 3479

Table 16 is a summary of the comparison between the selected option and the other alternatives. Modern milk production is associated with higher costs due to the cost of fixed capital, but the scalability of the activity remains very high, as evidenced by past projects to improve dairy production in Senegal.

Table 16. Summary of the chosen option and alternatives

Options and Alternatives	Scalability			Impact and Co-Benefits		Climate		
	Cost	Scalability	Easy Up-take/ Implementation	Impact on agriculture production	Co-benefits	Impact for climate adaptation	Future-proof for future climate	Mitigation potential
Chosen Option: Modern milk production	High (up-front costs are high, operating costs are relatively low)	High	High: infrastructure already exists; only requires installation of equipment and subsequent training	High: Possibility to produce animal-based fertilizer;	High: Alternative, richer and cheaper source of fertilizer for crop production	High (allows for a diverse source of income should other farming production activities be impacted by climate change)	High	Moderate
Alternative: traditional milk production	Moderate	Moderate	High	Moderate	Moderate	Moderate: Diversification of sources of income, food security	Moderate	Moderate

2.3 Fishpond

2.3.1 Description

Fishponds are a form of aquaculture, which refers to all animal production activities in an aquatic environment that can include fish farming, oyster and mussel farming (shellfish farming), shrimp farming, and seaweed farming (algoculture).[271] Aquaculture can take different geographic forms; for instance, marine culture is aquaculture that is practiced by the sea, while continental aquaculture is practiced in inland ponds, though they ultimately achieve the same aims of diversifying farmer incomes through similar practices. Continental aquaculture is the most common form of the practice, and it mainly occurs in freshwater sources, which are abundant throughout the country (ponds, lakes, rivers). The history of aquaculture is deeply rooted in the Casamance region (Ziguinchor, Sedhiou, and Kolda), though most aquaculture occurs in along the northern coastline and in the Senegal River.[272] Fishponds are the most common form of inland aquaculture in Senegal; indeed, no other country in West Africa has experienced such a rapid growth in the use of fishpond aquaculture as Senegal.[273]

Fishponds can serve multiple purposes for inland farming. For instance, a fishpond can play a key role in nutrient replenishment in agricultural fields that have experienced nutrient depletion due to insufficient inputs and repeated monocropping. This can be done by harvesting the nutrient-rich sediments found in fish ponds and dispersing them on agricultural fields to ensure a sufficient supply of nutrients and fertilizer to the soil.[274] Relatedly, fish ponds allow for an improved waste-management of organic waste as farm residues (animal manures, crop residues, household residues) are needed in order for the fishpond to function.[275] Another key advantage offered by fishponds is that it provides both a nutrient-dense source of food to farmers throughout the year, and allows farmers to benefit from an additional source of income. In the context of this project, the Executing Agency (ANIDA) proposes the construction of a 280 m3 fishpond in each of the family farms, along with the provision of fish fry and feed to farmers.

The main challenges of implementing fishponds, at scale, are the relatively high input costs (fish feed, nutrient input supply). Though relatively cheap compared to imports, nationally produced fish feed is of lower quality and is more suited to bottom-dwelling fish than those used in aquaculture production. The nature of these challenges, as well as the steps that can be taken to mitigate their impact on uptake, will be further explored in the next section.

[271]Bousso, M. (2022). Fisheries and Aquaculture in Senegal. United States Department of Agriculture (USDA).
[272]Ndour, N., Sambou, B., Sambou, A., & Dasylva, M. (2019). ENDOGENOUS KNOWALEDGE OF TRADITIONAL FISH AND RICE FARMERS IN LOWER-CASAMANCE (SENEGAL). Applied Science and Engineering Progress, 9, 128–138.

[273] Miller, J. (2006). Integrated irrigation and aquaculture in West Africa: Concepts, practices and potential.
[274] Muendo, P. N. (2006). The role of fish ponds in the nutrient dynamics of mixed farming systems.
[275] Ibid

2.3.2 Technical assessment of the activity and its alternatives

Cost

Fishponds have been a common practice throughout Senegal's history, but the practice has experienced slow growth since the 1980s.[276] One of the main barriers to implementing fishponds in Senegal mainly concern the availability and affordability of quality fish feed. Higher quality, imported fish feed ($1.3-$1.6/kg) can be twice the cost of nationally-produced fish feed ($0.62-$1.33/kg), the latter of which is often sinking fish feed, which is not adapted to surface-dwelling fish like Tilapia, one of the most commonly produced, aquaculture fish in Senegal.[277] [278]

While the input costs are high, initial funding to provide farmers with the opportunity to develop their aquaculture production would allow for the aquaculture sector to grow.
Some freshwater fish can fetch cheaper prices per kg than salt-water fish, though generally the price of farmed fish (Tilapia and African catfish in Senegal) is higher than salt-water fish (captain fish and octopus), with the exception of white grouper (3600 FCFA/kg or $6.60/kg). Farmed fish fetch between 1500 – 3000 FCFA/kg ($2.67-$5.35), while salt-water fish fetch between 750 FCFA/kg ($1.37) and 1720 FCFA ($3.21).[279] These price differences are generally due to higher input and management costs of farmed fish, as well as additional transport costs to markets in the case of in-land fishponds.

The growth of the sector could provide the necessary stimulus for the national supply of fish feed to grow, thereby driving down the price as supply grows. This may, in turn, drive the price of aquaculture-produced fish down, allowing for farmers to compete with salt-water fish. The project also plans a suite agricultural support services (Component 3) that will connect farmers with local markets, which will supply information on prices, which can limit the risk of raising fish. GCF funding would allow for the purchase of fry and feed will be provided to farmers, thereby surpassing the barriers to entry that they would normally face without funding from this project.

Scalability/ Ease of Uptake by Farmers

The potential for scalability of fishponds in Senegal is considerable; the country has over 1 million ha of exploitable, in-land lakes that can be used to support fishpond aquaculture.[280] Fish is also one of the most common staples in Senegalese food, as the country's consumption rate of fish is 37 kg/capita/year, which means that farmers would not have to adjust to the country's consumption patterns.[281] The use of fishponds is also widely used in the Basse Casamance region, where farmers have cultivated generations of experience in raising fish and

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[276] Bousso, M. (2022). Fisheries and Aquaculture in Senegal. United States Department of Agriculture (USDA).
[277] Central Luzon State University Science City of Muñoz. (2000). Feeding of Tilapia. Central Luzon State University Science City of Muñoz.
[278] Bousso, M. (2022). Fisheries and Aquaculture in Senegal. United States Department of Agriculture (USDA).
[279] Ibid
[280] Miller, J. (2006). Integrated irrigation and aquaculture in West Africa: Concepts, practices and potential.
[281] Ibid

growing rice symbiotically. In the Basse Casamance, rice-fish alternating with fish only culture has allowed for farmers to yield between 963 to 1,676 kg/ha in ponds fertilized with animal manure and fed farm by-products, and 590 kg/ha from rice fields.[282]

There are even several indigenous harvesting techniques for fishponds in Senegal, such as *etolum*, whereby harvesting is done in the low tide by draining the pond with a basket placed at the end of the pond's drainpipe.[283] The indigenous nature of this form of aquaculture, in which practitioners have generations of passed-down, local knowledge, will serve to more easily implement this practice in the context of a Naatangue farm.

Ease of implementation

The implementation of fishponds within Naatangue farms can be assured by various entities. Senegal has a variety of governmental and non-governmental organizations that have technical expertise in the implementation of aquaculture systems. For instance, the Ministry of Fisheries and Maritime Economie (Ministère de la Pêche et de l'Economie Maritime) hosts the National Agency of Aquaculutre (Agence Nationale de l'Aquaculture; ANA). The ANA is responsible for the following objectives: (1) identifying and valuating favorable locations for both maritime and continental aquaculture, (2) disseminating awareness campaigns and structuring company-led projects in different segments of the aquaculture supply chain, (3) reinforcing the management capacity of aquaculture professionals (technical, financial, commercial and organizational), (4) supporting the development of aquaculture production, (5) ensuring that quality control services are provided to producers, and (6) seeking national and foreign investment for aquaculture projects.[284] Between 2012 and 2018, the ANA trained 6,840 farmers in in-land aquaculture practices, such as in the acquisition and installation of tanks/ponds, management of fish production, production of fish feed, and good practices for financially efficient farming practices.[285]

There are also additional resources and institutions on which aquaculture farmers can rely, such as the National Training Centre of Fisheries and Aquaculture Technicians (CNFTPA) in Dakar, which trains aquaculture professionals on different skills related to fish processing, as well as the University Institute of Fishing and Aquaculture in Dakar, which provides university course in fisheries and aquaculture.[286] Therefore, ANIDA has a significant network of local experts with whom they can work to provide adequate training to farmers, as outlined in the activities of Component 3, and deliver the expected results.

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[282] Gemmill-Herren, B., van Dis, R., Ndiaye, T., Waly Sene, J.-M., Yimer, H., Zuellich, G., & Sene, O. S. (2020). A Holistic Lens on Rice Value Chain Pathways in Senegal; Application of "The Economics of Ecosystems and Biodiversity for Agriculture and Food" Framework

[283] Ibid

[284] Senegal.org. (2023). Agence Nationale de l'Aquaculture

[285] ANA, 2019. Rapport d'activités annuel 2018 (Rapport technique). ANA, Dakar, Sénégal.

[286] Deme, M., & Bah, M. (2012). Comparative Cost Study on Sole Fish: The Gambia and Senegal. USAID/BaNafaa.

Impact on agriculture and future-proof production capacity

Fishponds have been highly effective in improving and increasing yields of both fish and rice. A cross-regional study of the rice-fish cultivation system in sub-Saharan Africa found that this system, when compared to production systems that focused exclusively on rice or fish, that farmers were able to, on average, increase their yield of rice from 6.2 tons/ha to 7.5 tons/ha, and their yield of fish from 0.75 tons/ha to 2.25 tons/ha.[287] There are, though, threats to some models of fish ponds in Senegal, such as those that rely on shallow river systems, which have been threatened by overfishing and slower flow rates in the dry season due to recurring droughts. These climate risks are mitigated in the context of fishponds for this project as Naatangue fishponds do not depend on natural streams; instead, fish ponds in the Naatangue model are artificially constructed and relatively small in size (280 m3), allowing for farmers to provide better control the water conditions than in natural systems (ponds, rivers).

The National Adaptation Plan of the Fishery and Aquaculture Sector 2035 sets out a number of different initiatives to render in-land fish production more resilient to the impacts of climate change. These include the following measures: creation of basins for rain-water retention, adoption of biological resting points to allow for ponds to rest, saving and storing juvenile fish species into separate areas that are not at risk of drought, installation of water retention areas, recapturing salinized rice farms to practice tilapia aquaculture, and the construction of anti-salt dikes.[288] Therefore, there is an existing national adaptation plan that will assist in facilitating the success of Naatangue fishponds.

2.3.3 Considerations for successful implementation of this technology

As previously mentioned, one of the key considerations and limiting factors in adopting fishponds as a viable addition to a farm is the one of cost. The cost of inputs and maintenance has been identified in the previous subsections, but the project has already identified this challenge by planning for the distribution of fry and fish feed, along with the materials and labor required to build 280 m^3 fishponds. The GCF funding that will provide this support already alleviates the most important hurdle that farmers and ANIDA face in implementing this technique.

Other risks that fishponds may face as the impacts of climate change worsen include the salinization of continental waters, such as ponds. Fortunately, farmers in the Basse Casamance region have developed techniques that integrate fishponds and rice farming symbiotically so as to limit the salinization of the surface in water in which they raise fish and grow rice. Senegalese rice farmers have constructed fishponds along the foreshore area to cultivate fish as a means of safeguarding their rice fields from saltwater intrusion. These fishponds, ranging from 500 to 5,000 square meters in size, are typically 30 centimeters deep with a peripheral

[287] UNOSSC. (2019). Rice-fish Culture in Sub-Saharan Africa. South-South Galaxy.
[288] MINISTERE DE L'ENVIRONNEMENT MINISTERE DE LA PECHE ET DU DEVELOPPEMENT DURABLE, & MINISTERE DE LA PECHE ET DE L'ECONOMIE MARITIME. (2016). PLAN NATIONAL D'ADAPTATION DU SECTEUR DE LA PECHE ET DE L'AQUACULTURE FACE AU CHANGEMENT CLIMATIQUE HORIZON 2035.

canal that is one meter deep.[289] When the first rains arrive, the gates of both the rice fields and fishponds are opened to allow for the removal of any accumulated salt. After this, the gates are closed, and the runoff water is collected for use in rice planting and fish cultivation. Once rice has been planted from mid-August to mid-September, the seaward gates are opened during spring tides, allowing coastal fish to enter the ponds and become trapped due to the influx of freshwater.[290] Therefore, the threat of salt water is clearly identified and mitigated by farmers that currently use fishponds, and this knowledge can be transferred to other farmers. There is also the added benefit that the risk of salinization of Naatangue fishponds is mitigated due to its design; farmers can control how water enters in the fishpond because the pond structure is isolated from natural water sources.

The previous water assessments conducted for the selection of farms and interventions for crop irrigation also ensure that any proposed fishponds are adequately placed to avoid any potential water availability issues. These assessments provide valuable information on water availability and quality, which is crucial for determining the suitability of a site for fish farming, and ensuring that the fish farming activities complement the existing farming practices and contribute to the overall sustainability of the farm.

The risk of typhas growing in ponds in Senegal can pose a great risk to crop production. Following the construction of two dams between Senegal and Mauritania, the reduced flow of water created ideal conditions for the weed to grow[291]; in turn, the weed has reduced rice yields for farmers growing rice along riverbanks and in nearby ponds. However, Senegalese rice farmers have used this threat as an opportunity to generate additional income, as well as address gender inequity. Farmers have discovered that they can harvest typha and create a bio-coal that is more sustainable and provides an additional income for farmers.[292] This biocoal can replace firewood, on which 83% of the rural population relies for cooking and heating, while producing less smoke and burning longer than firewood.[293]

This additional source of income has also played a role in involving more women in agriculture; one project that facilitated the harvesting and production of bio-coal from Typha found that this discovery created additional employment opportunities for women, who would previously spend more time undertaking tasks at home (cooking and raising children, mainly).[294] The cultivation of Typha in ponds along the River Senegal also has significant potential in replacing traditional construction materials. This is significant as concrete and cement are not well adapted to the country's hot climate, and the building sector has struggled to render their

[289] Gemmill-Herren, B., van Dis, R., Ndiaye, T., Waly Sene, J.-M., Yimer, H., Zuellich, G., & Sene, O. S. (2020). A Holistic Lens on Rice Value Chain Pathways in Senegal; Application of "The Economics of Ecosystems and Biodiversity for Agriculture and Food" Framework.

[290] Ibid

[291] Nixdorf, K., Shamo, L., & Abadi, M. (2020). How people in Senegal are turning an invasive weed into a source of clean energy. Business Insider.

[292] Ibid

[293] Nixdorf, K., Shamo, L., & Abadi, M. (2020). How people in Senegal are turning an invasive weed into a source of clean energy. Business Insider.

[294] Ibid

production more sustainable.[295] Conversely, Typha's material properties allow for much better thermal insulation that is better suited to Senegal's climate.[296] The risk of Typha proliferating in Naatangue fishponds is also highly mitigated as the size and isolated construction of fishponds allow for farmers to have better control of the fishpond's environment, in contrast to fishponds found in natural ecosystems (lakes, ponds, rivers).

2.3.4 Overview of impact and co-benefits

One of the key impacts of farmers joining the fisheries sector through aquaculture is that it will allow for the country to address its falling fish supply. Due to uncontrolled, overfishing practices in the maritime sector, Senegal has seen its domestic supply of sea-caught fish dwindle over the last two decades.[297] Indeed, the white grouper species, *Epinephelus aeneus*, an emblematic and commonly consumed fish in Senegal has been threatened by extinction since the early 2000s.[298] In-land aquaculture, in the form of fishponds, could serve as an effective way to cultivate fish in a controlled environment, allowing for a more predictable supply of fish production.

A co-benefit of fishponds is that they allow farmers to harvest nutrients from fish tanks. In-land aquaculture generates significant quantities of sludge in the form of feces and uneaten feed that accumulate in the sediment of fishponds.[299] The sludge mix is rich in vital organic materials that plants need for growth, such as nitrogen (N), phosphorus (P), and other macronutrient and micronutrient contents.[300] One study found that a combination of sludge from fishponds (30%) and organic amendments (peanut shell and coir fiber), had the highest content of nutrients for organic fertilizer when compared to other organic and synthetic fertilizer mixtures.[301] This would allow farmers to reduce their expenses on synthetic fertilizers for their crop production, allowing them more disposal income for subsistence or farming needs. This is particularly relevant in Senegal, which saw the retail price of Nitrogen, Phosphorus, and Potassium fertilizer significantly increase (more than double) in 2021 as a result of the war in Ukraine.[302]

This benefit is coherent with the co-benefits of other animal production activities that will be implemented in this project (poultry and milk production), and will complement the organic

[295] Serra Sanchez, E. (2022, March 22). How to make the most of Typha weed, an invasive plant in Senegal. BirdLife International

[296] Ibid

[297] Thiao D, Leport J, Ndiaye B, Mbaye A. 2018. Need for adaptive solutions to food vulnerability induced by fish scarcity and unaffordability in Senegal. Aquat. Living Resources. 31: 25

[298] Thiao, D., & Laloë, F. (2012). A System of Indicators for Sustainability: An Example from the Senegalese Fisheries. Marine Resource Economics, 27, 267–282.

[299] Thanh, D. T., Ty, N. M., Hien, N. V., Berg, H., Nguyen, T. K. O., Vu, P. T., Minh, V. Q., & Da, C. T. (2023). Effects of organic fertilizers produced from fishpond sediment on growth performances and yield of Malabar and Amaranthus vegetables. Frontiers in Sustainable Food Systems, 7

[300] Thi Da, C., Anh Tu, P., Livsey, J., Tang, V. T., Berg, H., & Manzoni, S. (2020). Improving Productivity in Integrated Fish-Vegetable Farming Systems with Recycled Fish Pond Sediments. Agronomy, 10(7), Article 7.

[301] Ibid

[302] Gajigo, O. (2022). The Impact of Fertilizer Prices on Africa. APRI.

waste recycling technology and practices that are planned under the agroforestry activity, further described in the next section.

3. Agroforestry

3.1. Description

The objective of this package of activities (Activity 1.2.5 and Activities 2.1.1) is to strengthen and diversify productive bases for rural farmers through the introduction of climate-smart agroforestry practices, while also limiting the needs for additional inputs by promoting the recycling of waste. The activity consists of the deployment of resilient agroforestry technologies such as windbreaks / hedgerows, alley farming, green manures, fruit-tree biodigesters, compost pits, with the aims of improving soil fertility, generating food security, as well as climate proofing farm operations. Ultimately, the goal of this agroforestry system is to create an environment that is both resilient to the impacts of rising temperatures, natural disasters and fluctuations in precipitation, all the while fostering an environment in which its different components provide symbiotic services to one another.

Currently, most farmers in Senegal do not practice organic waste recycling through the use of composting or biodigesters, and also rely on firewood for fuel to power and heat their homes. More than 80% of farmers rely on locally-sourced firewood to fuel their activities and heat their homes, which contributes to excessive deforestation.[303] These farmers also rely on expensive synthetic fertilizers, which have seen significant price fluctuations in recent years, thereby reducing their real income.[304] As a result, there is a need to address both the adaptation and mitigation challenges created by the baseline of conventional farming activities.

Agroforestry also exists in different forms in Senegal, but most agroforestry systems do not yet employ a fully integrated, agro-silvopastoral system used in the Naatangue model. Examples of some, small-scale agroforestry initiatives that currently rely on silvoarable systems include projects in the Sokone municipality of the Fatick region, which only combine diversified fruit-tree production with hedgerow/windbreak tree species, such as Jatropha.[305] Other examples include the Forest Garden Program in the Fatick and Kaolack regions, which integrates hedgerow/windbreak farming, integrated-pest management, and organic waste recycling, but does not factor in animal production.[306] The Naatangue model encompasses all of these forms of farming while also include animal raising; this has the unique advantage of not only adding an additional source of income, but also provides nutrient-rich animal waste to the biodigester and composting systems that will be used in the Naatangue model.

In the context of this project, and more specifically this suite of activities, windbreaks/hedgerows will be planted with the goal of mitigating soil erosion by acting as a natural barrier to strong winds (thereby protecting the farm), while also serving as a natural barrier to excessive infiltration of fertilizers, pesticides and sediments that reach nearby

[303] ULB-Coopération. (2023). SENEGAL: Curbing deforestation

[304] Gajigo, O. (2022). The Impact of Fertilizer Prices on Africa. APRI. https://afripoli.org/the-impact-of-fertilizer-prices-on-africa

[305] Anne-Lise. (2020). Senegal: The assets of agroforestry for local communities.

[306] TreeNation. (2023). Reforestation project Forest Garden Program, Senegal.

waterways (thereby protecting areas outside the farm).[307] In addition, hedgerows also improve water infiltration, thereby mitigating the impacts of flooding by allowing for more water to infiltrate the surrounding soil. This latter benefit also allows for the soil to retain more water for the production of subsistence and cash crops.[308] In the Senegalese context, there are few species of trees that are more suitable to act as windbreaks/hedgerows than the Jatropha tree and the Leucaena tree, which are widely available species that are already grown at scale, nationally.

The aim of planting fruit trees in the Naatangue model is to provide an additional source of income to farmers, all the while reinforcing the resilience of the agroforestry structure of the Naatangue farm through the indirect ecosystem benefits of fruit trees on crop production. Fruit-tree planting can be particularly in impactful in Senegal, whose soils have been heavily depleted from monocropping groundnut.[309] Fruit-trees can help re-establish a balance of different nutrients that will assist in the production of both subsistence and cash crops for farmers, all the while providing an additional source of income. Depending on the placement of the trees, they can also help reinforce the hedgerows and windbreak shrubs to further mitigate the risk of soil erosion.[310]

Ultimately, fruit tree planting provides the necessary socio-economic and food security assistance farmers require in the immediate term while reinforcing the long-term resilience of a new farming ecosystem through the Naatangue model. This activity calls for the planting of a multitude of fruit-tree species, such as: Ziziphus mauritiana, Tamarindus indica, Adansonia digitata, Detarium senegalensi, Saba senegalensis, Aphania senegalensis, among many other species. Specifically, this project aims to plant the following across the village and family farms:

1. For family farms, 400 forestry trees will be planted per hectare, and each farm will be 1 ha in size (4,000 forestry trees)
2. Family farms will also have fruit-trees, whereby 3 lines of 100 m per hectare of fruit trees will be planted with a 7 m spacing between each line, otherwise representing 40 trees per hectare for each of 100, 1 ha farms (4,000 fruit trees).
3. For family farms, for larger village farms, there will be 5 ha reserved for intensive forestry planting, in which 130 trees/ha will be planted (650 trees for intensive forestry), and 10 ha will be reserved for arboreal tree planting, in which 40 trees will be planted per ha, across the 40 village farms (16,000 arboreal trees).

[307] Thiel, B., S.M. Smukler, M. Krzic, S. Gergel, and C. Terpsma. (2015). Using hedgerow biodiversity to enhance the carbon storage of farmland in the Fraser River delta of British Columbia. *Journal of Soil and Water Conservation*, 70:247–256. doi: 10.2489/jswc.70.4.247

[308] Wallace, E. E., McShane, G., Tych, W., Kretzschmar, A., McCann, T., & Chappell, N. A. (2021). The effect of hedgerow wild-margins on topsoil hydraulic properties, and overland-flow incidence, magnitude and water-quality. Hydrological Processes, 35(3), e14098. https://doi.org/10.1002/hyp.14098

[309] Faye, J. B., & Braun, Y. A. (2022). Soil and human health: Understanding agricultural and socio-environmental risk and resilience in the age of climate change. Health & Place, 77, 102799. https://doi.org/10.1016/j.healthplace.2022.102799

[310] Reforestaction. (2017, April 20). Reforestation in Senegal.

Waste recovery, promotion of biodigesters, establishment of compost pits and organic fertilizer will accompany operations supported by the project activities to unlock additional value streams, strengthen, and diversify the productive base of Naatangue farms, and minimize environmental externalities from project activities. The promotion of technologies and practices to mitigate waste by recycling organic byproducts of the agroforestry system aims to directly reduce the cost of purchasing synthetic fertilizers. For instance, biodigesters can break down the organic waste from farming practices (plant and animal waste) to produce organic fertilizer. This fertilizer can then be used in organic fertigation, whereby the nutrients and fertilizers recuperated from the biodigester can more efficiently reach the farmer's crops by applying said inputs directly into the irrigated watering system. Biodigesters can also provide biogas to farmers, which will limit the impact of deforestation for firewood consumption and can provide an additional income to farmers should they prefer to sell their fuel to markets.

In short, this package of goods provides the cyclical structure of the agroforestry system whereby windbreaks and hedgerows allow for improved soil protection and maintenance, fruit-trees provide further ecosystem services and additional income streams, and an organic waste recycling system that processes the waste of the two previously mentioned components into recycled, usable inputs for farmers. For waste recovery activities, this project plans on implementing the following infrastructure, training and activities in each of the identified village farms:

1. Construction of 3 pits per farm with 4 m^2 and a depth of 0.5m;
2. Collection of biodegradable waste for filling by producers;
3. Materials of biodigesters;
4. Training of producers on composting techniques for producers.

3.2. Technical assessment of the activity and its alternatives

3.2.1. Cost

Biodigesters and composting

The implementation of biodigesters in agricultural fields throughout the African continent has shown great promise in terms of reducing the money that farmers spend on fertilizer and nutrients, while also providing an additional source of income through the acquisition of biofuel, which they can either sell or use for personal consumption. However, one of the main barriers to the uptake of these systems is the cost. A cross-country study of the Sub-Saharan region by the World Bank reveals that, depending on the region and the type of biodigester, a typical, household-level digester varies between US$ 435 to US$ 1,667.[311] Though these represent high, up-front costs, it is worth highlighting that this cost is temporal, and not variable, over time. The net costs of biodigesters quickly become negative as the benefits of saving financial resources on fossil fuels for cooking and heating the home as well as selling biogas outweigh the initial investment of the biodigesters.[312] One report found that the average

[311] World Bank. (2019). The Power of Dung: Lessons learned from on-farm biodigester programs in Africa.

[312] Warnars, L., & Oppenoorth, H. (2014). A study on bioslurry results and uses.

yearly net benefits of having one biodigester on one farm in sub-Saharan Africa, resulted in net savings of US$140 from the avoided cost of buying synthetic fertilizer.[313]

The costs of biodigesters also vary considerably depending on the model selected, with each model having its unique advantages to specific climatic and soil conditions. Among the many models, there are four models that have been used for farming in sub-Saharan Africa, along with its costs, lifetime, construction requirements, manure required, advantages and disadvantages (these models are further discussed in section 3.4.4). Given the vast geographic and climatic differences between the implementation sites of this project, ANIDA and ISRA, as the authorities in this space in Senegal, project planners will decide the most suitable type of biodigester for each farm. Factors that will be considered include: fixed and variable costs (maintenance), size, ease of repair, required manure input, availability of equipment. The monetary and temporal costs are outlined in Table 17, below, and are further explored in Section 3.4.4.
Component 3 of this project will provide the necessary decision-making support that farmers will need from agricultural advisors from ANIDA and ISRA to make the best choice for their farm. These services have been provided for many years in the implementation of Naatangue farms, and the experts holding local knowledge of the soil, size and needs of different farms will be able to best advise farmers on the ideal biodigester model for their purposes.

It is estimated that the project will require 1 biodigester in each of the village farms that already undertake milk and animal raising activities. The approximate cost of a biogas system and its installation is estimated to be between US$ 800 – US$ 920 (in-line with estimates presented in Table 9, below), though the government provides a subisidy farmers that covers up to 40% of the associated costs of buying and installing a biodigester.[314] Senegal has an existing national plan to reinforce its domestic capacity for biodigester construction through the Programme National de Biogaz Senegal (PNBS), which, since 2009, has been tasked with creating a market for domestic biogas production by subsidizing the cost of materials and providing training and support to small and medium-sized biogas companies on the production of biodigesters. In 2021, alone, the programme has allowed for the domestic production of 2,309 biodigesters, and has created over 12,300 direct jobs.[315] There has also been significant foreign investment in the PNBS, such as from the Swiss Federal Department for Environment, Transport, Energy and Communication, which signed an agreement in 2021 with the Senegalese Ministry for Environment and Sustainable development to construct 60,000 biodigesters.[316] Senegalese companies, such as Sustainable Business For ALL (SB2-4ALL), could be valuable suppliers of biodigesters for the Naatangue project, for instance. Therefore, this project can benefit from existing, national initiatives and marketplace that can support farmers' access to biodigester systems and equipment, allowing for a high degree of complimentarity between the Naatangue farm project and the PNBS.

Biodigesters are, however, resource and input intensive technologies that demand a constant supply of water and organic materials in order to produce biogas and manure for farming actvities. Studies evaluating the water needs of biodigesters in sub-Saharan Africa estimate

[313] "SNV. (2015). "Bioslurry always means profit" Success stories from the Tanzania Domestic Biogas Program.

[314] Douard (2011). Sénégal, la tendance est au biodigesteur. BioEnergie. https://www.bioenergie-promotion.fr/16433/senegal-la-tendance-est-au-biodigesteur/

[315] Programme National de Biogas Senegal (2023) Accueil. https://pnb.sn/

[316] Magoum (2021). SÉNÉGAL : 60 000 biodigesteurs pour produire du biogaz à partir des boues fécales. Afrik 21. https://www.afrik21.africa/senegal-60%E2%80%89000-biodigesteurs-pour-produire-du-biogaz-a-partir-des-boues-fecales/

that the water required for each cow is approximately "50 dm3/day and 10 dm3/day for each pig providing manure to the digester, or 25 (±6) dm3/day for each person in the household, using a digester volume of 1.3 (±0.3) m3/capita."[317] Assessments of water-harvesting options for biodigesters in sub-Saharan Africa have found that storing water from the rainy season in fish ponds and reservoirs, and covering the fish pond/reservoir during the dry season to prevent evaporation, to be a viable option to provide biodigesters with a regular supply of water.[318] For certain Naatangue farms, farmers can source water from their fish pond to meet the needs of their biodigester during the dry season. Naatangue farms that do not have access to a fish pond or above-ground reservoir will have access to ground water through the solar-irrigation pumping systems; ground water does not require pretreatment for the proper functioning of a biodigester, thus allowing for a consistent supply of water throughout the farms in the proposed sites.[319]

Table 17. Characteristics of main household biogas digesters[320]

	Fixed Dome	Floating Drum	Prefabricate plastic tubular model	Prefabricated plastic molded model	Flexible ("bio") bag
Investment (US$)	700-900	900-1,200	700-900	600-800	410-810
Lifetime (years)	15-20	10-15	5-10	30	15
Construction time (days)	10	20-25	1	1	1

Windbreaks/Hedgerows and Fruit Trees

The selection of species is a key variable in assessing the costs and net benefits of implementing windbreaks and hedgerows in a Naatangue farm. Though many species offer varying advantages in terms of their net costs, one of the identified species of tree/shrub that can fulfil the role of the windbreak/hedgerow on a farm is the Jatropha tree, which has an average per hectare cost of production of 48,084 CFA (US$80).[321] Jatropha trees provide excellent windbreak services to crops by limiting the impact of wind-driven soil erosion, as well as a natural barrier against livestock.[322] In a project conducted by Reforest'Action, over 400,000 jatropha trees have been planted in agroforestry systems in the Fatick region. These Jatropha trees have provided economic benefits through the avoided cost of damage to crops from livestock as it provides a natural barrier to stray wildlife and cattle.[323] In addition, Jatropha trees can serve both as windbreaks/hedgerows, and provide an additional source of

[317] Bansal, V., Tumwesige, V., & Smith, J. U. (2017). Water for small-scale biogas digesters in sub-Saharan Africa. GCB Bioenergy, 9(2), 339–357.

[318] Murnyak D (2010) Fish farming basics of raising tilapia & implementing aquaculture projects, ECHO Technical Note.

[319] Bansal, V., Tumwesige, V., & Smith, J. U. (2017). Water for small-scale biogas digesters in sub-Saharan Africa. GCB Bioenergy, 9(2), 339–357.

[320] World Bank. (2019). The Power of Dung: Lessons learned from on-farm biodigester programs in Africa.

[321] Edna Energy, Environment, Development Program. (2007). Biofuels in Senegal Jatropha Program 2007-2012

[322] Reforestaction. (2017, April 20). Reforestation in Senegal.

[323] Ibid

income through the sale of their fruits, as well as their seeds, which produce a low carbon-emitting biofuel.[324]

Although the variability of species that can be used for windbreaks and hedgerows makes it difficult to compare their net cost/benefit, Jatropha trees are a promising option due to the numerous direct and indirect sources of income they can provide. Despite the costs of implementation, such as transportation, the fact that Jatropha trees are commonly found in Senegal makes them a more cost-effective choice compared to other trees, such as Paulownia, which could serve a similar purpose.[325]

The cost of fruit-tree planting also depends on the varieties selected and the maturity of the trees; younger trees will require more active attention from the farmers (regular pruning) and are more susceptible to severe climatic events, which renders them less cost effective than mature trees. Determining the exact cost of planting fruit-trees in Senegal at a per-hectare level is challenging, though a comparison of returns between monocultured systems and agroforestry systems using fruit-trees can provide an indication of the net benefits of their use. For instance, farming systems in Senegal that, "grow peanuts and maize monocultures generate a maximum of $200-400 per acre, while a forest garden [using fruit-trees] can generate up to $2,000."[326] This sharp increase in income is largely due to an extended growing and cultivation season that farmers have, as their production becomes year-round, allowing farmers to have a consistent source of income. The co-benefits of this additional income allow families to send their children to school, seek better medical care, amongst many other non-farming benefits.

Ultimately, ANIDA and ISRA's comprehensive understanding of the various options available to Senegalese farmers, based on the characteristics of their farms such as size, soil type, and climate, enables them to identify several indigenous and locally available ways to implement windbreaks/hedgerows and fruit-trees. This approach reduces the risk of implementation and ensures the long-term viability of the project's intervention. Using foreign inputs, such as non-native species of Senegal, carries a higher risk, but ANIDA and IRSA have accounted for this risk in the project by prioritizing the use of locally available flora. By doing so, they minimize the risk of introducing invasive species that could harm the local ecosystem and promote the use of sustainable and locally adapted practices.

3.2.2. Scalability

Biodigesters and Composting

As highlighted in Table 17, the scalability of biodigesters largely depends on the model. Aspects of biodigesters that lend themselves to be more scalable in the short term are low construction costs, low space requirements, and the ability to use locally sourced materials to further reduce costs. These aspects are covered in one of the simpler biodigester models, such

[324] Reforestaction. (2017, April 20). Reforestation in Senegal.

[325] Benge, M. D., & Agency for International Development, W. (1987). Paulownia tomentosa: An excellent tree for agroforestry and windbreaks in the more temperate regions of the developing countries. Washington, DC (USA) AID, Office of Forestry, Environment, and Natural Resources.

[326] Ecosia. (2019, March 28). Ecosia's trees in Senegal. The Ecosia Blog. https://blog.ecosia.org/ecosia-trees-senegal-agroforestry-agriculture/

as fixed dome (see Section 3.4.4.). Some of the aspects that could hinder the scalability of the biodigester are the relatively high labour costs in terms of installation and repair/maintenance. There are also structural considerations to consider in terms of a farmer's preference to use a biodigester, such as whether they have access to markets to sell the digestate they do not use, or to biofuel markets should they not use all the produced biofuel for personal consumption.

Overall, however, the variety of options that farmers have in terms of the type of biodigester, along with the various benefits they allow for, lends itself to being highly scalable. Composting has certain scalability advantages when compared to biodigesters, namely that the initial capital costs (materials and equipment) are much lower for compositing systems.[327] However, compost pits require significantly more surface area when compared to biodigesters, which acts as a hindrance to their scalability.[328] Regardless of the type of organic waste recycling system that farmers will prefer depending on the specifications of their farm, this project will not only provide advisory services from experts with local knowledge, but also structures to connect farmers with local markets, which will provide information to farmers on prices of their new products (see Component 3 of the logical framework).

Windbreaks/Hedgerows and Fruit Trees

The scalability of windbreaks/hedgerows can be easily ensured as there are already many Jatropha plantations that have produced mature trees throughout Senegal, meaning they can be quickly implemented at scale. For instance, the Jatropha Agroforestry Senegal project (2009-2033) currently has over 1,411 acres of Jatropha trees in the Fatick, Kaffrine and Kaolack regions, with the goal of creating an agroforestry system that can replenish the soil's nutrients.[329] At a larger scale, the Government of Senegal launched a National Jatropha Programme (NJP) in 2006, with the goal of planting 321,000 ha of Jatropha trees, with an average of 1000 ha in each rural locality.[330] The local availability of the tree can drive the price of transportation of older sapling trees down and render the availability of more mature tress more accessible as farmers which will generate benefits sooner. The availability of an internal, highly local market for Jatropha trees will render the adoption of windbreaks/hedgerows at scale more feasible as farmers will not need to travel long distances to source the trees. The executing agency of this project, ANIDA, together with ISRA, plans to introduce 5-month-old seedlings where mature trees are absent in village farms. ANIDA understands that these seedlings will require three additional years before reaching maturity in the local conditions, which will then allow for the sourcing of more seeds for the planting of more seedlings.

The scalability of fruit-tree planting is also dependent on access to seedlings and trees in the short-term, as well as the availability of agricultural advisory services. In another agroforestry project in Senegal, project promoters found that the scalability of the project was vastly improved by ensuring the deployment of advisors to farms to advise the placement and

[327] Couth, R., & Trois, C. (2012). Cost effective waste management through composting in Africa. Waste Management (New York, N.Y.), 32(12), 2518–2525.

[328] Couth, R., & Trois, C. (2012). Cost effective waste management through composting in Africa. Waste Management (New York, N.Y.), 32(12), 2518–2525.

[329] Carbon Sink. (2019). Jatropha Agroforestry Senegal Project.

[330] Dafrallah, T., Ackom, E. K., Dafrallah, T., & Ackom, E. K. (2016). Analysis of national Jatropha biodiesel programme in Senegal. AIMS Energy, 4(4), 589–605.

management of fruit trees (cutting, root management).[331] In the context of this project that will scale-up Naatangue farms, an entire component (Component 3) is dedicated to both training advisors and supporting producers through workshops and regular site visits.

3.2.3. Ease of up-take by farmers/Ease of implementation

The ease of up-take/implementation of agroforestry approaches is dependent on the affordability, scalability, and access to markets for the by-products of these technologies (biofuel, fruit…etc.).

In the case of bio-digesters, should the simpler, fixed dome model be adopted, there is a higher ease of implementation relative to the other biodigester models as it only requires 10 days of construction, and has one of the longest lifetimes of all models, without taking up much space. The latter benefit is a key factor in the ease of uptake as Naatangue farms (particularly the village model) are relatively small farming systems. Farmers must be able to ensure a minimum of 20 kg of fresh animal dung along with 20 litres of water to mix the slurry for the biodigester.[332] The ease of up-take by farmers of biodigesters could also be limited due to the amount of time anaerobic decomposition (the way in which biodigesters process organic compounds) requires when compared to anaerobic decomposition (composting). Given that composting is an aerobic process, the time required to break down the waste into usable manure is much faster, which may encourage farmers to select composting over a biodigester.[333] However, the output benefits of biodigesters are far greater as it not only produces a usable manure, but also a biogas that emits less CO_2 when burned and mitigates the use of firewood for fuel. Regression analyses have also found a higher degree of correlation between the ease of up-take by farmers of biodigesters and the provision of formal training by agricultural advisors.[334]

The adoption of hedgerows and windbreaks will depend on the availability of tree supply; if farmers start with seeds, it will require significant labour on their part to ensure the proper growth of the tree, which may disincentivize the incorporation of trees in farm operations. However, should the trees be planted as feathered whips, this would facilitate the up take as the maintenance costs would be lower. Likewise, the uptake of fruit trees in the beginning phases of the project will also depend on the availability of mature trees and agricultural advisory services to ensure the proper functioning of the system. As previously mentioned, Component 3 of this project (empowering farmer entrepreneurship through market integration and accelerating new agricultural markets) will ensure that ANIDA and other advisory organisations are deployed to project sites for assistance, monitoring and evaluation of agroforestry practices. These local organizations have years of experience in ensuring the proper functioning of Naatangue village and family farms, and understand the key barriers to up-take, which will facilitate the implementation of these systems.

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[331] CREATE! (2018, June 28). Tree Planting in Senegal | Blog Posts | CREATE! Create.

[332] Heegde, F. E. W. ter, & Sonder, K. (2007). Biogas for better life: An African initiative: domestic biogas in Africa; a first assessment of the potential and need: discussion paper.

[333] Okelo, A. (2020, January 13). Bio-Digester vs Composter. HubPages.

[334] Li, Q., Wang, J., Wang, X., & Wang, Y. (2022). The Impact of Training on Beef Cattle Farmers' Installation of Biogas Digesters. Energies, 15(9), Article 9

3.3. Impact on agriculture and future-proof production capacity

The use of biodigesters in Senegal have had considerable, positive impacts on agricultural production, particularly in terms of the use of digestate as a substitute for synthetic fertilizers and nutrients. A pilot project in which women in the Kolda region benefited from the installation of the biodigesters from the World Food Program (WFP) has allowed for women in the village of Talto Diega to double their rice production through the application of nutrient-rich digestate.[335] The biodigesters have also allowed women farmers to avoid the costs of searching for firewood to power their homes, and instead rely on biogas produced by the biodigesters.[336] The latter benefit also mitigates deforestation, and provides an extra income for women farmers to pay for their children's school tuition fees. In addition, one study on the entire sub-Saharan African region found that a single application of digestate on fodder crops contributed to the improved nutrition of the crop, thereby increasing the yield of milk by 50%, increasing the yield of maize by 92%, tomato yields by as much as 103%, and potato yields by 34%.[337]

Biodigesters are also not climate-sensitive, and can operate at varying temperatures and in heavy rains (unless the farmer selects the Prefabricate plastic tubular model (impaired function at >37 C) or the floating drum model (susceptible to corrosion without pre-treatment) [see Table 1]). This allows for biogas to be relatively future proof, all the while indirectly mitigating carbon by providing an alternative fuel source to firewood.

Hedgerows/windbreaks in the form of Jatropha trees are highly future proof in terms of their long-lasting and resilient nature. Jatropha trees require very little water and are suitable for most soil types and conditions.[338] This allows for the hedgerow to be maintained even in times of drought, thereby offering an extra layer of protection to a farm's crop production. Other windbreak species that have been used in the Kaffrine region, such as the Leucaena, which is a leguminous plant that fertilizes the soil through nitrogen fixation, may be better suited for farmers who operate on particularly degraded soils.[339] Like the Jatropha species, Leucaena can grow in particularly challenging conditions (high temperatures, degraded soils) and provides significant cover from soil erosion, which makes it an ideal candidate to use as a windbreak species in Naatangue farms.[340] The leaves and branches of Leucaena can also be repurposed as green manure to maintain soil moisture and further enrich the soil with vital nutrients for crop production. Finally, farmers can rely on other, indigenous plant species grown throughout agroforestry parks in Senegal, such as Faidherbia albida, a tree species that provides a nutritious fodder for animal raising, and fosters atmospheric nitrogen fixation in the soils, thereby improving the fertility of the surrounding land.[341] This species provision of fodder is

[335] Lo, O. (2020, September 4). Senegal: Cow dung proves 'green gold' for the women of Kolda | World Food Programme

[336] Ibid

[337] Warnars, L., & Oppenoorth, H. (2014). A study on bioslurry results and uses.

[338] Veolia. (n.d.). The jatropha sector, a powerful impetus for local development in West Africa. Fondation Veolia. Retrieved 27 April 2023

[339] Prince, H. (2021, July 28). Tree Planting Site: Kaffrine, Senegal. THE ENVIRONMENTOR.

[340] Ibid

[341] CIRAD. (2022). When ecosystem services rendered by trees compete with each other. CIRAD

also an example of how this agroforestry activity reinforces other activities in this project, as the milk production activity.

Fruit trees can act symbiotically with windbreaks and hedgerows, and even reinforce the protective capacity of the system by acting as an additional barrier to water and wind erosion. Fruit trees can also provide additional shade to crops, which allows for a cooler and humid growing environment for crop production.[342] One of the fruit-trees that will be used in the context of this project, *Tamarindus indica* (Tamarind tree), has the added benefit of providing significant shade to crops, which can help cash and subsistence crops resist heat waves and direct sunlight.[343]

3.4.Considerations for successful implementation of this technology

One of the key considerations that practitioners should note when implementing hedgerow cropping or alley cropping is the possibility of competition for nutrients and water between the hedgerow crops and the subsistence/cash crops, should the crops not be sufficiently distanced from hedgerows.[344] While this is true of the relationship between hedgerow trees and crops, the Jatropha tree is highly resource efficient (both in terms of nutrient and water uptake), which limits the likelihood of the hedgerow plants starving the crops of vital inputs.[345] In Senegal, however, the use of Jatropha trees has some under threat due to spread of Fusarium disease, a pathogen that kills the species. Farmers have had to replace these trees with fruit trees, which perform similar, services to the Jatropha tree, and provides an extra source of income through the sale of fruit.[346] Local advisors will assist farmers in identifying the presence of Fusarium disease, implementing proper measures to contain its spread, providing guidance on how to treat affected trees, and advising when to consider using alternative species to mitigate the risk of further infestation.

Finally, regardless of the species used as a hedgerow/windbreak, there is the added challenge of convincing farmers to reserve space on their farm for hedgerows in place of subsistence and cash crops, and such a change might lead to falling yields and income in the first years of implementation. However, with sufficient support from the agricultural experts that will provide training and guidance on these techniques to project beneficiaries, this risk should remain largely mitigated. Competition for resources could also be a concern between fruit-trees and hedgerows/windbreaks, though with appropriate spacing and management, this can be largely mitigated; ANIDA and ISRA have decades of experience in supporting these decisions, and the services they will provide to farmers through activities in Component 3 of

[342] Kumar, S., Prasad, R., Kumar, A., & Dhyani, S. (2019). Integration of fruit trees in agroforestry for sustainability and profitability of farming systems in arid and semi-arid regions.

[343] TreeNation. (2023). Reforestation project Forest Garden Program, Senegal.

[344] Achten, W., Akinnifesi, F., Maes, W., Trabucco, A., Aerts, R., Mathijs, E., Reubens, B., Singh, V., Verchot, L., & Muys, B. (2010). Chapter 4. Jatropha integrated agroforestry systems – Biodiesel pathways towards sustainable rural development. In Jatropha Curcas as a Premier Biofuel: Cost, Growing and Management (pp. 88–102).

[345] Maes, W., Achten, W., Reubens, B., Raes, D., Samson, R., & Muys, B. (2013). Plant–water relationships and growth strategies of Jatropha curcas L. seedlings under different levels of drought stress. Journal of Arid Environments, 877–884. https://doi.org/10.1016/j.jaridenv.2009.04.013

[346] Reforestaction. (2017, April 20). Reforestation in Senegal

this project will mitigate the risk of resource competition between the components of the Naatangue farms.

One of the main drawbacks of adopting biodigesters is the trade-off that farmers will have to make in selecting the most appropriate model for their farm; some may need to sacrifice space in order to cut costs (prefabricated plastic moulded model), while others will need to change their daily activities to ensure that the biodigester has sufficient raw inputs every day, which adds to the many responsibilities farmers already have. The difficulty of selecting the right biodigester can, however, be mitigated through the support of agricultural extension agents, who will provide expert guidance on the planning of the farm, as per Output 2.1 of this project, which will aim to train both agricultural advisors and producers on best practices for agroforestry techniques. The issue of limited space can be mitigated, however, by selecting a biodigester model that is built in the ground, such as the Fixed-Dome model (further discussed in Section 3.4.4.). Another risk is that farmers may not be aware or have access to new markets for the organic fertilizer and/or biogas that will be produced from their biodigesters, leaving them with an unused surplus. However, this will also be mitigated as agricultural advisors from ANIDA and other organizations will be mobilized to assist producers in accessing markets, understanding value chains, and how to best market their products.

Overall, the drawbacks of adopting resilient agroforestry practices and sustainable waste management techniques are that these require a complete re-training of how farmers operate on the farm, which may lead to steep learning curves. However, the long-term benefits are well-established within Senegal and the sub-Saharan region, and the project has dedicated an entire component (Component 3) to the training of experts and producers to ensure that these practices are well-employed to mitigate the risk of their failure.

3.5. Overview of impact and co-benefits

Table 18 and Table 19 show a breakdown of the chosen activities (hedgerows/windbreaks and fruit trees, and biodigesters and compost), compared to identified alternatives. The scalability, impact, and co-benefits, as well as the climate impact of these activities are assessed and compared with another.

Table 18. Hedgerows/Windbreaks and Fruit Trees

Options and Alternatives	Scalability			Impact and Co-Benefits		Climate	
	Cost	Scalability	Easy Up-take/ Implementation	Impact on agriculture production	Co-benefits	Impact for climate adaptation and mitigation	Future-proof for future climate
Jatropha Trees as windbreaks/ hedgerows	Average per hectare cost of production of 48,084 CFA (US$80)	High (several Jatropha plantations already in operation in Senegal)	High (mature trees already available at scale in the country, reducing the need to use seedlings which would slow implementation)	Replenishes soil nutrients, assisting in crop production. Provides protective cover from soil erosion (wind and rain, driven erosion)	Provides habitat for other species (honeybees), which help pollinize crops	Reduce the incidence of soil erosion and replenish soil nutrients. Provides carbon sequestration benefits	Jatropha trees are highly resistant to increases in temperature and can be planted in most soil types
Leucaena Trees as windbreaks/ hedgerows	High (due to the large area occupied by the crop, limiting space for planting subsistence and cash crops)	High (used in Senegal for agroforestry initiatives, currently)	High (mature trees already available at scale in the country, reducing the need to use seedlings which would slow implementation)	Broad leaves and large surface area allow for more effective wind-break potential per plant.	Potential competition with other crops but provides significant fertilization benefits through nitrogen fixation. Provides significant shade for crops that cannot be exposed to sun for long hours	Allows for continuous fixation of nitrogen regardless of climate conditions. Reduce the incidence of soil erosion and replenish soil nutrients. Provides carbon sequestration benefits	Leucaena trees are highly resistant to increases in temperature and can be planted in most soil types
Fruit-Trees (Papaya)	Low (Papaya is grown throughout Senegal, with an abundance of mature fruit-trees that can be planted in Naatangue farms	High (high existing supply of mature trees in Senegal)	Medium (Will depend on support from agricultural advisory services)	Provides additional shade to crops. Provides additional windbreak services (limiting soil erosion)	Provides additional income to farmers to use to send children to school	Fruit trees provide carbon sequestration services (62.8 metric tons of carbon per hectare in Senegal)[347]	The fruit-trees selected in this project (ex. Tamarindus indica is highly resistant to droughts)[348]

[347] Ecosia. (2019, March 28). Ecosia's trees in Senegal. The Ecosia Blog

[348] Van den Bilcke, N., Simbo, D. J., & Samson, R. (2013). Water relations and drought tolerance of young African tamarind (Tamarindus indica L.) trees. South African Journal of Botany, 88, 352–360. https://doi.org/10.1016/j.sajb.2013.09.002

Baseline (exposed crop fields)	Losses due to soil erosion from a lack of windbreak/ hedgerow barriers	High as this is the current baseline	High as this is the current baseline	Reduces yields as soil is more exposed to erosion	None	Leaves crops exposed to soil erosion	Soil erosion and land degradation likely to worsen without action

Table 19. Biodigesters and Compost

Options and Alternatives		**Scalability**			**Impact and Co-Benefits**		**Climate**	
		Cost	**Scalability**	**Easy Up-take/ Implementation**	**Impact on agriculture production**	**Co-benefits**	**Impact for climate adaptation and mitigation**	**Future-proof for future climate**
Bio-digester model[349]	**Fixed Dome**	Medium (US 700-900)	High (Construction creates local jobs)	Medium (requires little space, and construction is quick, but not suitable for all soil types)	Use of digestate to replace synthetic nutrients and fertilizer has vastly increased the yield of many crops in Senegal (rice, tomato, sorghum, amongst many others)	Creates construction jobs	All biodigesters provide an alternative source of fertilizer, which can be used much more easily and at a lower cost than imported, synthetic fertilizers. Reduces the need to use synthetic fertilizers that deplete soil quality. Mitigates indirect emissions from not using synthetic, fossil-based fertilizers. Biogas produced by biodigesters provides an extra source of income and will mitigate the risk of deforestation as many farmers forage for firewood to power and heat their homes, offering a clear carbon	N/A
	Floating Drum	High (US 900-1,200)	Low (requires regular treatments to prevent corrosion)	Medium-Low (easily constructed, easy to use, but high material costs, requires a lot of space		Provides a biogas that can be used for personal or commercial purposes		Low (Short lifespan)
	Prefabricate plastic tubular model	Medium (US 700-900)	Low (Requires twice as much water compared to other models)	Medium (Easy installation, requires a lot of space)		Provides a biogas that can be used for personal or commercial purposes		Low (very sensitive to high temperatures above 37 C)
	Prefabricated plastic molded model	Low (US 600-800)	High (Easily mass-produced)	High-medium (Easily mass-produced, takes considerable space)		Provides a biogas that can be used for personal or commercial purposes		N/A

349 World Bank. (2019). The Power of Dung: Lessons learned from on-farm biodigester programs in Africa.

	Flexible (“bio”) bag	Low (US 410-810)	Low (Requires twice as much water as other models	High-Medium (suitable for all soil types, highly prone to damage in the short and long term due to climatic factors)		Provides a biogas that can be used for personal or commercial purposes.	mitigation benefit from avoided emissions of burning wood.	Low: (Short life-span due to plastic sensitivity to solar radiation, sensitive to high temperatures)
Compost		Low	High (requires little input and marginal training)	High: Use is very simple (layering organic waste), and time required to get manure is much faster due to aerobic decomposition	Produces re-useable nutrients from waste for crop production	Un-used compost can be sold to other farmers as an extra source of income	Produces re-useable nutrients from waste for crop production	Un-used compost can be sold to other farmers as an extra source of income
Baseline (Continued use of synthetic fertilizer, firewood for personal consumption)		High (cost of synthetic fertilizer will continue to rise as fossil energies become more expensive, opportunity cost of time spent foraging for firewood limits farming activities)	High (this is already done by most farmers)	High (this is already done by most farmers)	Synthetic fertilizers are less efficient in improving yields, and contribute to nutrient loss in the soils	N/A	Contributes highly to indirect emissions from consumption of fossil-based fertilizer (low mitigation), and threatens adaptation to climate change as soil quality is lost	This practice will further contribute to deforestation (fire-wood sourcing), which will become less and less available as climate change worsens, and as soils become more stressed.

4. Farmer entrepreneurship market integration and new agricultural markets

4.1. Community-based savings fund

4.1.1. Description

[Description of the CbSF]

For family farms, the use of the funds is to develop agribusinesses, build agricultural production capacity, entrepreneurship and access to market, thereby enlarging farmers businesses.

For village farms, the funds will be used for collective purpose which is O&M of village farms.

Farmers participating in Naatangue farms will be organized into cooperatives. The cooperatives will form a community-based savings fund, and open a savings account within LBA, and put their contribution to the account. Participant farmers will be consulted, and the exact amount of contribution per farmer will be determined based on consultation in a participatory manner. In the baseline assessment, the amount of contribution is about 50,000 CFA for village farms. For family farms, CbSF has not been implemented before, and it is a new adoption, and the amount of contribution will be determined after consultation.

Once every season finishes, farmers will contribute pre-agreed amount to the savings account. Money will not be withdrawn by individual farmers, but will be used for collective use, for the operations and maintenance of farms. Collection of money will be needs-based, and its frequency is not on regular interval.

For family farms, 1 representative can join a cooperative. For village farms, producers are

If there are 20 family farms in one coordination area, there will be 20 farmers joining cooperatives and subsequently CbSF.

The savings account will be managed the cooperative, under the Bureau. Cooperatives follow national regulations and are guided by their manual of procedure under the Ministry of Agriculture. In the regulation, each member must contribute to the fund, in the amount of 30% of their income. For withdrawal, applications should be submitted to the Board of the Cooperative, and decisions can be made. Treasurer manages the savings account and disbursement.

If cooperatives need more agri inputs, they can get loans. Needs are collected in a collective manner. The fund that is available in the fund is not sufficient, they can consider loans, and fund can be the collateral.

LBA has been consulted on this arrangement.

This activity serves as the key, continuous financing mechanism of the project, which will ensure that there is consistent flow of capital available to farms that are beneficiaries of this project, as well as the development of new Naatangue family farms. The goal of the community-based savings fund is to serve as a mechanism that will minimize the need for future public expenditure. This scheme will be financed by the project beneficiaries after the establishment of the farms (once they begin earning an income) and will be institutionalized in the form of an agreement between ANIDA and the beneficiaries, in which the beneficiaries agree to contribute a sum towards the scheme.

It is important to note that the contribution towards the scheme will not come from the GCF's investment grant, but instead will be supplied by the farmers from existing community funds once they have up and running Naatangue farms. The GCF financial contribution towards this activity will be used solely for training and support in the design and early stages of implementation of the Scheme. All financial contributions to the scheme will be made from private farmer contributions. GCF funds will be utilized for training and support in the implementation of the fund, but the seed funding for the scheme fund will come solely from the contributions of the farmers.

Community-based savings fund have been implemented for other projects in Senegal. ANIDA has witnessed the usefulness of these funding mechanisms and aims to adopt it within the Naatangue farm project. Traditional community-based savings fund («tontines») are well known in Senegal and are very popular in rural areas. In fact, tontines are so popular that, as of 2018, they collectively bring in over US$ 200 million.[350] The idea of a tontine is simple: groups of similar professions who wish to finance a large, collective project pool their resources, and each member takes a turn in using the pooled resources, but must ensure that the resources are replenished by the next turn, after which another member of the tontine investors can use the funds for their own purposes.[351] The community-based savings fund will mainly contribute to providing a guarantee for traditional financial institutions and will be used to finance the following: maintenance of equipment, replacing technology…etc.

The benefit of a community-based savings fund (inspired from the indigenous "tontines" system) is two-fold:

> (1) they are traditional, collective saving instruments that are well known, and therefore accepted, forms of collective finance, and
>
> (2), contrary to other financing mechanisms, they do not have excessive interest rates or other modalities that would otherwise make them undesirable.[352]

The nature of a tontine is also one that calls for collective responsibility and dialogue among the donors to the scheme, which will serve to exchange information on farming practices and needs that farmers have to improve the functioning of their farm. Therefore, the community-based savings fund is not only a financing tool, but also a forum for farmers to discuss issues and share information.

The community-based savings fund will provide an alternative pathway for small-scale producers to access finance at the local scale to help with farm modernization. The newly created cooperatives (composed of farmers who invest in the scheme) will also link to the

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[350] Turner, L., & Akande, S. (2018, September 11). Bringing an ancient African savings system into the digital age. CNN. e

[351] Laurent, V. (2002). Tontine: La banque à l'africaine. L'Express.

[352] urbaSEN. (2014). Revolving Fund for Urban Renewal.

functioning of this scheme. The fund will be hosted in a financial institution that will be identified by the Rural Sector Development Support Fund (FADSR) and an agreement signed with the host institution. This institution will be either La Banque Agricole (LBA), as an already accredited GCF entity, or existing financial institutions that comply with the necessary fiduciary requirements (as CSE is not accredited for lending/blending incentives with the GCF).

By engaging financial institutions as implementing partners and including them in the national steering committee, there will be an opportunity to establish strong relationships between these institutions and producer organizations supported across this project. This will enable the agricultural entities to have access to a larger pool of funding at more favorable rates, ensuring their long-term sustainability and growth. The involvement of financial institutions in the project will not only bring additional financial resources, but also render their expertise in financial management and risk mitigation accessible to farmers, which will be valuable to the cooperatives. Ultimately, this institutional set-up will allow for farmers to attain better rates for large projects by leveraging their collective value as family farms, all the while benefiting from the financial expertise of institutions, thereby creating a funding tool that can operate well after the conclusion of this project.

ANIDA is structured in 5 coordination areas, and the 8 regions in which this project will be implemented are divided between these 5 coordination areas: St-Louis (North), Louga, Thies (West), Kaolack, Kaffrine (Center); Tamba (East), Ziguinchor and Kolda (South). In the short term, a cooperative of family farms will be created in each zone. For village farms, a cooperative will be created in each coordination area. In the medium term, the objective is to consolidate the family cooperatives into one cooperative, and likewise consolidate the village cooperatives into one cooperative, as well. In the longer term, the goal is to have a single cooperative bringing together both family farms and village farms. The community-based savings fund will follow the structure of the cooperatives and will follow their rules. There will therefore be 5 community-based savings fund for village farms and 5 community-based savings fund for family farms. The community-based savings fund will then follow the evolution of the cooperatives. Contributions and methods of problem solving will be discussed with the farmers and will be put into the statutes. The rules will be determined in a participatory manner.

Currently, the funds of the GIEs are fed by a contribution of 50,000 FCFA per ha after each growing season. Each beneficiary will sign an agreement to commit to respect the rules and to accept the sanctions in the event of non-compliance with the fund's operating rules; these sanctions may lead to the removal of equipment supplied to farmers benefiting from the Naatangue model. ANIDA can use its experience in the creation of Economic Interest Groups (GIEs) and cooperatives to support farmers in setting up community-based savings fund. ANIDA also provides support in the creation and management of these GIEs and cooperatives. . Each EIG or Cooperative already has its office which can manage its part of the community-based savings fund . The existing relationship that ANIDA and CSE currently have with LBA and FADSR will facilitate collaboration between farmers and these organizations. Farmers from family farms and village farms will be beneficiaries of the fund. Farmers will be able to access financing from LBA thanks to a guarantee from the fund manager. Any LBA funding to a farmer will require the approval of the fund manager. The latter will follow up to ensure that the loan is paid. The FADSR can intervene in case of need of recovery of the unpaid loan or non-contribution of a beneficiary. If equipment has to be repaired, the GIE or cooperative contacts ANIDA that will recommend a service provider. . Figure 3, below, provides an illustration of how the Community-Based Savings Fund will be managed across the different actors in the context of this project.

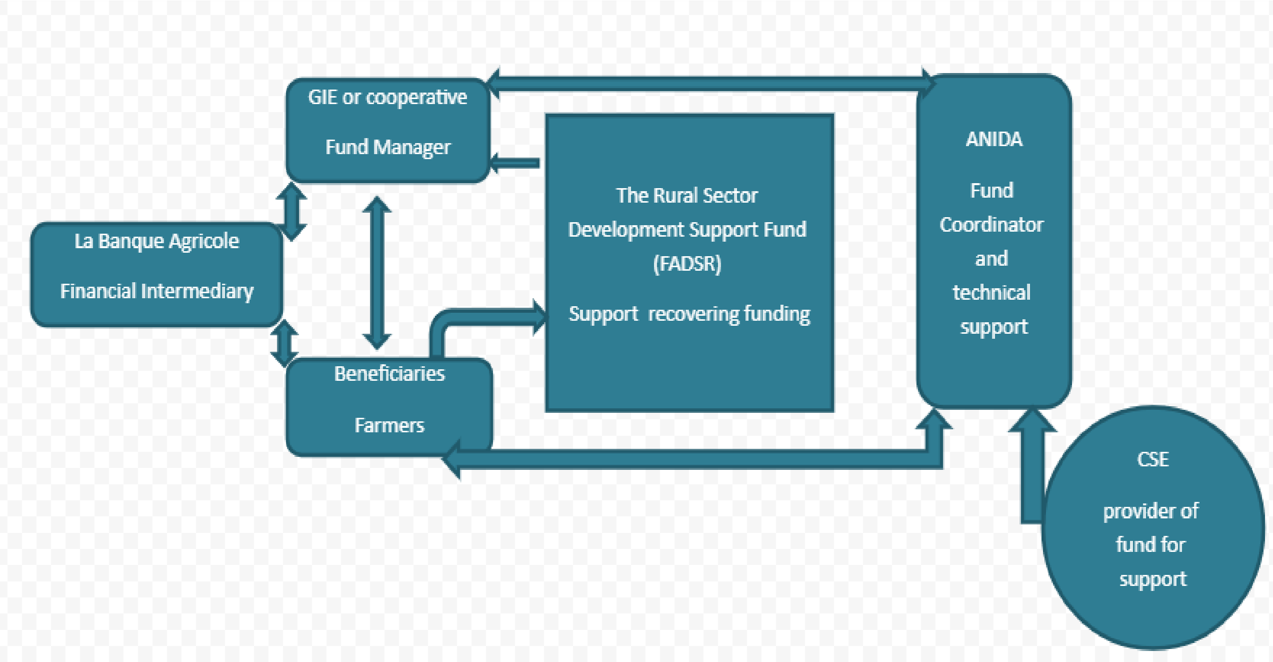

Figure 3: Proposed structure of the community-based savings fund

4.1.2. Technical assessment of the activity

Cost, Ease of Up-Take and Scalability

Though the Naatangué community-based savings fund has not yet been created, calculations from the Economic and Financial Analysis estimate that the community-based savings fund will amount to US$ 1,126,089 in year five, otherwise representing the cost of the implementation of family farms during the first four years of project implementation, and assuming a contribution equal that will be determined in a participatory manner.

The proposed approach for setting up a community-based savings fund for Naatangue Farms emphasizes a participatory and co-design process to ensure the active involvement. ANIDA plans to sign an agreement with the family farm beneficiaries from this project, outlining the mobilization procedures and soliciting their input in the design of the fund. To ensure sustainability and ownership of the fund, farmers will supply the fund as they have done with existing community funds. ANIDA intends to engage with selected producers and suggest a financial contribution after the initial set up of the scheme. The exact contribution amount will be determined through consultation between ANIDA and the family farmers, who will have the opportunity to suggest higher or lower contributions based on their own needs and financial capabilities. Through this co-design approach, the community-based savings fund will be designed in a way that is tailored to the specific needs and context of the family farms. The inclusion of the beneficiaries in the design process will ensure that the fund is equitable, sustainable, and appropriate for the community it serves.

The design of the community-based savings fund in the context of this project is participatory and tailored to the needs of the beneficiaries. The familiar functioning of the fund, which works similarly as *a tontine*, will also serve as a catalyst for participation as farmers are well aware of the structure of a community-based savings fund. The implementation and solicitation of participation within the fund is, therefore, facilitated by the familiarity and flexibility of the scheme.

4.1.3. Overview of impact and co-benefits

One of the co-benefits of the community-based savings fund is the establishment of farming cooperatives though the formalization of operations. These cooperatives contribute to the objective of providing farmers and their capacity organizations professionals guaranteeing viability and development of their activities. Member farmers will be able to use, at very favorable prices and conditions, modern and efficient equipment for carrying out various tasks of tillage and for the treatment of crops. The establishment of agricultural cooperatives reduces producer burden and build technical capacity. The agricultural cooperatives will be hubs for training and capacity building. They also provide a vehicle for knowledge and innovation sharing and catalytic impact through scaling and dissemination of best practices as well as financial support through marketing training and the management of the community-based savings fund. The cooperatives also provide a natural forum to scale impact through dissemination of lessons learned and best practices to other regions and producers, but also to private sector actors working to improve financial offerings and support for small-scale producers. The involvement of financial institutions as implementing partners and in the national steering committee will allow a solid development of relations between these institutions and producers' cooperatives to have access to greater funding at preferential rates.

This private-public element of the community-based savings fund for Naatangue Farms is a key aspect of its sustainability and effectiveness and will facilitate the ease of up-take by both farmers and the financial institutions involved in managing the fund. Private investments from farmer contributions will provide a significant source of capital to finance the operations of the fund, while public entities such as ANIDA and the GCF will provide support through hosting, technical assistance, and capacity building for setting the structures for its deployment. This partnership approach allows for the pooling of resources and expertise, resulting in a more comprehensive and impactful initiative. ANIDA's involvement in the scheme provides an essential public element to the partnership, ensuring that the initiative remains accountable, transparent, and equitable. ANIDA's expertise in agriculture and rural development will be invaluable in supporting the fund's establishment and management, while also ensuring that the interests of all stakeholders, including farmers, are represented, and addressed. The involvement of the GCF in providing support towards early technical assistance and capacity building and training for setting up the community-based savings fund is another essential public element of the partnership. By bringing together the resources and expertise of private and public entities, the initiative will be more comprehensive, impactful, and sustainable than if pursued by any one group alone. The resulting partnership will serve as a model for paradigm shift in sustainable agriculture and rural development in Senegal and beyond.

Another co-benefit of the revolving fund is that they are particularly popular among female producer organizations. As one of the overarching goals of this project is to achieve a higher degree of gender parity in terms of involvement in Naatangue farms, the popularity of the revolving fund model among female producer organizations makes it more likely to encourage female producers to participate in the fund. An example of this is the community-based savings fund established by the Senegalese Federation of Inhabitants (FSH); 96% of the FSH is composed of women living throughout different municipalities of Senegal (Dakar, Thiès and Louga) who collectively pool resources and establish a governance modality whereby members can discuss housing priorities and implement them collectively.[353] The collective nature of this scheme will be mirrored in the Naatangue farm project by establishing governance modalities that allow beneficiaries and fund managers to discuss priority issues in family farms and share information on best practices and solutions. Therefore, the scheme functions not only as a means for financing activities, but also as a forum for farmers to regularly meet and discuss individual priorities, thereby facilitating the identification of common issues and goals amongst farmers.

4.1.4. Summary of Proposed Option and Alternatives

The proposed community-based savings fund has several advantages. It leverages existing community-based systems, builds on traditional financial practices, and fosters a private-public partnership between ANIDA, financial institutions, and small-scale farmers. By involving financial institutions, the scheme offers greater access to financing for small-scale producers at preferential rates. The establishment of agricultural cooperatives reduces producer burden and builds technical capacity. The cooperatives will also provide a vehicle for knowledge and innovation sharing and catalytic impact through scaling and dissemination of best practices as well as financial support through marketing training and the management of the scheme. The GCF contribution will support the establishment of the structure, but the beneficiaries' financial contribution will ensure that additional impact can be sustained and developed past the initial injection of GCF grant towards setting up the Naatangue farms and upscaling climate-smart practices. Ultimately, the fund fosters a community-based approach to collectively managing funds which will ensure a high degree of financial autonomy and long-term viability following the exit of CSE and ANIDA.

Table 20 below is a summary of the comparison between the selected option to create a community-based savings fund and the alternatives. One alternative to the community-based savings fund is to assist family farms to apply for loans from the national banks to finance repair and development projects; however, this comes with considerable disadvantages, notably higher interest rates on loans that would be for individual projects, and not benefit the wider community. Individual loans are also not flexible and are not easily tailored to the needs of individual farmers, which would discourage farmers from seeking financial support to maintain their farms. Doing nothing will expose the family farmers to losses in the future, especially as equipment begins to wear down and the functionality of the Naatangue farm is lost. There must be an autonomous financing mechanism that can assure the availability of equipment and repair services to farmers, so as to ensure that public expenditure does not become a necessary means for the long-term success of the project, as a whole.

353 urbaSEN. (2014). Revolving Fund for Urban Renewal.

Table 20. Summary of the chosen option and alternatives

Options and Alternatives	Scalability			Impact and Co-Benefits		Climate		
	Cost	Scalability	Easy Up-take/ Implementation	Impact on agriculture production	Co-benefits	Impact for climate adaptation	Future-proof for future climate	Mitigation potential
Chosen Option: Community-based savings fund	The amount of money that will be re-invested by farmers after Y4 of the project's implementation. The cost is flexible and tailored to the farmer's capacity and willingness to participate in the fund	High	Moderate	High	High	High	The nature of the fund will continue to be participatory and tailored to farming needs, which will be conditioned by climate conditions	N/A
Alternative: Individual bank loans	Very high: high interest rates and costs associated with preparing a detailed financial plan for reimbursement	Low (individual loans are, by nature, reserved to singular people)	Low (requires that farmers have credit history)	Low and negative (the costs of the loan would likely outweigh short and long-term gains)	None	None	None	None
Alternative: No financing mechanism	Low (short-term), High (long-term, due to the potential losses with equipment failure)	High (baseline)	High (baseline	Low and negative (doing nothing would expose farmers to dysfunctional equipment		N/A	Not future-proof, climate change will put stress on equipment that will need replacing	None

4.2. Training of Advisors/Producers and Marketing Support

4.2.1. Description

The final suite of activities is what will allow the technical activities (solar-drip irrigation, poultry farming, dairy production, fishponds, and agroforestry) to fully realize their potential. This farming model will be novel to most of the project beneficiaries, and therefore, extensive training and guidance will need to be provided to both advisors, and subsequently, producers, on how to best utilize the Naatangue model, and how to ensure products from the model can be sold to maximize farmer income.

Therefore, this suite of activities should be regarded as the catalyst for success of the Naatangue model. This section refers to the following activities of the logical framework: parts of activities 1.2.2, 1.2.4, 1.2.5, 2.1.1, as well as activities 3.1.1 – 3.1.4. Therefore, training and marketing activities for both ANIDA advisors and producers are encompassed throughout all three components of the project, demonstrating how important ANIDA regards the professionalization of all actors involved in implementing the Naatangue farm model.

The first suite of activities concerns the training of agricultural advisors and, subsequently, producers. The aim is for ANIDA to assess the current capacity and knowledge of their agricultural advisors in delivering effective workshops and materials to provide to producers. The second element of the activity is for these agricultural advisors to perform regular, on-site visits in both village and family farms to ensure that the new equipment and/or technique of the Naatangue model is not only implemented effectively, but also assure that farmers understand how to use and extract as much value and benefit from the new technique and/or equipment. This training will also take the form of monitoring and evaluation missions, on-site, to make sure that the project is successfully implemented over time. This is particularly important in the initial phases of the project, during which farmers will have to be particularly hands-on to ensure, for instance, that the agroforestry seedlings are sufficiently attended to, and that solar equipment is maintained.

Besides training, ANIDA also seeks to create a marketing environment that will facilitate the sale of Naatangue farm products in local, regional and national markets. This will involve a range of activities, with the ultimate goals of making sure that producer cooperatives are (1) sufficiently organized to leverage financing from local, banking institutions (such as the Banque Agricole), and (2) understand how to process and price their production in the market place by being trained in the various value chains of their products, be given access to information on food prices, and gain insights into different strategies for raw product processing; (3) Ultimately generate a demand for Naatangue products and farming systems so as to naturally scale up operations.

Ultimately, ANIDA will provide the theoretical (knowledge-sharing) and operational (marketing) framework to catalyze the success of the Naatangue model. ANIDA recognizes that the project's success hinges on the ability of farmers to produce and sell effectively to an internal market. ANIDA's vast experience in understanding agricultural market dynamics, along with the delivery of the Naatangue model, will ensure the success of implementing the project's various technical activities.

4.2.2. Technical assessment of the activity

Scalability and Ease of Up-Take and Implementation

ANIDA advisors have regularly participated in a range of agroforestry training courses and site-visits in different countries; they have well-established connections with agro-ecological experts in Brazil, from whom they benefited from an on-site training in 2019. ANIDA had participated in this training to strengthen agroecological practices in 20 Naatangue family farms.[354] The training allowed for the agricultural advisors to:

- Note the progress made and the difficulties encountered by Naatangue farmers.
- Introduce new plant species to promote crop diversification.
- Improve technical capacities for the use of organic fertilizers.
- Install a bank of legumes for seed production and soil fertilization.

Senegalese farmers employing various agroforestry techniques have also benefitted from training courses. In September and October 2019, twelve farmers and four agricultural advisors from ANIDA also received training in agroecological management in Brazil. Upon their return, they began to develop a new production scheme that preserves the environment to ensure the sustainability of their production.[355] Therefore, there is a clear track-record of both agricultural advisors and farmers making use of agroforestry training courses, which will facilitate the continued up-take of information through future training courses on the implementation of Naatangue farms.

On-site visits to the various family farms will be a key factor in the advisers' ability to suggest the right combination of farming components to maximize the benefits of the Naatangue model. In previous donor-funded projects, such as a capacity-building project for the implementation of *Waar-Wi* farms in Senegal, ANIDA prepared an extensive training program for agricultural advisors and consultants that covered many of the same topics that advisers will need to understand to assist in the creation and consolidation of family and village farms. Table 21, below, provides a detailed description of the training program, and demonstrates ANIDA's experience in providing such technical training to agricultural advisers.

Table 21- Example of Training Program Developed by ANIDA for Agricultural Advisors

Topics	Suppliers	Notes
Presentation techniques and training on the agricultural environment	DFMV, specialist in capacity building and organisational development	
Method of evaluation of a training action Method of maintenance and		30% of training in the classroom and 70% in the field (on a farm)
Maintenance of equipment/pumping station	DFMV, external provider	
Method of maintenance and conservation of the irrigation system	DFMV, external provider, enterprises	
Computing (data recording)	DFMV, head of the CISE	
Irrigation techniques	DFMV, external provider	20% of training in the classroom and 80% on a farm
Horticultural production techniques	DFMV, external provider	
Forage production techniques	DFMV, external provider	
Poultry production techniques	DFMV, external provider	
Dairy production techniques	DFMV, external provider	
Techniques for transplanting agroforestry nurseries	DFMV, external provider, DREEC	

354 ANIDA (2019). Rapport Annuel

355 ANIDA (2019). Rapport Annuel

Production management and organization (mixed and integrated)	DFMV, external provider	40% of training in the classroom and 60% on a farm
Credit and inventory management	DFMV, external provider	

This training program demonstrates ANIDA's deep understanding of the most effective ways of preparing and delivering training modules to agricultural advisers on a wide variety of topics. ANIDA has also prepared a training module for producers, which further demonstrates their applied experience in training producers on agroforestry techniques similar to those underlined in the Naatangue model. This training program, further outlined in **Error! Reference source not found.** (see Annex), also demonstrates ANIDA's network of highly-trained experts in a variety of high-specialized topics pertaining to agroforestry, including: poultry-breeding, solid waste management, and value chain training. With GCF funding, ANIDA and ISRA will be able to mobilize their existing network of experts to provide the same training to Naatangue farmers across the village and family farmers. The funding will cover the transportation for regular site visits, training materials and consultant fees, where needed.

Marketing support will allow for the scale-up of existing marketing structures by connecting existing (village) and new (family) Naatangue farmers to access marketing institutions and structures that allow for better producer prices. Indeed, one of the marketing activities calls for the use and access of digital products to farmers as a key mechanism that will allow farmers to gain access to product pricing information, as well as an alternative way to sell their products. For instance, "loumas" are established marketplaces that remove intermediary actors in the sale of producer goods to the market by offering producers the opportunity to market their goods directly to consumers in public marketplaces. There are now digital versions of loumas, whereby producers can not only advertise their goods online through a phone, but also gain key information on the prices of agricultural products so as to better capture the market for certain products; such services include "Mlouma", which provides digital information to Senegalese farmers on agricultural prices, projected temperature and climate information, as well as other key information that helps farmers plan their production ahead of harvesting season.[356]

Another key component of the marketing service will be the recording of production data in each of the farms by the agricultural advisers; this will allow for the monitoring of production and economic benefits, allowing ANIDA to tailor any interventions as soon as trends indicate that certain farms require assistance with one or more aspects of their production within the Naatangue farm model.

Therefore, Naatangue farmers will only provide added value to these existing structures by participating in online and digital marketplaces; in turn, these Loumas (whether physical or digital) will allow farmers to make better decisions in terms of planning their production and pricing their goods. Marketing support will also take the form of advising farmers on the comparative profitability of selling raw and processed goods. ANIDA has found that, at times, the sale of raw goods barely covers the cost of production; in these cases, they have successfully provided tailored training on how to process specific, raw fruit and vegetables

[356] Mlouma. (2023). Le Digital au service de l'agriculture Mlouma. Mlouma.

that allowed farmers to extend the shelf life of their production, and benefit from higher prices. For instance, the Pasa Loumakaf project, a US$ 25 million project financed by the African Development Bank, provided extensive training support to farmers on improving their production practices, which involved marketing support and training workshops on processing raw output into processed goods that can be stored and sold throughout the year and fetch higher prices.[357] ANIDA was heavily involved in several marketing aspects of this project, and its experience in delivering such marketing support services will facilitate the similar delivery of training and marketing services in the context of the upscaling of Naatangue farms.

Overall, the Naatangue project places a strong emphasis on building human capital by investing in training for farmers, training the trainers, and other project beneficiaries. By investing in capacity building across farming equipment, practices, and markets, small scale farmers are better equipped to cope with the impacts of climate change and maintain their operations even in difficult conditions. In doing so, the Naatangue project can ensure that the active population is better prepared to adapt to climate change while contributing to the overall goal of climate-resilient development pathways. Furthermore, the project's marketing efforts also contribute to its replicability and scalability by generating a demand-driven farm model that can last beyond the project. The clear identification of a new typology of farms in Senegal through the project's marketing efforts can inspire other farmers and organizations to adopt similar approaches. This can lead to a larger-scale paradigm shift in the agricultural sector towards sustainable farming practices.

[357] AfDB. (2019). In Senegal, the African Development Bank supports farmers to build food security—Senegal

5. Exit strategy and sustainability of the project

To ensure the long-term sustainability of the investments in the Naatangué farm program, regular monitoring missions are conducted to assess the condition of various components of the farms, such as irrigation networks, pumping stations, control cabinets, and monitoring of novel agricultural practices. The program schedules periodic preventive maintenance based on a well-formalized management plan, and this maintenance is carried out with rigorously respected periodicity. To handle the maintenance tasks, ANIDA disposes of electromechanical technicians in each of the 5 coordination areas, who are responsible for responding to the requests from the producers and are ready to be dispatched for both preventive and curative maintenance. Furthermore, there are With these measures in place, the Naatangué program is able to ensure that the farms remain in good working condition and continue to provide benefits to the producers over the long term.

For effective operations and maintenance, ANIDA is using monitoring software to conduct day to day monitoring of all the Naatangué farms across the country. In addition, a more centralized monitoring system will be in place by mid-2024. The system will provide real time digital data on the operations of Naatangué farms.

The long-term viability of solar-drip irrigation systems in the Naatangue model is well-established through ANIDA's experience in helping farmers procure and install equipment, as well as monitor the use of the equipment through several site visits in the years following their implementation. By 2019, 205 Naatangue farms have solar-powered drip irrigation systems, surpassing ANIDA's initial target of installing solar pump systems in 170 farms.[358] Throughout the year, ANIDA provided over 28 site-visits to farms to provide maintenance and preventative-damage assistance to farmers, half of which specifically targeted assistance in maintenance issues pertaining to solar pumping systems.[359I] This demonstrates the long-term viability of the pumping system as ANIDA has provided assistance with this technology over the last several years for over 200 Naatangue farms. Other Naatangue farm projects, such as those lead by the Spanish Agency for International Cooperation and Development in 2021, were successful because the project included several monitoring and evaluation activities by ANIDA and other agencies in Senegal to ensure that equipment would continue to be used throughout each of the four growing seasons of the project.[360] Specifically, Senegalese agricultural agencies would conduct regular site visits to ensure that each part of the solar-powered irrigation system, from the solar panels and pump to the irrigation tubing functioned properly.[361]

This project also planned for a detailed training course for agricultural agents that subsequently trained project beneficiaries, with specific theoretical and practical courses on the solar-pumping system. The similar design of this project to the Upscaling Naatangue farm project allowed for the continuous use of solar-powered irrigation equipment throughout the project's

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[358] ANIDA (2020). Rapport d'Activités.

[359] Ibid

[360] Agencia Española de Cooperación Internacional para el Desarrollo (AECID). (2020). Anexo I: Descripción de la acción. PACERSEN. Agencia Española de Cooperación Internacional para el Desarrollo (AECID). MINISTERIO DE ASUNTOS EXTERIORES UNIÓN EUROPEA Y COOPERACIÓN OFICINA DE INTERPRETACIÓN DE LENGUAS.

[361] Ibid

lifecycle (4 years) on over 500 ha of farmland.[362] ANIDA has recognized that the continued use of solar pumps requires a consistent presence throughout the country‘s various regions. As of 2014, ANIDA has nominated two additional zonal coordinators in the “Sud“ and “Centre“ region, thereby covering all four of Senegal‘s main regions (including Nord and Ouest). ANIDA has found that the proximity of zonal coordinators for agricultural projects has allowed for an improved monitoring of farming activities, thereby assuring the continued use of novel agricultural techniques.[363] Likewise, the Upscaling Naatangue Farms project also aims to further train agricultural advisors in order to build off an existing network of trained advisors, and see to that even more beneficiaries benefit from the Naatangue model. Regular site visits from technicians have been particularly useful in mitigating the abandonment of solar pumping systems during periods in which there was little sun. ANIDA has found from internal assessments that farmers would often cease using solar pumps when they could not generate power as easily during cloudy days. To address this, ANIDA employed an electro-mechanic who could train local technicians in each of the country’s regions on how to improve the functioning of solar panels during cloudy days. The proximity of trained, local technicians throughout the country facilitated the ease with which farmers could continue using solar pumps.[364]

To enhance sustainability of Naatangue farms, a public-private partnership has been proposed to increase their financial sustainability. The community-based savings fund, outlined in Section 5, is a crucial component that catalyses farm sustainability and scalability. By reducing financial risks associated with farming, this fund encourages farmers to adopt sustainable practices and enables them to access resources during difficult times. In case of crop destruction due to natural disasters, farmers can use the fund to purchase new seeds and other necessary inputs, without resorting to high-interest loans. Moreover, the savings fund supports replicability and scalability beyond the project area. New farmers can join the Naatangue farm model, using the communal fund as collateral and subsequently contributing back to the fund as they earn income. This creates a self-sustaining system that can support farmers even after the project ends.

The project's marketing efforts also contribute to its replicability and scalability by creating a demand-driven farm model that can last beyond the project. Through its marketing efforts, the project has identified a new typology of farms in Senegal that can inspire other farmers and organizations to adopt similar approaches. This can lead to a paradigm shift in the agricultural sector, towards more sustainable farming practices at a larger scale.3 tier approach in financing O&M:

1. Tender (guarantee from service providers / companies)
2. ANIDA co-financing
3. Community-based savings fund for village farms

[362] Ibid

[363] ANIDA (2014). Rapport d’activites 2014.

[364] Interview with ANIDA experts

SECTION IV: SPECIFIC INFORMATION ON THE PROJECT

4.1. Policy landscape

Senegal ratified the United Nations Framework Convention on Climate Change (UNFCCC) in May 1994 and the Kyoto Protocol in July 2001. In 2006, the country developed a National Adaptation Programme of Action (NAPA[365]), which defines its priorities for adaptation to climate change, including the water collection and saving, the dissemination of agroforestry techniques, crop diversification and training of beneficiaries on climate change related issues. Through components 1, 2 and 3 which focus on the scaling up of water saving infrastructures, agroforestry practices and the establishment of cooperatives, this project participates in the realization of these options. In 2015, Senegal submitted its INDC and has been developing its NDC since 2017. This strategy is currently the overarching instrument that delineates the country's climate action. Adoption of agroforestry combined with farmer managed natural regeneration (FMNR) and conservative agriculture, as envisioned in this project, are among the adaptation options in the short / medium terms (2020-2035) identified by the NDC.

Senegal's environmental policies refer to two main documents: The Environmental Action Plan (PNAE in French acronym), adopted in 1997 and the "Policy Letter for the Environment et Sustainable Development Sector (LPSEDD 2016-2020)". To reverse the current negative trends of land degradation and its impacts on sustainable livelihoods, the LPSEDD gives priority to promoting the modification of agrarian farming systems and techniques to mechanized climate smart agriculture driven by inclusiveness and innovation technologies. Component 1 of this project is in line with this priority. Activities planned under Components 1 and 3 will contribute to achieving the objectives set in the LPSEDD by aiming to fight deforestation and land degradation as a means to reduce the adverse effects of climate change, and enhance coordination and capacity building to develop livelihoods and strengthen the resilience of vulnerable groups.

The country's development plan "Plan Sénégal Emergent" (PSE) places organizes small producers around operators through the development of financing mechanisms for activities. Through its third component this project directly supports the development of this type of agriculture by organizing producers and beneficiaries mainly around cooperatives.

The National Action Plan to Combat Desertification (PAN / LCD) has identified climate change as one of the principal drivers of desertification. The appropriate responses identified by this plan include the development of agroforestry. In this context, the project contributes to the implementation of these actions through the first and the second component which aims to scale up agroforestry practices.

4.2. Legal and regulatory landscape

The project will comply with the national regulations in force, in particular:

- Law No. 2001-01 of 15 January 2001 on the Environment Code;
- Law n ° 2013-10 of 28 December 2013 on the General Code of Local Government;

[365] Senegal's 2015 NAP is being validated by donors; data are not available from the public. Only certain sectoral reports are validated (fishing sector).

- The new Forest Code which define the authorizations in case of clearing or tree cutting to make the installations for the farms;
- Law No. 97-17 of 1 December 1997 on the Labor Code.

4.3. Current and recently closed projects

In parallel, several other interventions have been implemented in the field of agriculture because it is a sector that represents 16% of the country's GDP. Many of these projects were funded by foreign sources, mainly IFAD, and had significant impacts on the sector. Among these we can mention :

- **The Food Sovereignty Support Program (PASA in french acronym) – 10 years**: this is a program to support the professionalization of family farming by increasing access to basic socio-economic services for a total of $ 6.6 million. It intervenes in the areas of Podor, Louga, Kébémer, Tivaouane, Mbour, Sedhiou and Koungheul.
- **The Agricultural Sector Support Project - Extension (PAFA-E in french acronym) – 7 years**: this is a project to improve agricultural production and productivity through a better flow of products at remunerative prices and strengthening institutional capacities, for an amount of $ 51.2 million. It concerns the areas of: Louga, Diourbel, Fatick, Kaolack and Kaffrine.
- **The Agricultural Development and Rural Entrepreneurship Support Program (PADAER in french acronym) – 8 years**: This is a program to contribute to the reduction of rural poverty and the stimulation of economic growth in Kedougou, Kolda, Matam and Tambacounda. The aim was to improve the access of small producers and their organizations to efficient services, technologies and production infrastructure through support for product processing, professionalization of actors, improvement of supply agricultural products, etc. for a total amount of $ 51 million.
- **The project to support the resilience of agricultural value chains (PARFA in french acronym) - 4 years**: contribute to the improvement of the economic situation and the ecological environment of the rural communities by strengthening the capacities of the actors at national, regional and local level, promotion of mechanisms for consultation and integration of good practices, scaling up of good practices, sustainable and resilient for a sustainable management of resources (water, land, energy) for $ 9.3 million. It operates in the same areas as the PAFA-E namely the areas of: Louga, Diourbel, Fatick, Kaolack and Kaffrine.

Regarding the alignment with the GCF Country Programme of Senegal, particularly the Components 2 and 3 which focuses on adaptation, food security, climate resilient livelihoods and inclusive climate governance.

4.4. Summary of the project evaluation report of previous activities/projects

Agriculture is thus placed by the public authorities at the heart of the government's development strategy, as evidenced by the important place reserved for it in the Emerging Senegal Plan (PSE), in particular in its axis 1 "Structural transformation of the economy and Growth”. This strong ambition for the agricultural sector is reflected in the development objectives set out in the Program for the Revival and Acceleration of the Senegalese Agriculture Cadence (PRACAS) agricultural version of the PSE. The intervention of ANIDA falls within the framework of the implementation of PRACAS through the significant contribution to two strong objectives of the PES in the field of Agriculture:

- Modernization of family farms;
- Promotion of High Added Value sectors.

Main achievements

ANIDA has signed with the Food Security Support Project in Louga, Matam and Kaffrine Regions (PASALouMaKaf), an agreement as Executing Agency, for the construction of agricultural farms.

European Union funding: A project to develop 400 Naatangué farms has been introduced by ANIDA to the European Union to seek funding. Following the visit to the Naatangué farms of Aga Babou and Ndianda, the EU decided to grant funding of 20 million euros for the realization of the Support Project for the reduction of migration through the Creation of Rural Jobs in Senegal (PACERSEN). Scheduled for a period of 3 years, from 2017, it is funded through the Spanish Agency for International Development Cooperation (AECID) and the Italian Agency for Development Cooperation (AICS) which will ensure the management and coordination technical aspect of the project. These two institutions will work closely with ANIDA chosen as the Executing Agency for the said project.

Regional Support Project for the Initiative for Irrigation in the Sahel (PARIIS): Financed by the World Bank, PARIIS will be carried out in Senegal in the 3 priority intervention areas (PIA) selected: the PIA A (valley the Senegal River); PIA B (natural region of Casamance) and PIA C (groundnut basin). The experiences of family farms developed by ANIDA around hydraulic boreholes for market gardening activities will be capitalized in the PIA C in addition to the lowland developments developed by the management of the Retention Basins through the PAPIL. ANIDA was chosen as the Executing Agency for the development of 12 farms including 10 of 10 ha and 2 of 5 ha for a total cost of 1.140 billion investments not taking into account the cost of support activities. the development and remuneration of the contracting authority.

Agricultural Mechanization Project: This project is a highly concessional financing of 3 million euros for the benefit of ANIDA offered to the State of Senegal by the Austrian Bank UniCredit Bank and guaranteed by the Austrian government. The goal of this project is to acquire a series of agricultural equipment and material that can be used on agricultural farms by different farmers through CLMAs (Agricultural Machinery Rental Centers) which will be installed in locations chosen by the organization. Agency. These Centers will serve as a structure that can integrate the agricultural farm cooperatives that ANIDA intends to set up in these three zonal intervention coordination units. The member farmers will be able to use, at very favorable prices and conditions, modern and efficient equipment for carrying out various tillage tasks and for the treatment of crops. This financing offer is submitted for review to the Ministry of the Economy and Finance.

Brazilian Cooperation: After the creation of 11 family farms by the PAIS program financed by the Brazilian Cooperation, ANIDA has submitted a request for a second phase.

Operation and Maintenance (O&M)

Building up a maintenance strategy for first aid intervention is essential to sustain activities on farms. This is a process that is consolidated every year through the acquisition of dewatering equipment and spare parts to build up the stock of response equipment. This activity 'is an acquisition of supplies carried out annually at 100%.

For the sustainability of investments, regular farm monitoring missions are carried out on farms to see the state of the irrigation network, pumping stations, boreholes, control cabinets and their components (contactor, thermal relay, circuit breaker, cable etc.). These missions can be carried out at the request of the producers or by simple routine monitoring of activities on the farms. They are of great importance because they allow you to anticipate breakdowns. On each farm, it is important to ensure the proper functioning of the measuring devices which are the information sensors (meter, pressure gauge, etc.). To this end, periodic preventive maintenance is scheduled according to a rigorously respected periodicity and well formalized in the management of each farm. An electromechanical technician is recruited by the Agency to deal with requests from producers in terms of preventive and curative maintenance. The latter can use an external service provider supported by the producers if the intervention requires it.

Lessons learned[366]

- This type of project must be meticulously prepared, with a well formulated feasibility file;
- The project implementation schedule must take into account the realities on the ground and allow sufficient time for proper infrastructure construction;
- Project teams must be put in place in good time following approval funding to ensure an effective start-up in the field and adequate implementation of project activities;
- Sites need to be secured by planting Melifera or other species around the farms;
- Reforestation of the farms to create a microclimate favourable to crop crops;
- Improving the technical specifications of certain structures (gates);
- The choice of companies in charge of the work must take into account their financial capacities and equipment levels, to avoid delays in project implementation project;
- Close monitoring of the work to ensure that contractors meet construction deadlines.
- Self-sufficient energy supply for farms by installing solar equipment

Conclusion

Indeed, the construction of infrastructure, which is one of the major strategic orientations,

[366] EVALUATION FINALE DU PROJET DE COOPERATION DELEGUEE PACERSEN BIS

shows a rate of 86% for the Naatangué village farms and 133% for the emerging agricultural areas.

For the development, the operating results of the farms contributed globally to the achievement of the objectives of the performance contract in terms of fruit and vegetable production amounted to 28,283 tonnes against 35,000 tonnes as the target value, i.e. a rate achievement of objectives of 81%. Also the strong diversification of speculations and the contribution of emerging agricultural areas were decisive in the creation of added value and jobs (13,600). Animal production is a transversal diversification program for development. It recorded satisfactory results and even exceedances with regard to milk production, the production of broilers respectively by 162% and 187%. However, certain activities require special attention in order to reach the desired levels of satisfaction, in particular the creation of Naatangue family farms (23%), whose financing scheme has not yet been tested by the financial structures involved in the financing of the rural world partly explains its level of Implementation.

Even if the results are generally satisfactory for the development, the targets are not reached because of the combination of several factors, the most important of which are related to the difficulties of access to campaign credits, to the non-development of some farms not received.

Regarding the improvement of the organizational and intervention efficiency of the Agency, significant progress was noted. However, even if the investment budget has increased significantly in recent years, its execution is currently posing difficulties due to the low level of allocations allocated to operations. This can constitute a real risk for the respect of the commitments signed with partners for whom the Agency ensures the delegated project management. The lack of control of financial resources leads to disruptions in the realization of forecasts.

4.5. Theory of Change of the project

Theory of Change:

Impact Paradigm Shift

If village and family farms have access to solar powered drip irrigation, climate resilient agriculture practices for agroforestry, crop and livestock, finance and marketing services, **then** village and family farms will become financially sustainable and resilient to the impacts of climate change, **because** farmers have water availability all year, agricultural production is increased and diversified, and value of commercialization is improved.

Outcomes and co-Benefits

Outcome 1	Outcome 2	Outcome 3	Co-benefit 1	Co-benefit 2
Outcome 1: Resilience of village and family farms improved	**Outcome 2:** Climate-smart agriculture capacity of advisory services and smallholder farmers strengthened to support sustainable agriculture	**Outcome 3:** Farmers' entrepreneurship, producer groups and agricultural cooperatives strengthened to promote access to finance and marketing	**Co-benefit 1:** Creation of jobs for young people and women	**Co-benefit 2:** Sustainable water management and soil quality improved

Outputs

Output 1.1: Naatangué family farms developed and operational	**Output 1.2:** Village farms improved	**Output 1.3:** Agroforestry practices adopted into Naatangué family and village farms	**Output 2.1:** Advisory staff trained on climate smart technological packages	**Output 2.2:** Farmers trained on climate smart technologies	**Output 3.1:** Producer organizations trained in organizational development and entrepreneurship	**Output 3.2:** Agricultural cooperatives established and operational	**Output 3.3:** Community saving funds operational

Activities

- Selection of beneficiaries for Naatangué family farms
- Planning and equipping of family farms and construction of infrastructures
- Establishment of community-based contribution schemes
- Monitoring and control of productive farms' activities
- Acquisition and installation of solar equipment
- Establishment and integration of poultry farming activities
- Establishment of milk processing unit
- Introduction of resilient climate-smart crop-livestock agroforestry practices technologies
- Domestication of forest fruit trees

- Development of training materials.

Training of trainers for agricultural advisors on climate smart technological packages, domestication of forest fruit trees and agroforestry resilient practices
- Hands on training on infrastructures and equipment of agricultural advisors
- Training of farmers on climate-smart technological packages

- Training of agricultural advisors on value chains, organizational dynamics and marketing
- Training of producers' associations in organizational development and entrepreneurship
- Establishment of farming cooperatives
- Provision of marketing support to producers and farmer cooperatives
- Establishment of community-based saving funds

Barriers, risks

Lack of efficient water management and control all year	Limited adaptation mechanisms to climate change for small-scale farmers	Limited technical capacity of advisory services to provide advice to farmers on climate-smart agriculture practices and commercial value chains	Limited access to finance of family and village farms for climate adaptation and improving value of commercialization	Lack of financial sustainability of family and village farms limiting their ability to finance the next agricultural cropping season adequately and timely

Assumptions

- Farmers (men and women) are willing to adopt climate smart technologies and to organize in producer groups and agricultural cooperatives.
- Farmers members (men and women) of producers' associations and cooperatives strengthen their understanding of value chains as well as management, marketing, and leadership skills.
- Farmers (men and women) are willing to contribute to the community-based saving funds.

SECTION V: IMPLEMENTATION ARRANGEMENTS

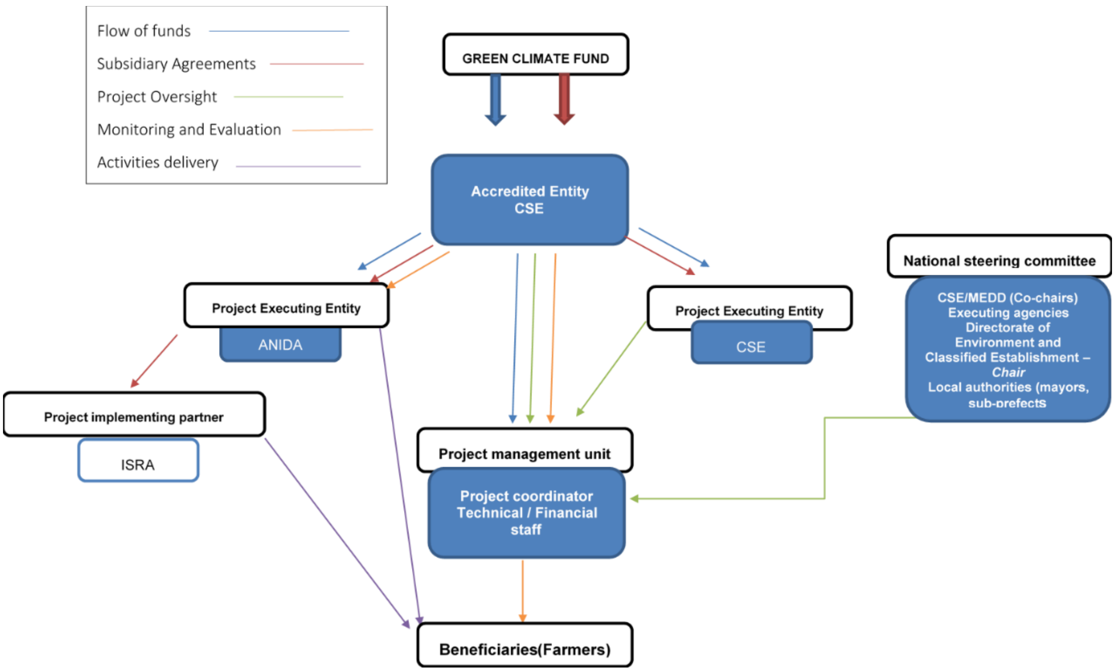
5.1. Capacity assessment and due diligence on the executing entities

ANIDA which the main executing entity has procedures for each of its activity from selecting beneficiaries to supporting the producers in marketing their products. The experts from ANIDA in charge of the application of the procedures are well defined and the procedures are put in place. ANIDA also has a procurement cell with a procurement specialist who has in charge the monitoring of the whole procurement process.

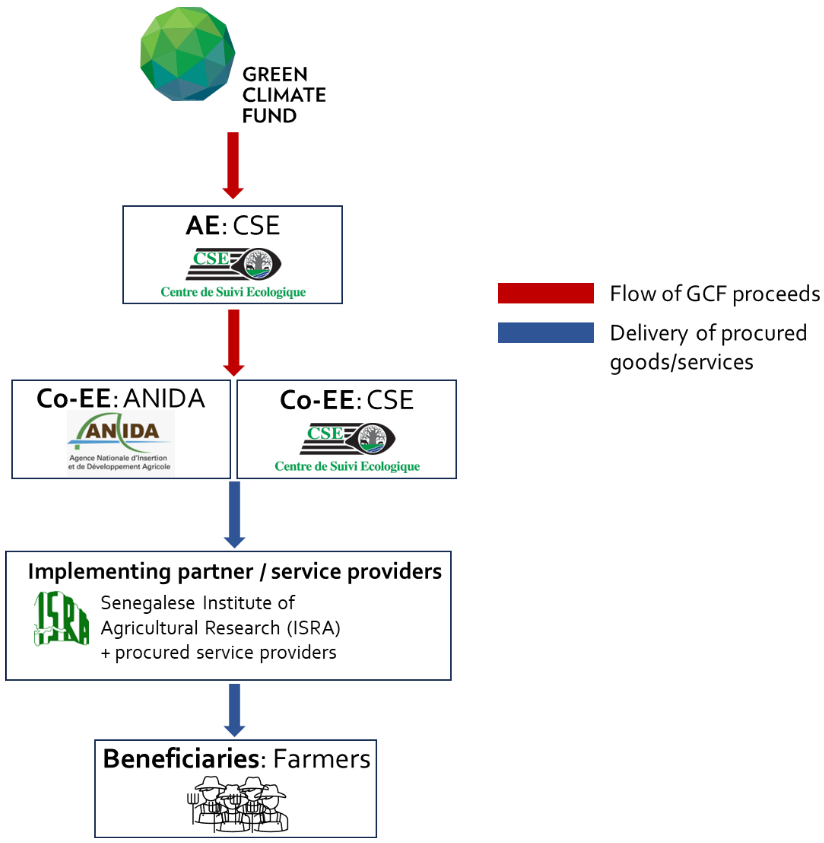
5.2. Implementation arrangements and governance of the project

The project implementation builds, through cooperation with many institutions, an accredited entity, an executing entity.

CSE is the accredited entity with extensive experience in the management of projects for climate change adaptation in collaboration with the Adaptation Fund. Moreover, CSE has been co-opted by the Adaptation Fund as the national implementing entity of climate change projects. Finally, CSE enjoys a proven technical expertise as well as administrative and financial procedures recognized worldwide (e.g. the GCF) and nationally for autonomous project management.
Details are provided in the full project document.



5.3. Institutional and project level grievance redress mechanism



CSE has developed its own grievance redress mechanism (GRM) as part of its environmental policy in order to make available a framework for resolving specific grievances. The scope of the existing mechanism includes all issue, concern, problem or claim arising from activities within the framework of projects or programs executed or implemented by CSE and that an individual or community group wants CSE to address and resolve. This includes physical, psychological, social or environmental and gender harms and prejudice.

For now, the Department of environment and classified establishments is the national body which is tasked too receive and address complaints related to projects. Any person, community or local collectivities wishing to complain about the harms or prejudice arising from activities within the framework of projects implemented by CSE can submit a claim to CSE's grievance team.

For the project, a project level grievance redress mechanism will be developed. The objective will be to work with the existing regional coordination. ANIDA has local regional coordination that have a better knowledge of the local issues and organization. First of all, there will be the identification of the local issue management at the village level and then at the commune level. The questions that will be asked are: how are the issues are managed? What is the role of the chief of the village in the issues management? What are the roles of the different administrative authorities when an issue is arise?

The project level GRM will lean on the administrative authorities. The complaints will be received by the chief of the village then the project management unit (PMU) of the project, then the mayor, then the prefect and at the end the governor. At each phase of the complaint management, the PMU will maintain CSE informed but CSE will only intervene when the complaint is raised at the governor level.

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Annex 2c – Example of water availability studies conduced by ANIDlA

Annex 2d – Breakdown of proposed activities by region

Annex 2e - Example of a Training Course on Agroforestry Techniques Designed by ANIDA for Producers