

Climate risk and food security in Senegal:

Analysis of climate impacts on food security and livelihoods



Senegalese National Agency for Civil Aviation and Meteorology



CLIMATE CHANGE
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* This analysis has been undertaken and published through a collaborative effort between the National Agency for Civil Aviation and Meteorology of Senegal (ANACIM), 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 (IRI) and the WFP Country Office in Senegal.

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This analysis is part of the Resilience Project Initiative coordinated by WFP's Office for Climate Change, Environment and Disaster Risk Reduction. The Resilience Project is a collaborative effort between WFP, the Swiss Agency for Development and Cooperation and partners to strengthen the capacities of governments and other key partners to provide effective support for greater resilience in the context of food and nutrition security

Foreword

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Senegal is highly vulnerable to shocks associated with climate change. Recent years have been marked by erratic rainfall patterns and rising sea-levels which are increasing the rates of soil erosion, salinization in agricultural soils, and destruction of critical infrastructure. These climate-related events have led to the increased vulnerability to food security in Senegal. For instance, the 2011/2012 drought-induced food insecurity and subsequent floods of 2012 in the Sahel was a clear demonstration of climate impacts on food insecurity.

The negative impacts of climate change are real: increasingly, erratic rainfall and rising sea-levels will likely result in more extreme weather events, as the latest scientific evidence suggests. These events will likely continue to have a detrimental effect on developing countries, such as Senegal.

It is therefore critical to ensure food security in at-risk populations and to enhance the resilience among the most vulnerable populations. In order to identify policies that support the most vulnerable it is important to understand the climatic impacts on vulnerable populations, and then use this information to identify *who* are the most vulnerable and *why* in order to prioritise interventions. This report hence provides a comprehensive analysis of climate risk impacts on food security and livelihoods that could form the basis for prioritising typologies of interventions to manage these risks.

This report explores several key issues. For instance, it examines the historical relationships between climate and food security indicators and also analyses the sensitivities of livelihoods to climate risks and uses this information to identify *who* is potentially most at risk. We consider that this type of work is instrumental, not only in advancing the climate change and food security dialogue in Senegal, but also in providing concrete inputs for adaptation planning.

Finally, I would also like to acknowledge the dedication that has gone into this analysis. This report is the result of a collaborative effort between the National Agency for Civil Aviation and Meteorology of Senegal (ANACIM), 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 (IRI) and the WFP Country Office in Senegal. This type of collaboration between international and national organisations is the type of work that is needed to engage experts from different fields to better understand the different risks and the range of implications on livelihoods and food security.

Foreword

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Food security is a priority issue for the Government of Senegal. Food security is highly sensitive to climate risk in Senegal, in particular droughts and floods. Climate risk affects livelihoods and exacerbates environmental degradation, poverty, and food insecurity. Indeed, recent climate-related events and trends — including the 2011/2012 food security crisis in the Sahel — have highlighted their potential impact on access and availability to food.

Rainfall in particular, as identified in this study, is highly variable across the country and throughout the year; and is the key climatic variable affecting food security in Senegal. This report further suggests that food security indicators in Senegal, including agricultural production, and key measures of food access such as, food consumption score, expenditure on food, and coping strategy index, are strongly correlated to climate variability.

Given the clear impact of climate on food security, WFP has made addressing the impact of climate change on hunger a priority in the most vulnerable countries. WFP's strategy to address climate change issues emphasises the importance of enhancing the resilience of vulnerable communities through asset creation and capacity development at national and community levels. A core component of this strategy is to work with partners to strengthen the evidence base of climate impacts on food security, and to use this information to better inform its food assistance programmes.

Understanding the ways in which climate risks affect vulnerability and livelihoods is a key step towards identifying the regions and communities that should be prioritised as well as identifying the appropriate response mechanisms. This analysis therefore; i) examines the historical relationships between climate and food security; ii) analyses the ways in which livelihoods are affected by climate risks, and; iii) uses this information to identify priorities for interventions.

We hope that this report will not only help to advance the climate change and food security dialogue in Senegal, but also provide concrete inputs for adaptation planning to build resilience particularly in the most vulnerable regions of the country.

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Executive summary

Food security is highly sensitive to climate risks in Senegal. Recent climate-related events, specifically the 2011/2012 drought, have highlighted the potential impact of climate on food production, access to markets, and livelihoods. However, the ways in which specific vulnerabilities are linked to climate have not been well studied. The purpose of this analysis is to quantitatively and qualitatively assess climate (including climate variability, change, and extremes) impacts on household food security and livelihoods. The analytical method carried out for this research consisted of two components: (i) a dynamic analysis to evaluate the relationship between historic and current climatic variability and food security indicators, using long-term historical data; and (ii) a descriptive analysis to establish a baseline against which vulnerability to future risks can be assessed, using household data from the 2011 CFSVA survey.

The analysis highlights the following trends:

Climate: Climate change is characterised by high rainfall variability at seasonal, inter-annual and multi-decadal scales, and is one of the key contributors to food insecurity in the key agricultural areas of the country. Historically, climate change in Senegal was linked to persistent drought in the 1970s and the 1980s. Recent observations suggest a reversal of these conditions with higher precipitation; however, this increase has resulted from increasing rainfall intensity rather than frequency. These trends highlight that rainfall patterns are highly erratic in Senegal, and in the Sahel, more generally, and can result in a more uncertain risk environment in the future.

Climate impacts on food production: Rainfall is the key climatic determinant of food production in Senegal. Wetter years are generally associated with higher food production. Analysis shows that the main staple crops (rice, millet, groundnuts, and sorghum) are highly sensitive to changes in annual precipitation patterns, resulting in lower crop production in years with lower rainfall. Of particular concern is that crop production appears to be especially responsive to rainfall variability in the key agricultural areas, such as the groundnut basin (*bassin arachidier*).

Climate impacts on food access: Access to markets is critical to food security in Senegal. In this context, two inter-related climatic impacts could affect the ability of households to access food during critical months. First, if the lean season intensifies due to climatic variability (for example, the onset of the rainy season could be delayed) it is likely that households would have to purchase more of their food during the lean season. Second, under a scenario of increasingly erratic rainfall, extreme climate events such as floods could destroy or severely affect infrastructure, reducing the ability of households to purchase food. Infrastructure is a key aspect, especially in the southern parts of the country where access to markets is critical for ensuring household food security.

Climate impacts on livelihoods: Livelihood activities are highly climate-sensitive in Senegal: subsistence agriculture, cash crops, livestock rearing, *marâchage* (vegetable growing), and daily agricultural labour are the main sources of income. The proportion of income that comes from such climate-sensitive source is highest in the central parts of the country. Moreover, aggravating climatic factors are concentrated in this region, suggesting that incomes in the groundnut basin are highly sensitive to climate.

To conclude, the report identifies the following policies to enhance food security and climate risk management outcomes:

Mainstreaming climate risk management into development and food security strategies

Integrating climate risk management structures into broader development pathways offers a cost-effective manner of addressing multiple development challenges, while accounting for the emerging risks posed by climate variability and change. Social protection and safety nets offer critical platforms for investing in risk management for the most vulnerable and should become a policy priority. Successful scaling up should be implemented at the community level, as well as at the national, regional and global levels by adapting successful experiences and best practices in resilience building.

Focus on the most vulnerable

All rural livelihood systems in Senegal are highly sensitive to climate given their dependence on rainfall. Recent climate trends show that climatic conditions that aggravate food security are concentrated in the central parts of the country. These regions experience irregular rainfall patterns during the rainy season, erratic start of the rainy season, and long dry spell length that could affect crop production. Climate projections suggest that these trends could continue over the next few decades. Strategies for *livelihood and income diversification* are critical to ensuring resilience against more intense climate-related risks. For example, migration (both seasonal and permanent) has become an important source of household income for at-risk populations. *Landscape transformation* through land rehabilitation can also be a cost-effective solution to manage climate risks, by contributing to both drought and flood risk management.

Manage uncertainties associated with climate change

Both droughts and floods can occur in the same growing season, with potentially devastating impacts on crop and livestock production. Strategies to address climate risk should focus on developing capacities to better analyse and anticipate risks. The introduction of *early warning systems and contingency plans* can support climate risk management and food security strategies.

Integrate climate change adaptation and mitigation efforts

Addressing climate impacts on the most food insecure requires a twin-track approach which incorporates adaptation and mitigation efforts. Where possible, initiatives to address climate impacts should also aim to reduce greenhouse gas emissions through mitigation activities, and low-carbon development. Such initiatives should also ensure that the poorest and most vulnerable communities are not negatively affected.

Part I: Introduction and context

Introduction

This report presents the findings of an analysis carried out to identify relationships between climate variables and food security indicators. The analysis has three main objectives. (1) The analysis aims to identify spatial *and* temporal relationships between food security and climate variables. In order to do so, long-term data series of food security indicators (crop yields, food prices, livestock product output) and climate parameters (precipitation and temperature) were correlated at the national and sub-national data. (2) The second objective of the analysis is to establish a vulnerability baseline to assess the factors that render a household vulnerable to climate variability. (3) The final objective of this study is to identify a set of key policies to build adaptive capacity and reduce climate-related food insecurity in the most vulnerable communities.

National context

Demography

Senegal is a West African country with a population of around 13 million (World Bank, 2011a). Population is unevenly distributed across the country, with the majority of people living near the Atlantic coast, in relative proximity to the capital city Dakar, a pole of attraction for national and regional economies (Club du Sahel 1998). The eastern regions of the country, particularly Kédougou in the far southeastern corner, are less densely populated (Figure 1).

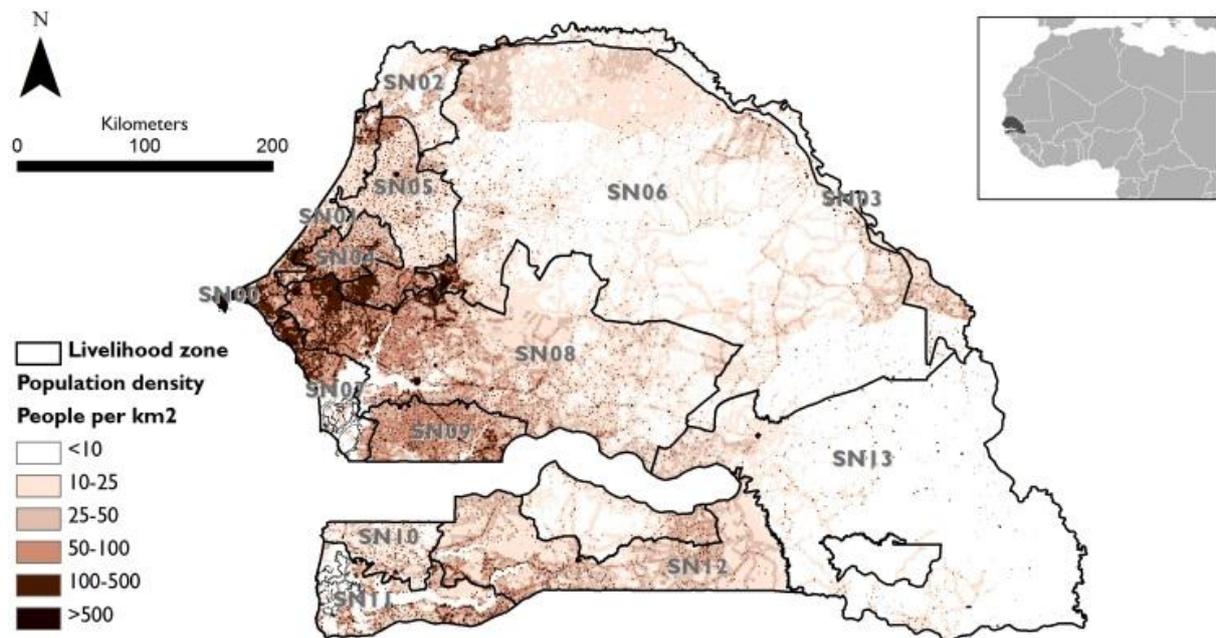


Figure 1. Population density in Senegal, 2008. [Source: LandScan (2008), FEWS NET (2012)]

Senegal has one of the highest population growth rates in the world (2.56 per cent, 26th in the world; UN-DESA, 2010). In contrast to its land-locked Sahelian neighbors, Mali, Burkina Faso and Niger, however, rapid population growth in Senegal is defined by urbanization: growth rates are higher in the western parts of the country, and are driven primarily by migration from rural to urban areas. Not surprisingly, then, the most rapid population growth has occurred in Dakar: in 1960, 14

per cent of the country's population lived in the capital whereas now over 25 per cent of the country lives in Dakar.

Demographic pressure is an issue of major concern: as population growth continues to outpace growth in agricultural production, the challenges of addressing poverty and food insecurity have increased. In addition, population growth, agricultural expansion and persistence of drought at the end of the 20th century all contribute to land degradation, particularly in the western and northern parts of Senegal (Figure 2).

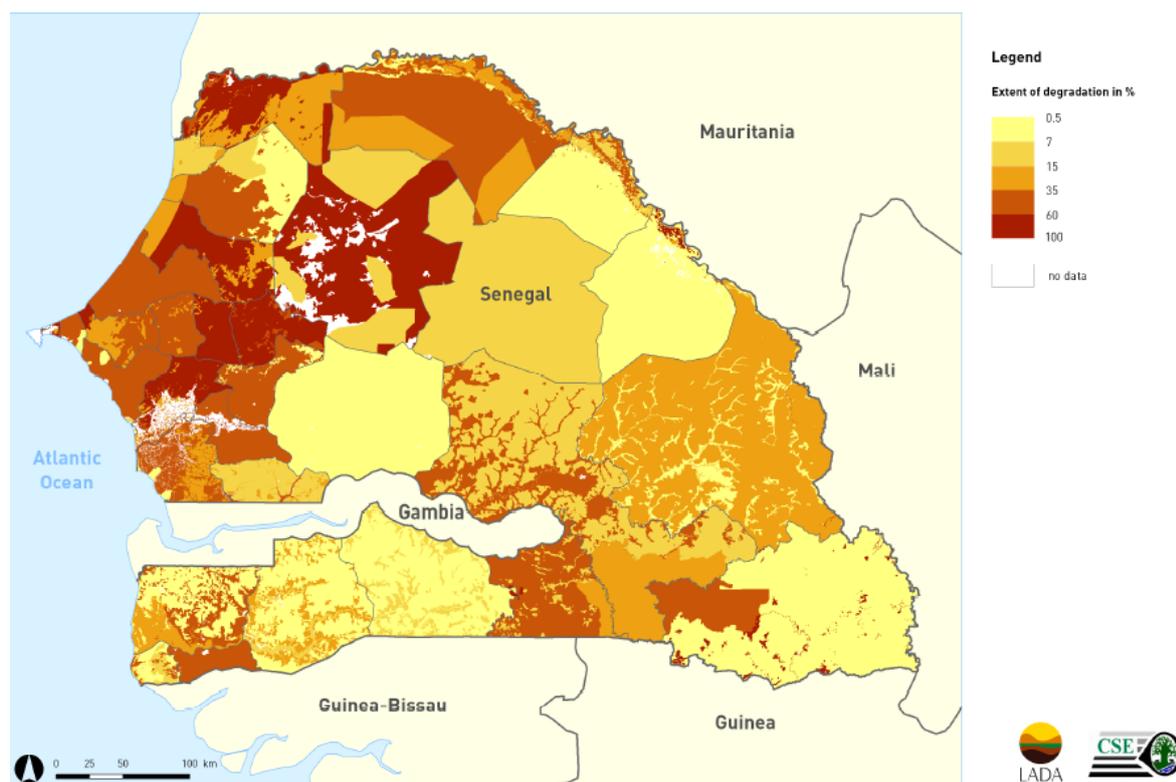


Figure 2. Extent of land degradation in Senegal. [Source: CSE and FAO (2010)]

As Figure 2 highlights, the highest degradation rates are in northwestern Senegal. This is closely linked to three trends. First, persistent drought in the 1970s and 1980s severely affected the natural and managed ecosystems of the climatologically drier northern regions (Gonzalez et al. 2011). Secondly, agricultural expansion has accelerated due to increased demand in land. Third, heavy localised grazing in the Saint-Louis region has been associated with an increase in livestock numbers coupled with reduction of grazing land.

Poverty

Some progress has been made to reduce poverty, with poverty incidence declining from 68 per cent to 57 per cent between 1994/1995 and 2001/2002 (ESAM II, 2002). However, poverty rates remain high especially in rural areas: according to the latest Senegalese Household Survey (ESAM II), 58 per cent of rural households are below the poverty threshold², compared to 43 per cent in towns and 34 per cent in Dakar. As a result, 65 per cent of poor households live in rural areas although the rural sector accounts for 55 per cent of the population.

² The national poverty threshold is determined by the cost of food and essential non-food items.

These results are confirmed by the wealth index³ (WFP, 2011; Figure 3). Urban households possess more assets than rural households. The departments with highest levels of poverty are Ranérou, in the northeastern region of Matam (94 per cent of households surveyed are very poor or poor), Salémata in the southeastern region of Kédougou (89 per cent of households are very poor or poor) and Koumpentoum in the eastern region of Tambacounda (85 per cent of households are considered very poor or poor). In contrast, poverty rates are much lower in the western regions of Diourbel, Thiès, Fatick, and Dakar (23%, 27%, 34%, 0.3% respectively) where major urban centres are located. This highlights huge disparities in poverty rates between urban and rural areas, but it also highlights the high prevalence of poverty throughout the country.

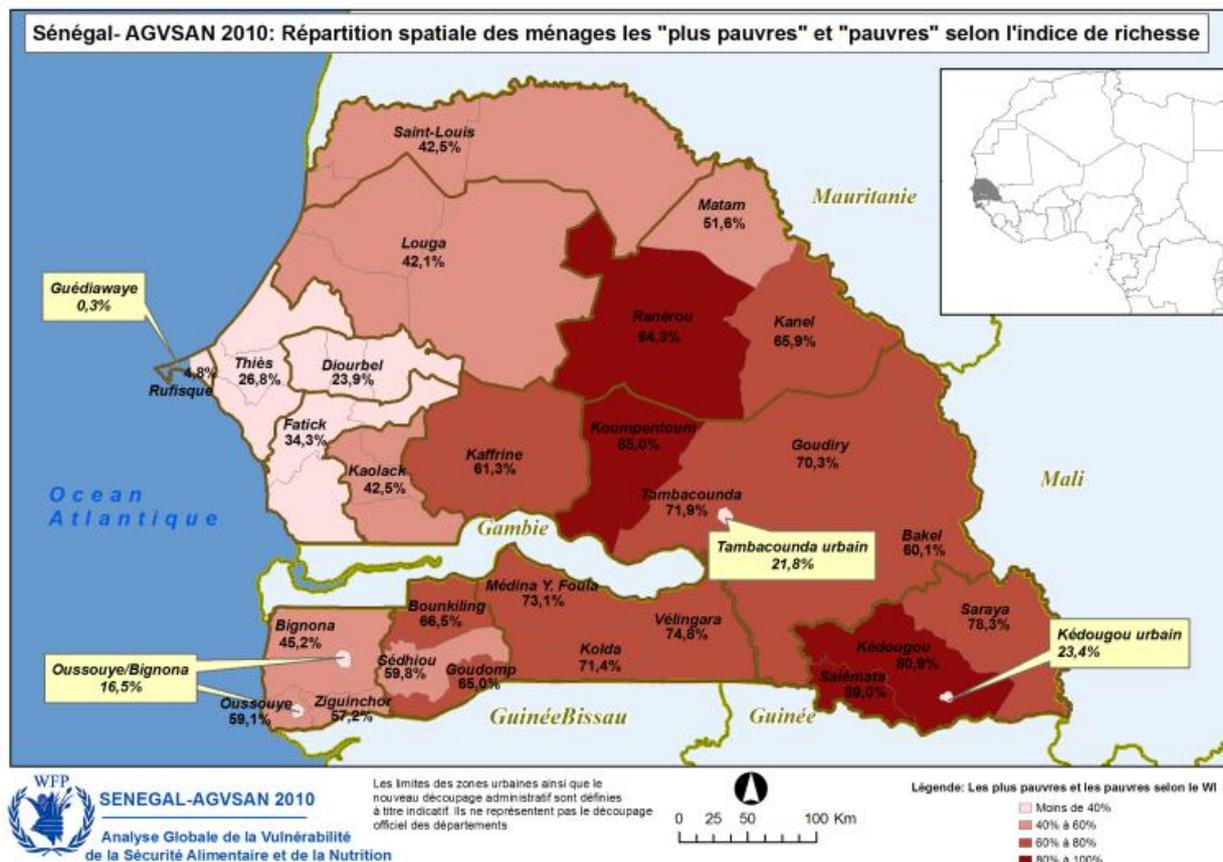


Figure 3. Poverty incidence based on the household wealth index. [Source: WFP (2011)]

Poverty trends are closely linked to the following factors:

- *Education level.* Poverty levels decrease more sharply among families where the head of household has secondary education or higher.
- *Household size.* Larger households tend to be poorer than smaller ones.
- Poverty is less widespread among female-headed households. This could be due to the larger size of targeted asset transfers to female-headed households.
- *Demographic growth.* Progress in agricultural production does not match higher demand for food.

³ The wealth index measures household wealth based on ownership of non-productive assets (such as radio, television sets, DVD players, refrigerators, and mobile phones, among others) and housing conditions, and is a proxy for household income.

Food security context

Despite some development progress in recent years, Senegal is a highly food insecure country: estimates suggest that over 15 per cent of rural households, and over 8 per cent of urban households are food insecure (WFP, 2011). High rainfall variability at inter-annual and inter-decadal scales, particularly in key production areas (Fall et al., 2006; McSweeney et al., 2010) affects agricultural production. The drought of the 1970s and 1980s highlighted the potential of climate-related processes to affect food security in Senegal, and the Sahel more generally (Spinage, 2012).

Geographically, food insecurity is more prevalent in the southern and central parts of the country, especially in the regions of Ziguinchor, Kolda and Kédougou (Figure 4). We distinguish the south from the center. The analysis presented here suggests a role for climate in the food insecurity in the center, which is the main region of agricultural production, not in the south. This is because the southern regions are climatologically wetter and less variable. Therefore, the food insecurity that characterizes the south may be the consequence of the long-term **conflict** that has plagued Casamance (Ziguinchor and Kolda regions), and more generally of its “landlockedness”: the difficult transportation and communication conditions linking the south and east with the rest of the country, especially with the port of Dakar. For these same general reasons, **lack of access to markets** may also be the major contributor to food insecurity in the eastern parts of the country (Kédougou and Matam). For the central part of the country, often referred to as the “groundnut basin”, because this is where cash-crop exploitation took roots during French colonization, the greater dependence of livelihoods on agriculture, and exposure to rainfall variability, as we will see, justifies a more in-depth exploration of the role of climate in shaping food insecurity. In recent years, **price volatility** has been a key driver of food insecurity across the country, particularly in urban areas. In addition, **climate-related shocks** such as droughts and floods affect the ability of households to meet their food requirements, and can lead to food insecurity.

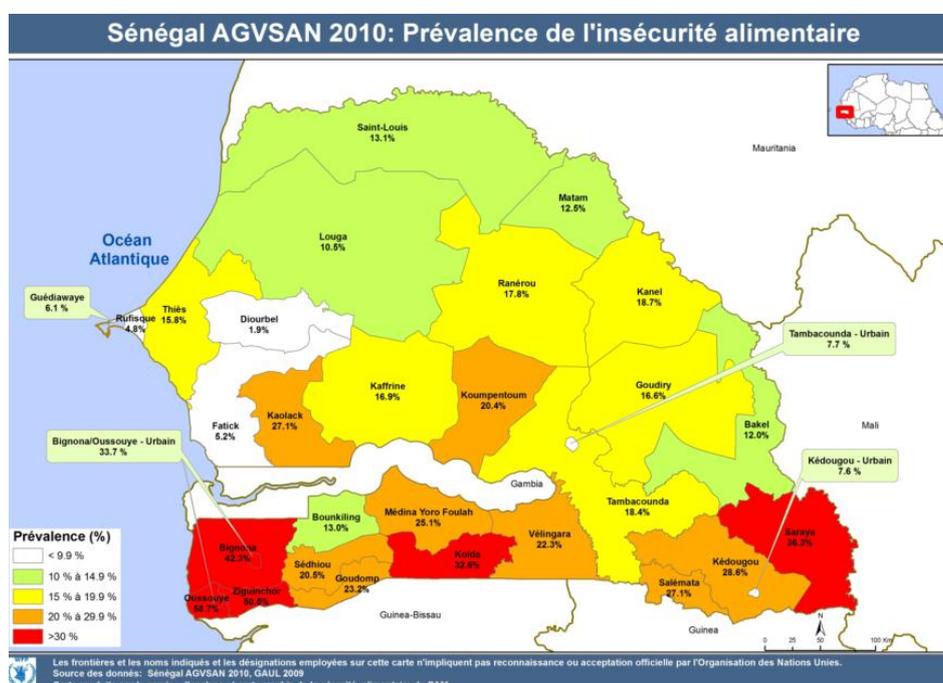


Figure 4. Prevalence of food insecurity in Senegal. [Source: WFP (2011)]

In the absence of adaptation measure, **longer-term climate variability and change** exacerbate risks to food security by accelerating environmental degradation, resource scarcity, food price and production changes, and disaster magnitudes – all of which have impacts on conflict, poverty, access to markets, price volatility and shocks.

Conflict

According to the CFSVA (WFP, 2011), prevalence of food insecurity is highest in the Casamance region, with food insecurity rates of above 40 per cent in Ziguinchor. We link these to conflict.

The Casamance region has been affected by a conflict for independence since 1982. The conflict has led to a rapid decline in agricultural production, destruction of infrastructure and livelihood assets, and an increase in chronic poverty. Furthermore, the conflict complicates development and food assistance efforts in the region.

Food security trend

Despite an increase in the number of undernourished people in Senegal, the prevalence of undernourishment has decreased, relative to the 1991 undernourishment rates (FAO/WFP, 2010; Figure 5). However, despite improvements in the food security situation, Senegal is considered a least developed country and is ranked 155 out of 187 countries according to the Human Development Index of the United Nations Development Programme (UNDP, 2011).

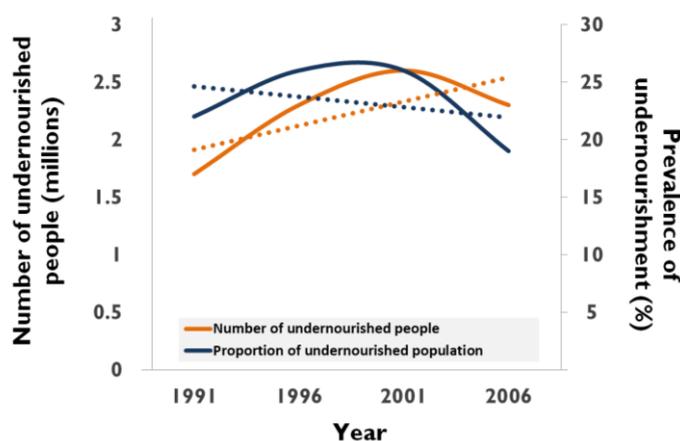


Figure 5. Undernourishment trends in Senegal, 1991-2007

The graphs show the trends in undernourishment, both in absolute (orange line) and relative (blue line) terms between 1991 and 2006. The graphs show a decline in the proportion of people who are undernourished.

Source: FAO (2011)

Climate-related disaster trends and impacts

Like most of Sahelian West Africa, the climate of Senegal is characterized by high spatial and temporal variability in precipitation. On average, most of the annual precipitation falls between June and September, in a typical monsoonal pattern of alternation of wet and distinctly dry seasons. Annual mean precipitation decreases from south to north, from ~1000 to 200 mm/year (Figure 6). This spatial distribution of rainfall partly explains patterns in livelihood activities: agro-forestry and cash crops are mostly grown in the south; agro-pastoralism is mostly practiced in central Senegal; and pastoralism is mostly practiced in the north (FEWS NET, 2012a).

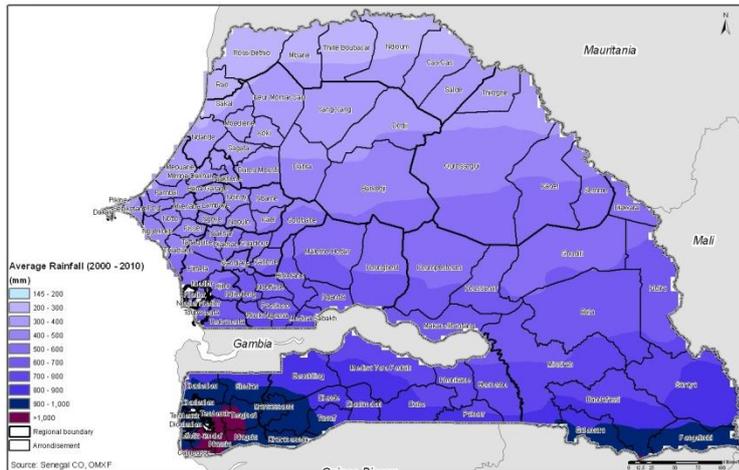


Figure 6. Distribution of rainfall, average from 1999 to 2012.

The map shows the average annual distribution of rainfall across Senegal between 1999 and 2012. Generally there is a south-to-north decline in rainfall.

Source: USGS (2012)

Rainfall is better distributed during the rainy season in the southern parts (especially in Kédougou) and more irregular in the north-western parts of the country (Thiès, Louga, Saint-Louis) – this rainfall pattern exacerbates flood risk along the north-western coast of Senegal.

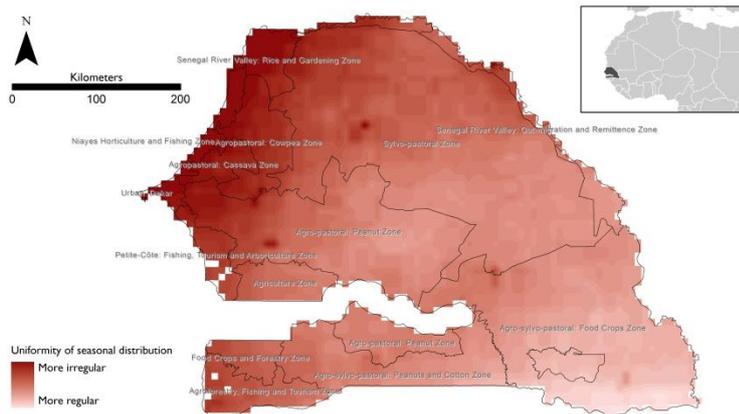


Figure 7. Uniformity of rainfall in Senegal, average from 1999-2011

The graphs show the uniformity of rainfall distribution during the rainfall season. Darker colours indicate more intensity in precipitation patterns (i.e. more rainfall concentrated in shorter periods).

Source: USGS (2012)

Gridded station precipitation data show high intra-seasonal (Figure 7) and inter-decadal (Figure 8) variation in precipitation: there has been a noticeable decline in precipitation between the late 1960s and the mid-1980s, but an increase since the mid-1990s (Ali and Lebel, 2009; McSweeney et al., 2010; Salack et al., 2011). This evolution is part and parcel of the late-20th century persistence of drought that affected the entire Sahelian belt, and more recent partial recovery.

The exceptional Sahelian drought that occurred between the late 1960s and the mid-1980s highlighted the potential impact of long-term climate variability on livelihoods and food security. More recent events attest to the continued sensitivity. For example, during the 2000 drought, peanut revenues declined from 68.4 to 17.4 billion FCFA representing a 74 per cent decline. In the same year, revenue from millet and sorghum fell from 30 to 12 billion FCFA, representing a 60 per cent decline in revenue (World Bank, 2011b).

It has been more difficult to assess the frequency of droughts in Senegal in recent years as humanitarian appeals show that since 2000 droughts occurred only in 2002 (284,000 people affected) and in 2011 (806,000 people affected according to the 2012 SAP analysis conducted by WFP and partners), while anecdotal information suggests that droughts events may also have

occurred in 2000 and 2006/2007⁴. Information on these events and on their effects for food security is sparse and does not allow carrying out systematic analysis of trends.

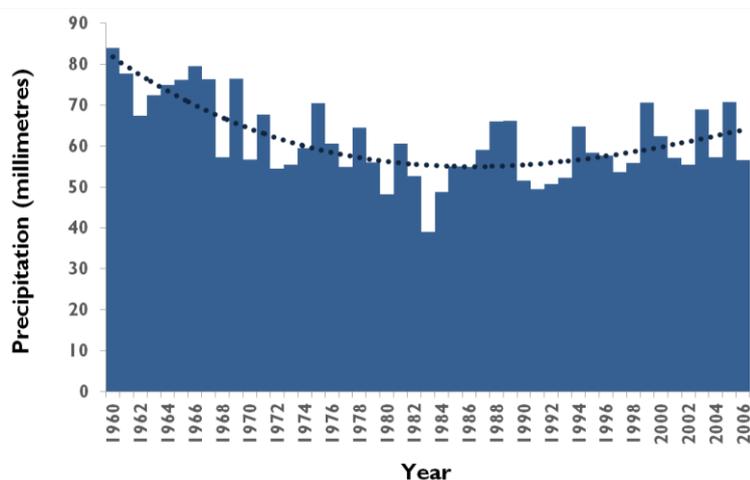


Figure 8. Annual precipitation trends, 1960-2006

The graph shows the variability in rainfall as well as the long-term trend in rainfall between 1960 and 2006. The graph indicates a decline in annual precipitation between 1960 and the mid-1980s, followed by an increase in rainfall after 1995.

Source: McSweeney et al. (2010)

Meanwhile, in recent years floods appear to have become more frequent, in association with the increased frequency of heavy rainfall events. Unrestricted expansion of the built environment likely also played a role. During the decades of persistent drought such expansion took place, for example, in low-lying areas of the Greater Dakar region where runoff has a tendency to collect after heavy rains (Mbow et al., 2008). Between 2000 and 2012, flood damage was recorded in at least 8 years. In three of these years, floods have affected over 150,000 people (179,000 in 2002, 250,000 in 2008 and 360,000 in 2009) and have destroyed infrastructure, public equipment and private property. In addition, water-borne diseases are said to have become more common due to the presence of stagnant water (World Bank, 2011b).

More recently, recurrent floods across the country have also affected livelihoods. Between 1980 and 2012, floods have affected between 400,000 and 600,000 people annually and have caused a cumulative damage of over US\$42 million. Floods affect the poorest populations, who tend to live in areas with low access to infrastructure. The 2008 floods, for example, affected over 250,000 people and destroyed infrastructure, public equipment and private property. In addition, water-borne diseases also became more common due to the presence of stagnant water (World Bank, 2011b). The recent 2012 floods along the Senegal River and in low-lying areas of Greater Dakar have affected almost 265,000 people, exacerbating the drought-induced food security crisis of 2011/2012 (WFP, 2012). Consecutive floods and droughts, often occurring in the same agricultural season, contribute to the degradation of livelihoods in the longer-run, in the absence of adaptation mechanisms.

Climate-related shocks such as droughts and floods affect the ability of households to meet their food requirements, and can lead to food insecurity. Disaster reports released by the Office for Coordination of Humanitarian Affairs (OCHA) [ReliefWeb](#) reveal that, over the last 25 years, floods occurring during the rainy season (normally between June and August) have become more frequent

⁴ Alternatively, see here < http://www.food-security.net/cp.php?id_fiche=135 > for historical information covering the period 1987/88 to 2006/07.

(Figure 9). The frequency of floods has increased significantly between 1990 and the present. Between 1990 and 2000, only one flood with humanitarian implications was registered, whereas between 2000 and 2010, 6 floods were reported. Since 2000, the majority of these have been linked to intra-seasonal variability during the monsoon, which could be potentially linked to long-term climate change (Roudier et al., 2011). Focus group discussions with at-risk populations in Kaffrine further show that rainfall variability, extreme rainfall events, and long dry spells are the key climatic factors affecting food security (Mertz et al., 2009).

The most recent historical record suggests no discernible trend in drought frequency (Figure 9). However, the 2011/2012 drought is considered to be one of the worst on record, with over 800,000 people at risk. **Here it is important to note that droughts have occurred in other years but are not registered** in the ReliefWeb or EM-DAT databases in the period of 1990 to 2012; the 2006/2007 droughts is notably excluded from these records because no humanitarian appeal was released.

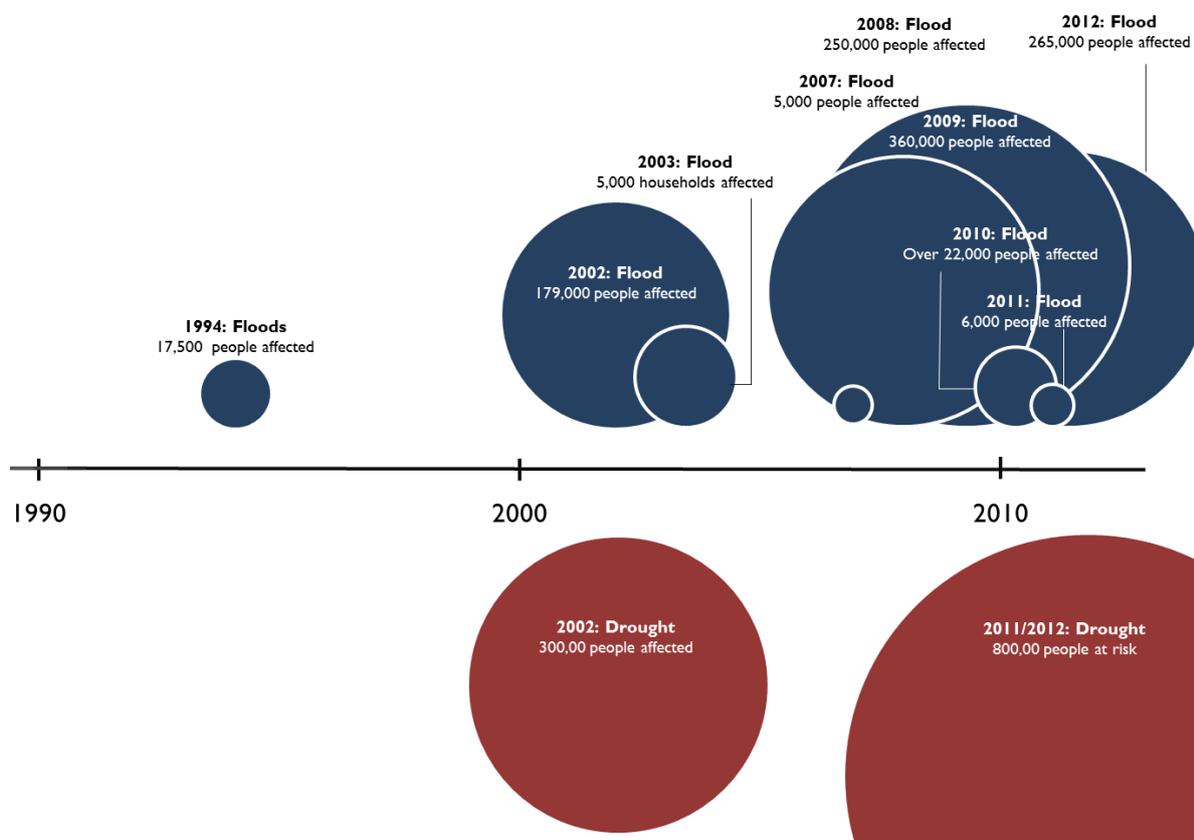


Figure 9. Flood and drought frequency between 1994 and 2012. The diagram shows the frequency of floods and droughts, as well as the number of affected people as reported in OCHA's ReliefWeb. The diagram also highlights those floods associated with anomalous rainy seasons. The data suggest an increasing frequency of floods: from 1 in 10 years (between 1990 and 2000) to 6 in 10 years (between 2000 and 2010). Only the on-going drought has been reported in ReliefWeb. Available data do not capture the intensity or duration of disasters, which are needed to identify trends in magnitude. [Source: ReliefWeb, 2012]

Vulnerability to climatic factors

The frequency of poor growing seasons (measured in terms of number of years out of the last 10 years), variation in the start of the rainy season (measured in terms of regularity of the start of

season), and dry spell length (measured in terms of consecutive days of no rainfall) are important climatic factors that could exacerbate food insecurity trends.

Areas with high frequency of poor growing seasons are concentrated in the northern parts of Senegal – this explains the dependence on livestock over crops (see livelihood zones map). Moderate frequency in poor growing seasons indicates potential influence of climate on crop production.

High variability in the start of the rainy season means that farmers with no access to irrigation are highly vulnerable to climatic variability because they are unable to plan the timing of planting and harvesting crops.

Dry spell length is another useful indicator of vulnerability to climate. Moderate dry spell length during the growing season (4 days) could have implications for crop production, and potentially for food prices. Long dry spells render agriculture unviable (such as in northern Senegal).

By intersecting these indicators it is possible to identify areas where climatic variability might have the greatest negative impact on food security (Figure 10). The results show that these aggravating climatic factors coincide in central Senegal, particularly near the groundnut basin and in the southern parts of the sylvo-pastoral zones.

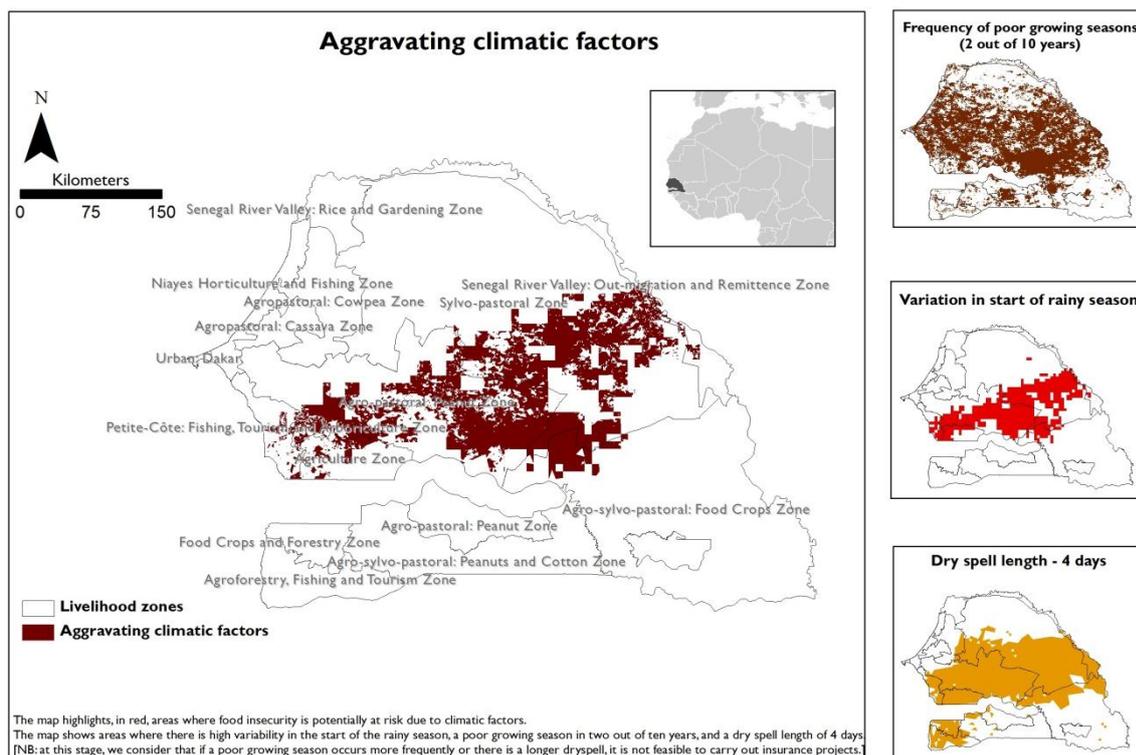


Figure 10. Areas where frequency of poor growing seasons, variation in start of rainy season, and dry spell length coincide, potentially affecting food security outcomes. [Source: SPOT-VGT, 2012; USGS, 2012]

Recent climate trends and climate change projections

Mean annual temperature has increased by almost half a degree Centigrade between 1960 and 2006 (Figure 11), with the most rapid increase in the post-monsoon months (October-December).

Temperature variations also follow a clear spatial pattern: coastal areas are cooler due to the mitigating effect of the Atlantic Ocean, whereas inland areas tend to be warmer (Fall et al., 2006).

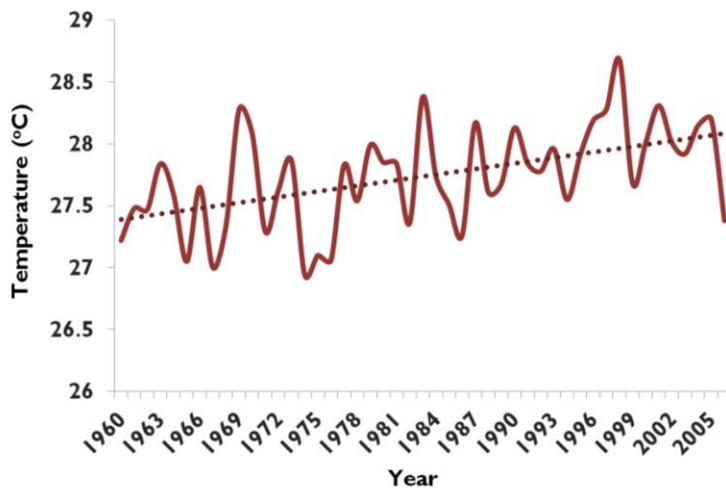


Figure 11. Average temperature trends in Senegal, 1960-2006

The graph shows inter-annual variability and the long-term trend for temperature across Senegal. The data show a clear increase in temperature during this period

Source: McSweeney et al. (2010)

However, as remarked in the prior sub-section, it is the high rainfall variability at seasonal, inter-annual and multi-decadal scales that characterizes climate change in Senegal. Variability at inter-annual and multi-decadal time scales, in Senegal as across the Sahel, is known to be largely the effect of the oceans' influence – warming of the tropical oceans, and reduced warming of the North Atlantic compared to the South Atlantic, explain persistent late-20th century drought. Conversely, the more recent recovery of precipitation can be ascribed to a reversal to warming in the North Atlantic, partly explained by a reduction in sulphate aerosol loading consequent to pollution control measures taken in North America and Europe (Chang et al 2011; Booth et al 2012). The upward trend in temperature is consistent with the simultaneous drying up to the 1980s. Thereafter, temperature and precipitation trends seem to have decoupled, with temperatures continuing to rise despite the partial recovery of precipitation (FEWS 2012c).

This complexity in the recent evolution of climate is reflected by the difference in household perceptions of rainfall variability: according to research by Mertz et al. (2009), households in communities of Eastern Saloum (Kaffrine) generally report a declining trend in rainfall in the past 20 years, although a few households reported that “rains have returned” since 2000, and others have reported that rainfall vary too much to determine any meaningful trends.

Across West Africa, temperatures are projected to increase by 3-4°C by 2100. In Senegal, annual temperature is expected to increase by up to 3°C by the 2060s and 5°C by the 2090s. The projected rate of **warming is faster in the interior regions of Senegal**, compared to the coastal areas. This could result in higher drought magnitudes.

The apparent disagreement among climate models in the direction of future precipitation change can in part be reconciled through the same lens of oceanic influence that has guided interpretation of recent past. Preliminary results show that the majority of models that project increased precipitation do so in light of the sub-tropical North Atlantic warming up more than the global tropical oceans. In analogy to the El Niño-Southern Oscillation's influence on global tropical climate, warmer oceans raise the threshold for precipitation to occur, which initially translates into drought. However, when that higher threshold is met locally, e.g. in the case of Senegal, with moisture convergence from the

North Atlantic, it can lead to heavy rains. Another manifestation of the higher threshold for precipitation in a warming world is a delayed onset of the rainy season, and increased precipitation later in the season, i.e. a different intra-seasonal distribution of rains (Biasutti and Sobel 2011; Seth et al 2012). In sum, changes are consistent in the direction of erratic rainfall, with higher rainfall in heavy rainfall events potentially leading to higher flood risk, but fewer rainfall events overall leading to higher frequency of dry spells.

Another potential risk is **sea-level rise**. Already at present, sea-level rise has resulted in coastal retreat of about 1 to 2 metres annually in Senegal (UN-HABITAT and UNEP, 2010). Further evidence highlights that salinization has increased — especially in the groundnut basin — as a result of drought *and* sea-level rise, and continued sea-level rise could result in further deterioration of soil quality and erosion along the sandy coastlines (Niang, 1990; Brown et al., 2011)

Projections suggest that sea levels could rise by up to 1 metre by 2100 with potentially devastating effects on some of the largest cities along the coast. A 1-m rise in sea level could inundate and destroy over 6,000 km² of land, accounting for 8 per cent of the country's territory, and up to US\$700 million worth of infrastructure would be at risk. Initial studies suggest that up 180,000 people (over 1 per cent of the population) could be displaced by a sea-level rise of 1 metre (Dennis et al., 1995). In addition, environmental degradation and soil erosion would exacerbate the risks posed by sea-level rise.

Sea-level changes and increased intensity of storm surges are known to lead to coastal erosion, which together pose a major threat to the population and economy of Senegal. Economic activities such as fishing, tourism, and agriculture are adversely affected by sea-level rise. The observed decline rate of the shoreline varies between one to two metres per year for sandy beaches, with the coastal zones between Joal and Djiffere and between Saint-Louis and the Mbao-Bargny most affected. Urban centres are also highly exposed: for instance, most of Dakar is vulnerable to sea-level rise. Coastal erosion is particularly felt in the area of Rufisque-Bargny with the narrowing of the beach of Rufisque, particularly along the center of the city, resulting in overhanging buildings and stripped roads in Merina and Thiawlene. Potential losses arising from sea-level rise are quite high: over \$2 billion are considered exposed (15 per cent of the national gross domestic product) (World Bank, 2011b).

Regional climate trends

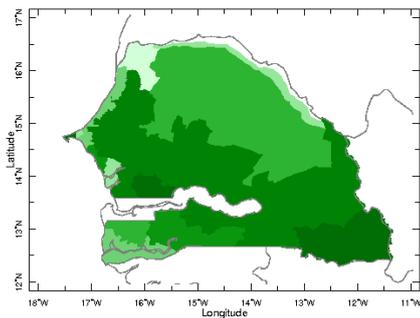
It is difficult to understand the whole range of climate impacts on food security by excluding regional climate trends. Historical regional trends, for example in changes in the character of precipitation, i.e. frequency and intensity of daily precipitation, in conjunction with the advances in the dynamical interpretation of climate change projections briefly discussed remain a critical component of understanding the relationships between food security and climate. Historically, regional climate change was linked to persistent drought in the 1970s and the 1980s. More recently, observations suggest a reversal of these conditions with higher precipitation; however, this increase has resulted from increasing rainfall intensity rather than frequency. Acknowledging these relationships, this analysis highlights potential linkages between climate and food security at the regional level where possible.

Part II: Climate trends and food security

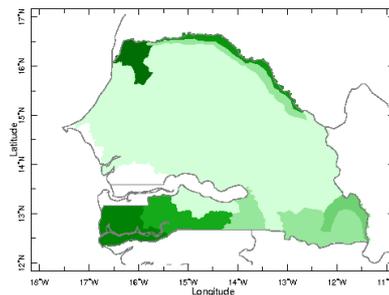
National crop production trends

Groundnut, rice, millet, sorghum, and maize are the main crops grown in Senegal, and analysed in this study. Figure 12 shows the proportion of households growing these crops (groundnut in panel A, rice in panel B, millet in panel C, sorghum in panel D, and maize in panel E) across livelihood zones. Generally, these crops are grown across the entire country, with a large proportion of households in the central parts of the country engaging in their production. The main exceptions are rice (which is grown in southern Senegal and along the Senegal River) and maize (which is mostly grown by a majority of households in southeastern Senegal).

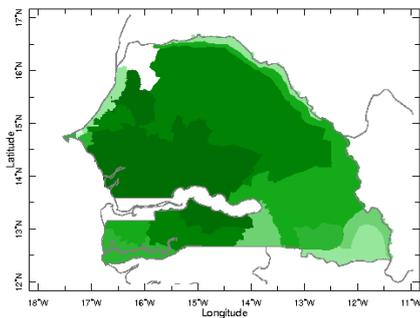
(A) Proportion of households growing groundnut



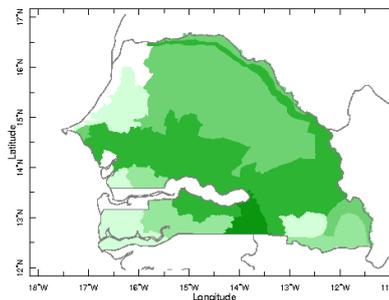
(B) Proportion of households growing rice



(C) Proportion of households growing millet



(D) Proportion of households growing sorghum



(E) Proportion of households growing maize

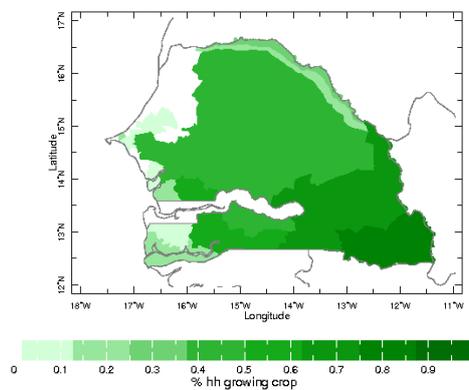


Figure 12. Percentage of households growing groundnut (A), rice (B), millet (C), sorghum (D), and maize (E). [Source: WFP (2011)]

Crop production and yields for the five most common crops in Senegal (groundnut, millet, paddy rice, sorghum, and maize) have almost doubled between 1961 and 2010, but with large differences between years (Figure 13; FAOSTAT, 2012).

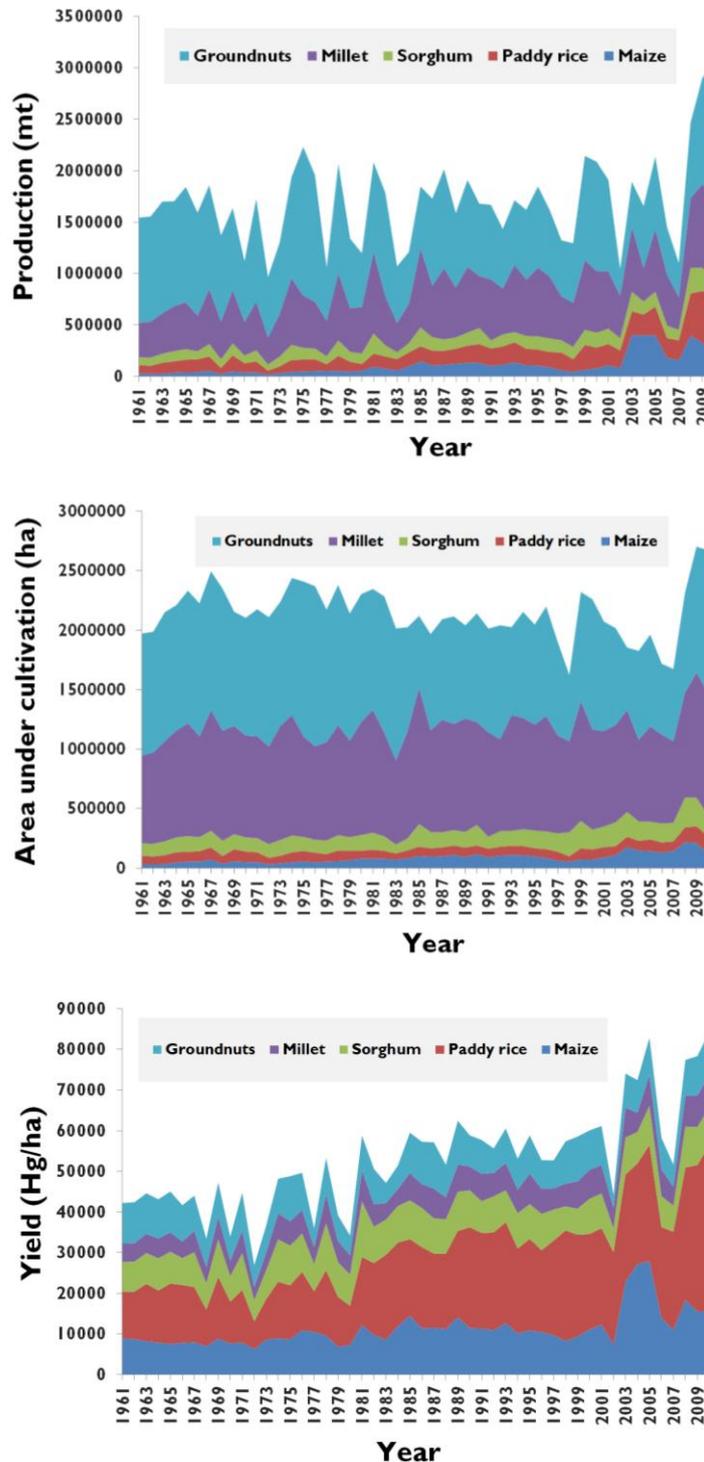
Area under production has been rather stable in this period with some significant declines in the late 1990s and mid-2000s. Therefore, increases in production appear to be related to increases in yields, rather than due to area expansion – this is particularly true for paddy rice and maize.

The total production of the five crops has increased in a non-linear form. Marked increases occurred after the droughts of the early 1970s, and again early 1980s, and more recently after the droughts of 2002 and 2007, suggesting that while crop production is highly sensitive to climate in Senegal, government policies may have adjusted in reaction to drought.

Production of groundnut, for instance, decreased significantly in drought years (most notably in 1972, 1977, 1984, 2002, and 2007).

Rice production, on the other hand, has increased exponentially since the late 1990s due to an increase in both area harvested (especially along the Senegal River Valley) and increases in productivity.

Figure 13. Trends in production (top), area harvested (middle) and yield (bottom) of groundnut, millet, paddy rice, sorghum and maize, between 1961 and 2010.



Climate-agricultural production relationship

Climate variability, particularly variability in precipitation, has a strong relationship with crop yields⁵. About 50% per cent of variations in the total production of groundnut, millet, sorghum, rice, and maize is explained by interannual rainfall variability⁶ ($R^2 = 0.504$, $p < 0.05$ for total production, see also Table 1 and Figure 14).

That 50 per cent of variations in yield are unexplained by the model highlights the importance of other climatic and non-climatic variables that are not included, such as differences in farm inputs, irrigation techniques, and economic changes influencing agricultural management techniques.

However, that 50 per cent of variability in yields is explained by a simple measure of variation in precipitation shows that rainfall provides substantial information about crop production changes. The results of this analysis compared favourably with previous global assessments (e.g. Lobell and Field, 2007), suggesting that climatic factors and agricultural production have a particularly high correlation in Senegal. These results suggest that, in the absence of adaptation measures, climate change could affect food production in the country.

Table 1. Precipitation and yield correlations, 1960-2010.

Crop	Pearson's coefficient (p-value)
All	0.710 (<0.05)
Rice	0.770 (<0.05)
Millet	0.625 (<0.05)
Groundnut	0.612 (<0.05)
Sorghum	0.610 (<0.05)
Maize	0.420 (<0.05)

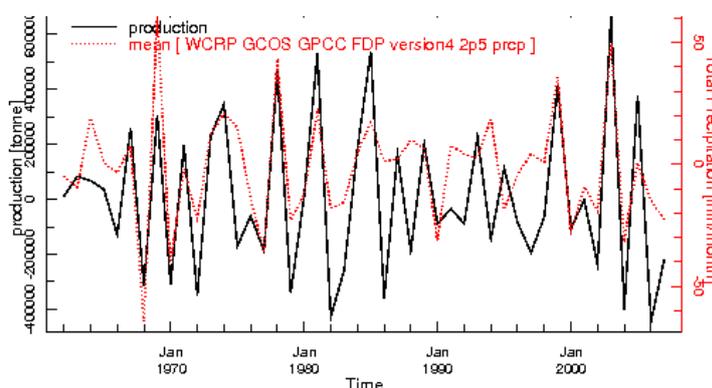


Figure 14. Relationship between precipitation and production

The graph shows the year-to-year variations in both rainfall (red) and crop production (black) between 1960 and 2010. The graph shows that dry years are usually associated with lower production.

Source: WCRP GCOS (2010), FAOSTAT (2012)

The relationship between crop production and other rainfall statistics further illustrates the importance of climatic variables on food security.

Table 2 illustrates the correlations between different rainfall statistics (“first onset” date is defined as the first day after May recording a rainy event greater than or equal to 20mm over three consecutive days, “true onset” date is an onset not followed by dry spell of 15 consecutive days⁷, and the number of dry spells of 7, 10 and 15 days are consecutive days without rain in the rainy season) and production of rice, maize, millet, sorghum, and peanuts.

⁵ Using a first-different time series for climate and crop production (i.e. the difference in values from one year to the next), the relationship between both indicators can be evaluated, while accounting for trends that are attributable to technological advances (cf. Lobell and Field, 2007).

⁶ Other climatic indicators, such as temperature, humidity, and radiation were initially considered, but precipitation was chosen for simplicity purposes, given that precipitation had the highest correlation with all factors.

⁷ We differentiate these two because several farmers plant their seeds at the first important rainy event which is likely to be followed by dry spells that could affect crop production.

Table 2. Correlations between rainfall statistics and crop yields at national level (1961-2010). Crops yields are from FAOStat, and rainfall statistics are from the National Agency for Civil Aviation and Meteorology of Senegal

Rainfall statistic	Crop				
	Rice	Maize	Millet	Sorghum	Groundnut
First onset	-0.21	-0.13	-0.06	-0.12	-0.22
True onset	-0.19	-0.16	-0.13	-0.20	-0.29
Dry spell (7 days)	-0.19	-0.07	-0.38	-0.29	-0.30
Dry spell (10 days)	-0.24	-0.15	-0.50	-0.38	-0.39
Dry spell (15 days)	-0.09	-0.18	-0.37	-0.29	-0.24

With the exception of groundnut and true onset data, crop production is only weakly correlated with date of onset. The negative correlation suggests that an early onset is linked to a longer rainy season and higher crop production. The low correlation between millet and onset date can be explained by the fact that farmers typically plant millet at a certain calendar date, whether the actual start of the rainy season has occurred or not, to cope with high rainfall variability, especially variability in the length of the rainy season. Dry spell frequency is more strongly, and negatively correlated with yield, especially the yield of millet, sorghum and groundnut, highlighting the significant effect of dry spells on crop production in a semi-arid climate.

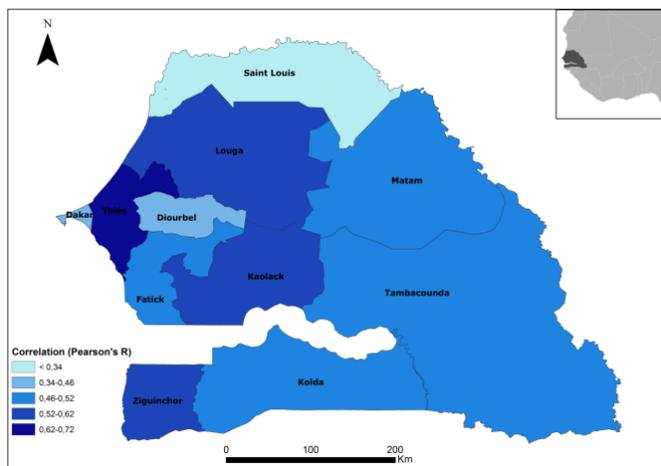


Figure 15. Correlations between cereal production and seasonal rainfall at region level, 2000-2012

The map shows the correlations between cereal production and seasonal rainfall in the period 2000-2012, at regional level. The map highlights that correlations are strongest in Thiès, Kaolack, Louga and Ziguinchor.

Source: TAMSAT (2012), FAOSTAT (2012)

At sub-national level, rainfall has a strong correlation with cereal production (Figure 15). The lowest correlation is in Saint-Louis ($R=0.34$), where crop production (mainly rice) occurs through flood-recession agriculture. The strongest correlations are in Thiès ($R=0.73$), Kaolack ($R=0.63$), Louga ($R=0.57$), and Ziguinchor ($R=0.56$), suggesting that these are the most vulnerable areas to climate variability. Of particular concern is Kaolack, the key producing region of Senegal, where aggravating climatic factors also concentrate.

A calculation of the change in number of years during which any given location received sufficient rains to grow groundnut between the wet 1941-1970 and dry 1971-2000 periods illustrates the idea (Figure 16). Places at the northern edge of the historical groundnut basin, where almost every household grows said crop, used to receive more than 500 mm of rain in 2 out of 3 years during

the wet decades in mid-20th century. These places have only been receiving the same amounts \bar{I} in 3 years during the more recent persistent drought.

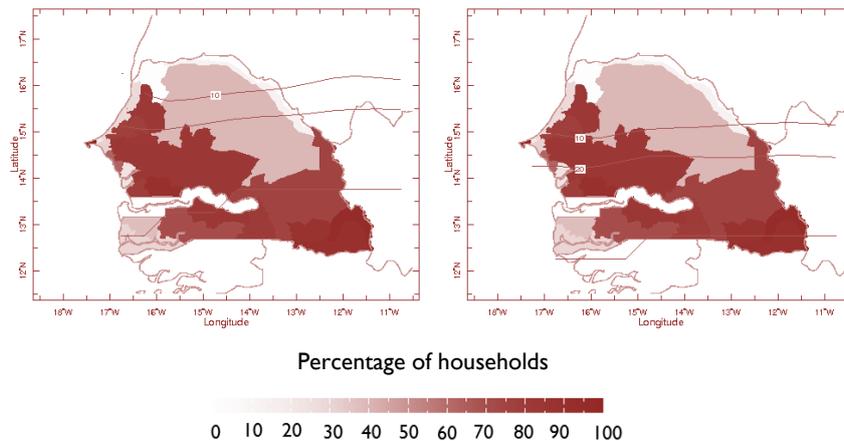


Figure 16. Number of years during the wet (1941-1970) and dry (1971-2000) periods that any location received at least 500 mm of rain (during the May-October season), the minimum water requirement to grow groundnut. In colour is the per cent of households, by livelihood zone, that grow groundnut.

The correlations between seasonal rainfall estimates derived from GPCC data, and yields disaggregated by crop are also strong, especially in the northern parts of the country (Figure 17, from left: groundnut, millet, rice). Overall, correlations in the southern regions are lower. This is because rainfall in the southern regions is usually sufficient for agricultural production. Correlations are stronger in the climatologically drier northern regions where rainfall is sufficient for crop production only in some years, as seen in Figure 17. The correlations for rice do not follow a clear spatial pattern: there are no (or weak) correlations in most of the country, except in Fatick ($R=0.56$), Ziguinchor ($R=0.40$), and Kaolack ($R=0.27$) where rice production is rain-fed.

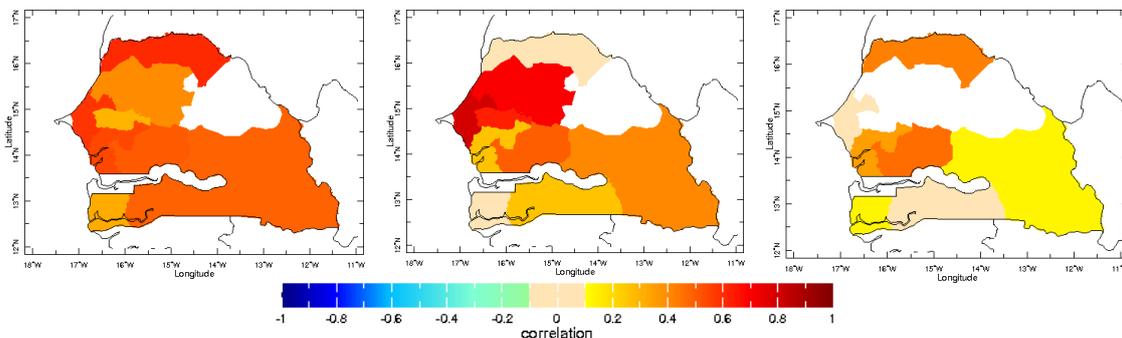


Figure 17. Correlations between seasonal (May-October) rainfall estimates and production of groundnut (left), millet (middle), and rice (right). [Source: GPCC, FAOSTAT/CountryStat (2012)]

An analysis of annual Normalised Difference Vegetation Index (NDVI) values between 1999 and 2011 shows high inter-annual variability, with particularly low vegetation levels across the country in 2002 and 2007 as confirmed by maps of production trends (Figure 18). In food security terms, NDVI anomalies often translate into longer hunger period of up to 6 weeks.

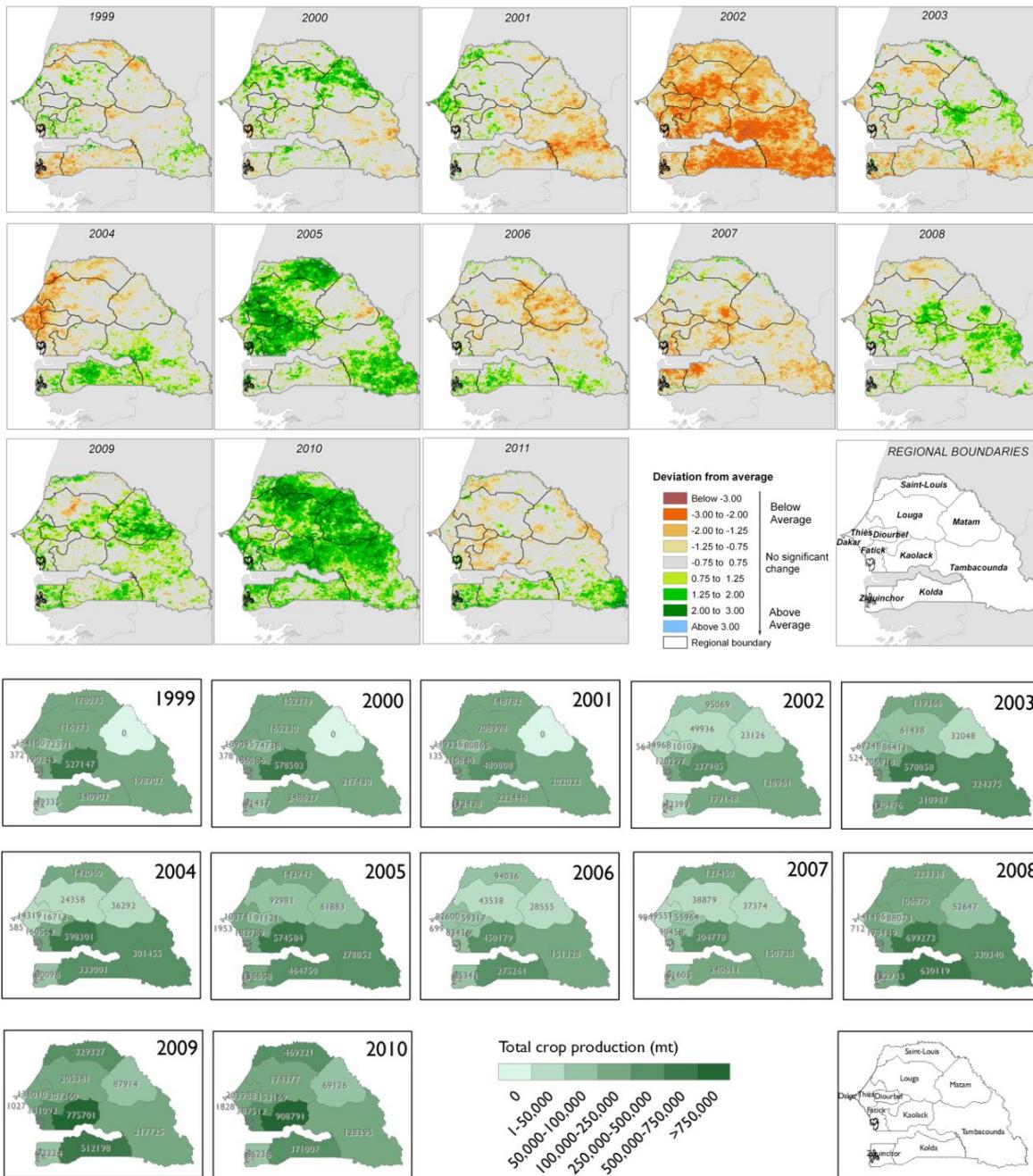


Figure 18. Annual mean vegetation conditions, using NDVI and total production of groundnut, millet, sorghum, rice, and cotton. [Source: SPOT-VGT (2012), FAOSTAT (2012)]

Recent trends in Senegal show that maximum seasonal NDVI has increased between 1982 and 2012, especially in the northern regions (Figure 19). This is partly linked to an increase in seasonal rainfall in the same period. The greatest increase in seasonal rainfall (approximately 10 mm/year) has occurred in the southern parts of Senegal, particularly around Kédougou. The maps highlight two inter-related factors. First, the strongest NDVI increases do not correspond to the strongest increases in seasonal rainfall. This is because in areas where seasonal rainfall is above 500-600mm per year, NDVI does not vary significantly at inter-annual scales. Second, in areas where rainfall is marginal (particularly in the central and northern parts of the country), the relationship between rainfall and NDVI is fairly tight and therefore any increases in rainfall are reflected in NDVI trends.

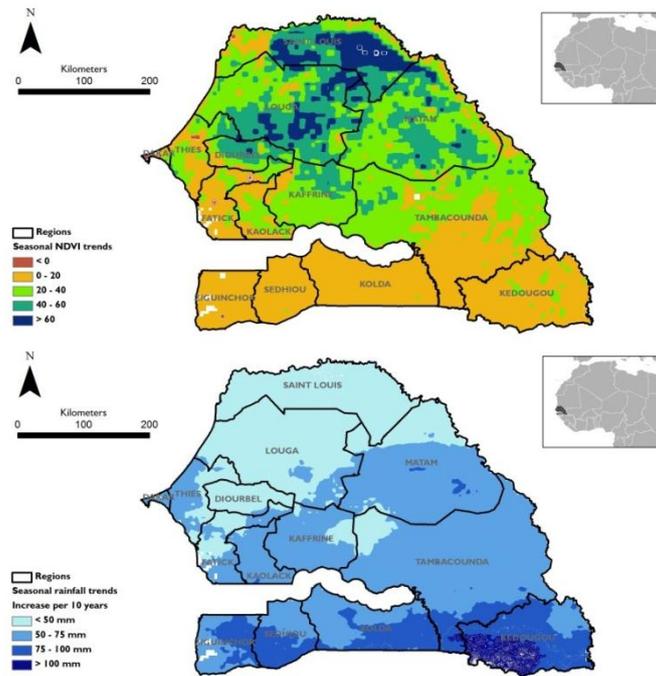


Figure 99. Trends in NDVI and rainfall estimates. [Source: Tucker et al. (2005); combination of GIMMS and SPOT-VGT data]

Climate and food prices

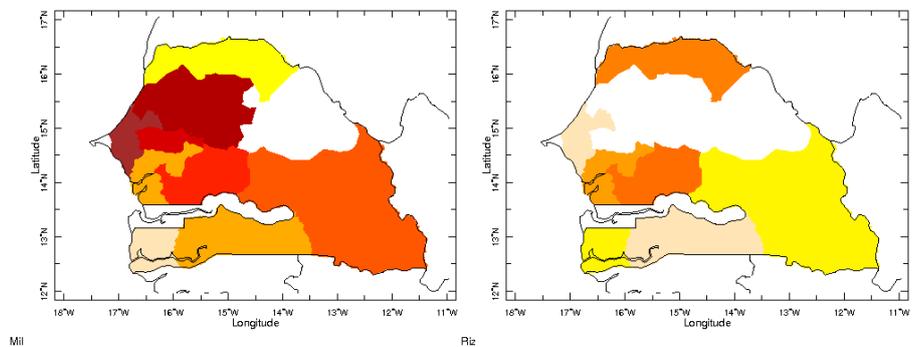
Even when climate and agricultural production are strongly correlated, correlations between climate and food price are not as straightforward, since markets can be non-local. Especially in the case of imported food commodities, most notably rice in the case of Senegal, food prices are likely to be affected by climate in other countries, and by global price trends.

To illustrate the relative influences of climate on local production and global market in setting local price, we compare and contrast the cases of millet, which is produced locally, and rice, which is predominantly imported. As seen above, at national scale millet production is strongly positively correlated with precipitation ($r=0.87$ using precipitation estimates from the coarse resolution CPC Merged Analysis of Precipitation (CMAP) lower but still significant values with other datasets), and so is rice production ($r=0.74$). Here we have taken annual production, May-October precipitation in the same production year, and price averaged from October following the harvest to the following September (from January to June of the year following the harvest), using production and price data from FAO/CountryStat for the years between 1998 and 2008⁸. Millet production is also negatively correlated with producer price ($r=-0.775$). Consistently, millet prices are negatively correlated with precipitation ($r=-0.68$). This suggests that insufficient rains translate into a bad harvest, even in the case of rice, as it is grown in the northern Senegal River valley. In the case of millet, a bad harvest translates into decreased supply/increased demand, and high farmer prices, as expected from a closed system. Conversely, an abundant harvest would translate into low prices.

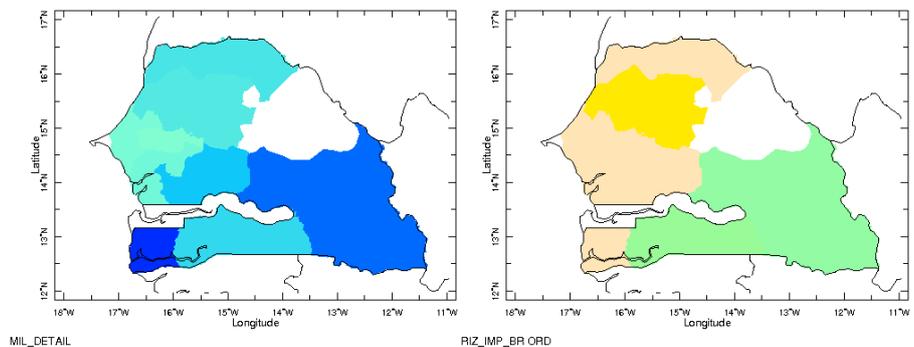
The maps in Figure 20 compare the correlations of precipitation and production, precipitation and price, and production and price at subnational scale for millet (left) and rice (right). Correlations are higher in the case of millet than in that of rice. In the case of millet, it is noteworthy to highlight the

⁸ A comparable national-level dataset for the price of rice was not available at the time when the analysis was conducted.

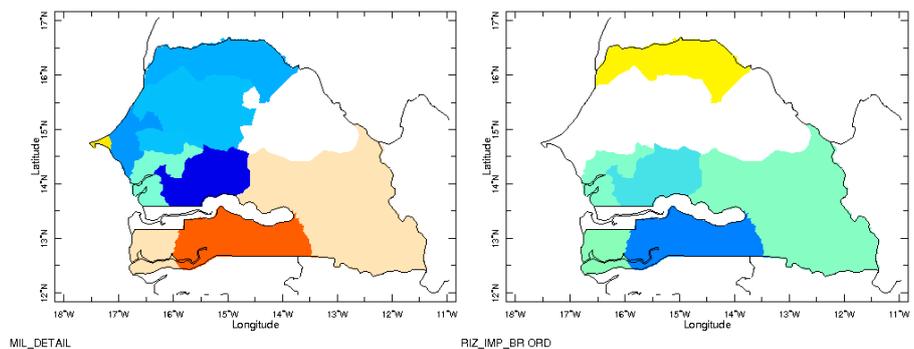
reversal in spatial pattern in the strength of correlations: positive correlations between precipitation and production are strongest in the northern/western regions, negative correlations between precipitation and price are strongest in the southern/eastern regions. While the northern regions are drier and production is most sensitive to climate variability here, the correlations with price seem to indicate a stronger sensitivity of the southern/eastern regions of Senegal to market forces, specifically to difficulties in market access.



Correlations of production of millet and rice with precipitation at regional scale



Correlations of price of millet and (imported) rice with precipitation at regional scale



Correlations of production and price of millet (left) and rice (right: price is that of imported rice)

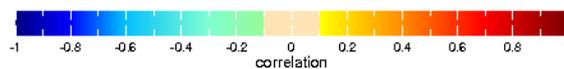


Figure 20. Correlations of production and precipitation (top), price and precipitation (middle), and production and price (bottom) of millet and rice. [Source: WFP (2011) and CPC/CMAP (2012)]

Part III: Climate impacts on livelihoods

This section analyses the sensitivity of households in Senegal to climate risk using data from the Comprehensive Food Security and Vulnerability Analysis (WFP, 2011). This is done by considering how different livelihood components, including food sources, income sources, and access to markets relate to food security and coping strategies, and how these might be affected by climate trends. The analysis is done at the livelihood zone level. Livelihood zones, areas with fairly homogeneous livelihood patterns, were identified based on consultation with the Government of Senegal, the Food and Agriculture Organisation of the United Nations (FAO), the United Nations Children’s Fund (UNICEF), the United States Agency for International Development (USAID), FEWS NET, and the United Nations World Food Programme (WFP).

Livelihood zones

Livelihood activities are closely linked to rainfall climatology. Generally, in the wetter south, households practice activities related to agriculture and forestry. In contrast in the Sahelian parts of Senegal, households engage in agro-pastoralism and pastoralism. The three exceptions are (1) coastal areas, where households mostly practice fishing, (2) the Senegal River Valley where households engage in rice agriculture, and (3) the eastern Senegal River Valley where households depend on remittances and migration for their livelihoods (Figure 21; FEWS NET, 2012a; FEWS NET, 2012b). Across all livelihood zones, climate-related risks such as droughts and floods, and rainfall variability have been highlighted as significant risks to ensuring food and livelihood security (FEWS NET, 2012b).

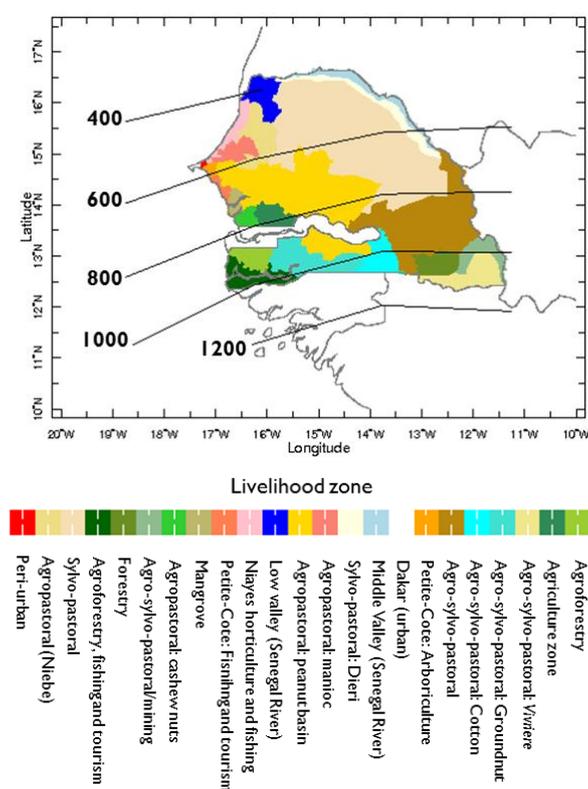


Figure 21. Livelihood zones in Senegal overlaid with rainfall climatology (contours from north to south represent 400, 600, 800, 1000, and 1200mm May-October averages, 1979 and 2012). [Source: FEWS NET, 2012a and GPCP (2012)]

Food security situation

There is no single measure for food security. Indicators for diet quantity (caloric intake) and diet quality (diversity) provide useful information about food security trends and problems across the country. For example, while some regions might have access to sufficient energy for a healthy lifestyle (rich diet quantity), all the calories might come from one single food source (poor diet diversity). Similarly, the food security situation in some regions varies throughout the year, with food security being particularly low in the agricultural lean seasons. It is therefore important to consider multiple indicators food security and seasonality to obtain a more accurate picture of hunger trends.

In addition, food security is closely linked to poverty and undernutrition issues. Figure 22 below shows an overlap of (1) areas with high prevalence of food insecurity, together with (2) areas with high rates of global chronic malnutrition (GCM) as well as (3) areas with high poverty incidence, providing a more comprehensive picture of food security trends in the country. The map shows that food security problems are concentrated in the southern and central parts of the country, particularly in the Ziguinchor and Kolda regions of Casamance, and in Kédougou and Kaffrine regions.

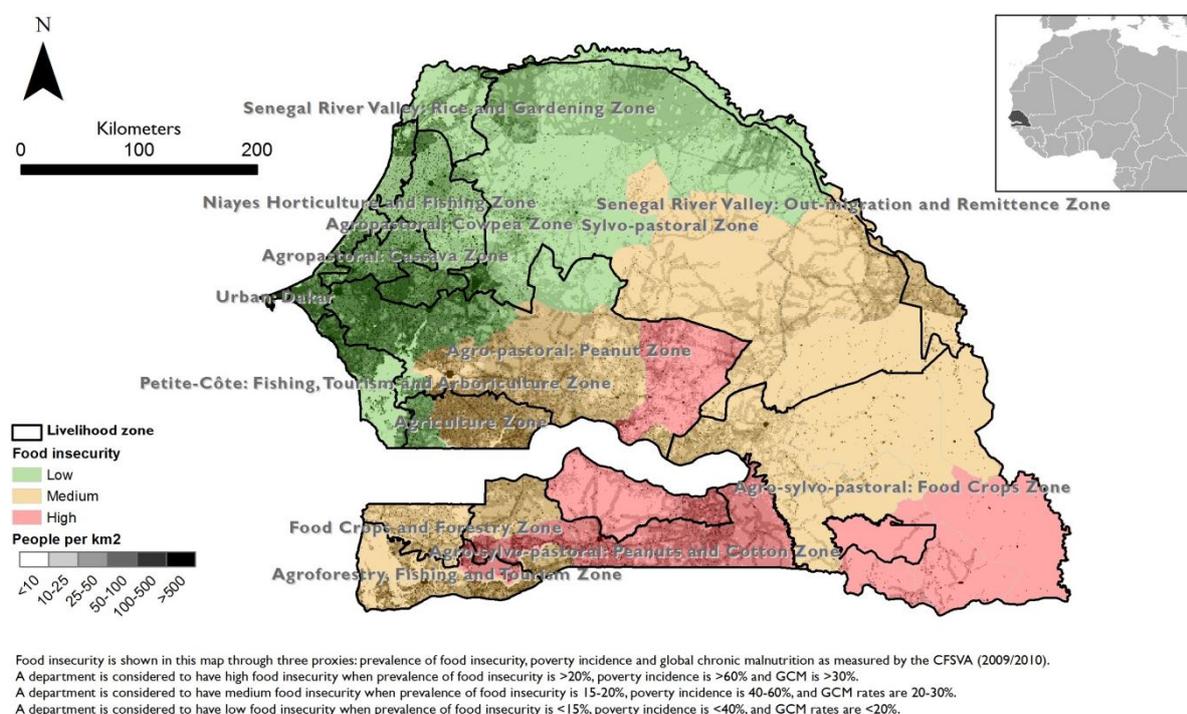


Figure 22. Food security situation in Senegal [Source: WFP, 2011]

Food consumption and sources

Diet quantity and diversity

The average household in Senegal consumes three meals a day. During the lean season, however, 21 per cent of households interviewed mentioned that they reduce the number of meals consumed in a day. Among these, 14 per cent of households continue to reduce the number of meals consumed after the lean season highlighting that a significant amount of households are affected for a long period.

Cereals and tubers accounted for 99 per cent of all food types consumed in the seven days prior to the CFSVA. Rice is the main staple consumed in the country (80 per cent of households consume rice), followed by millet (62 per cent of households consume millet). Over 60 per cent of households also consume animal products, including both meat and milk.

The household food diversity score (HFDS)⁹ indicates that diet diversity is higher in urban areas compared to rural areas highlighting that urban households have better access to diverse food types compared to rural households. The highest diet diversity is in Dakar and Saint-Louis, whereas the weakest diet diversity scores are recorded in Kolda, Kédougou, Ziguinchor, and Kaffrine (Figure 23).

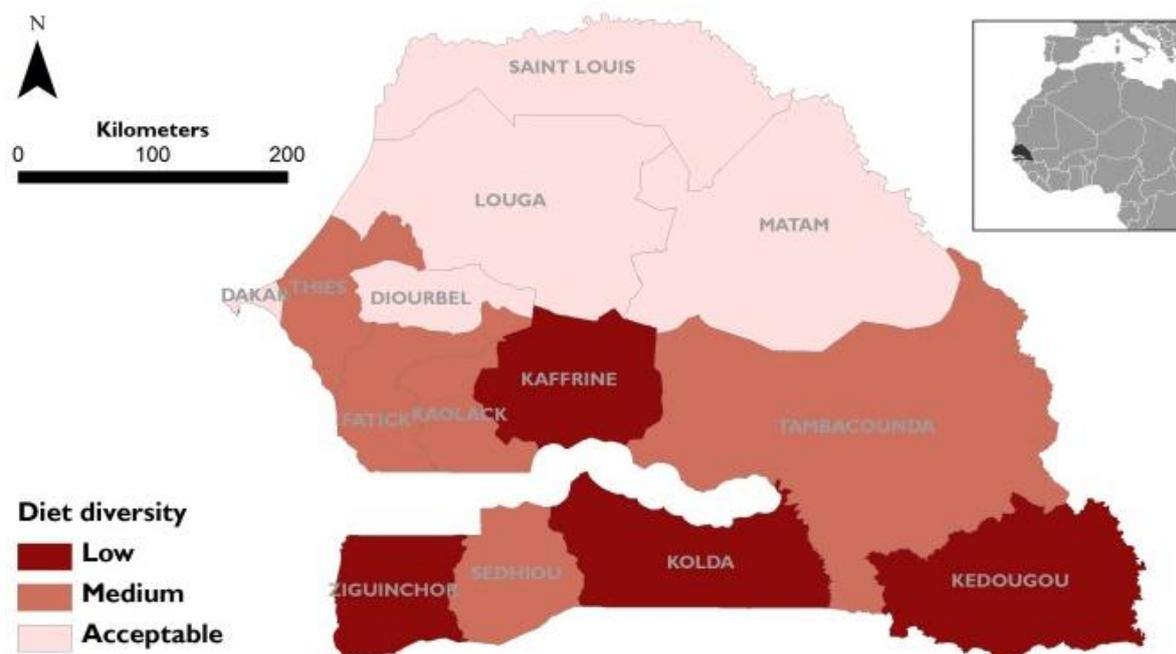


Figure 23. Diet diversity across the regions of Senegal as measured by the household food diversity score (HDFS). [Source: WFP, 2011]

Food sources

Households purchase most of their food: 87 per cent of rural households and 97 per cent of urban households buy their food. Consumption from own production is the second most common food source and accounts for approximately 10 per cent of all food in rural households. The remaining food is obtained from credit/borrowing, and in-kind gifts.

Food sources also depend on the crop that is being consumed (Figure 24). Households buy most of their rice (over 90 per cent of rice is purchased) while households produce most of the millet they consume (almost 60 per cent of millet is produced for own consumption). This highlights that millet production across the country is primarily for own consumption – particularly across the central part of the country. As shown in Part I, it is this region of Senegal that is most vulnerable to climate

⁹ The HFDS measures the number of food groups consumed by a household. Unlike the food consumption score (FCS), the HFDS does not weight food groups based on their nutritional value. In addition, the HFDS considers only food consumed during the past 24 hours (instead of the past 7 days). This indicator has a high coefficient of variation high variability in meals consumed during one day, and should therefore be considered only at strata level – not household level.

It is important to note that there is no universal measurement of diet diversity that can differentiate between a “good” diet and a “bad” one. For the purposes of this analysis, households are divided according to terciles: weak, medium and acceptable diet diversity.

risks and therefore rainfall variability will likely have an impact on millet production and generally on food security in these regions.

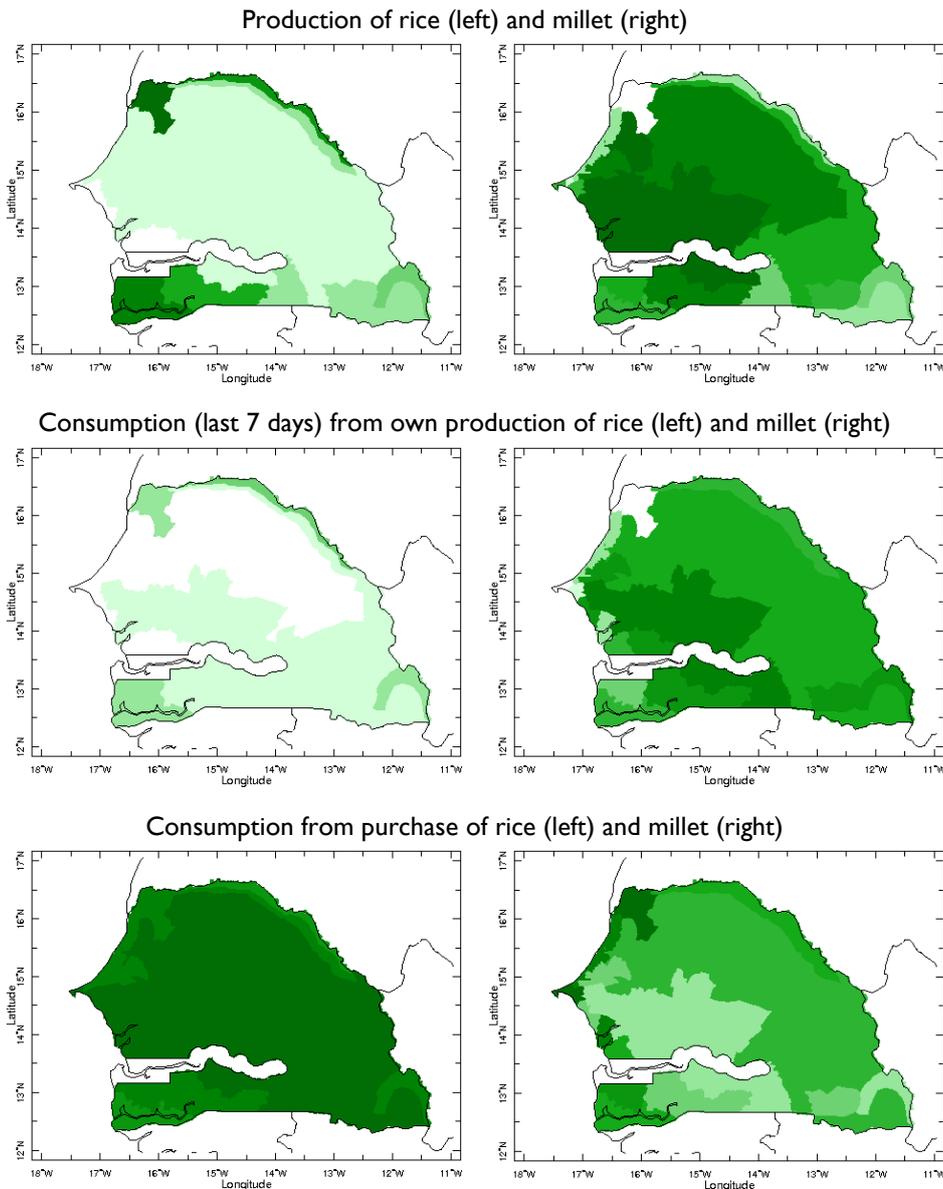


Figure 24. Production (top), consumption from own production (middle), and consumption from purchase (bottom) of rice (left) and millet (right). [Source: WFP, 2011]

The fact that across all livelihood zones, households purchase over 80 per cent of their food suggests a strong dependence on markets. Therefore, vulnerabilities to climate risk depend highly on how food markets are affected by climate variability. As shown in Part II, there is a strong correlation between precipitation and yields, and production and food prices following the harvest – suggesting that rainfall variability could increase food price volatility rendering households highly vulnerable.

A market flow analysis further illustrates the trade flows for millet and rice (Figure 25). Millet surpluses occur in the central parts of the country, in the groundnut basin. Surpluses are exported internally mainly to the northern parts of the country and to Dakar. Due to the high dependence on millet from this region, any significant reductions in production linked to rainfall variability could

affect food price and food security more generally across the country. A smaller proportion of the millet consumed in Senegal, especially around Tambacounda and Bakel, is also produced in Mali suggesting that any significant variations in production in Mali might also affect food prices in Senegal. Since Senegal and Mali are part of the same “broadly Sahelian” climatic region, a large-scale drought is likely to affect the food producing regions of the two countries in the same way, exacerbating food insecurity at regional level.

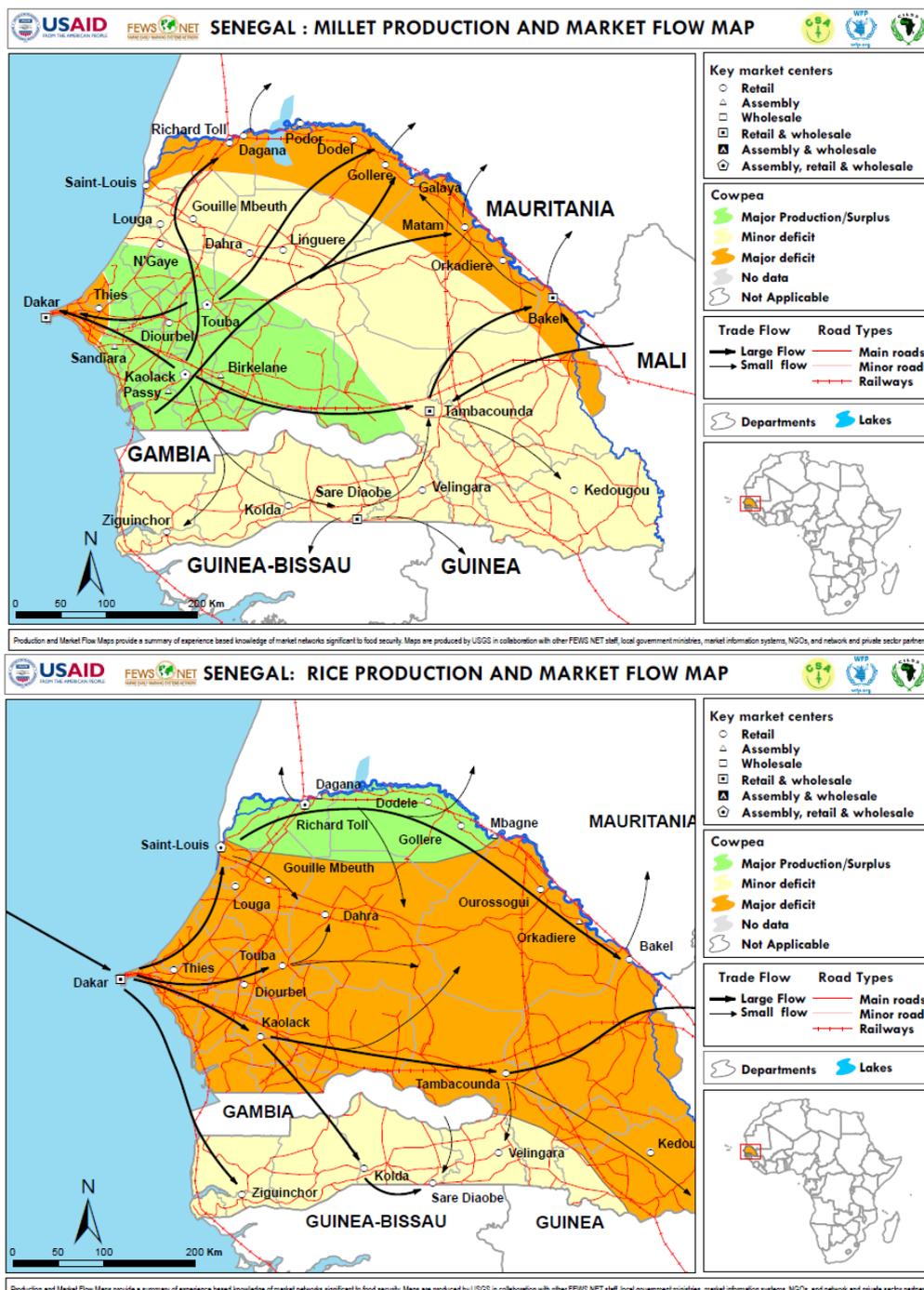


Figure 25. Market flow maps for millet (top) and rice (bottom). [Source: FEWS NET, 2012]

Rice surpluses occur mostly in the northern parts of the country, along the Senegal River. Most of the surpluses are traded internally, or are sold to Mauritanian markets. Given the high preference

for rice in the country (over 80 per cent of households consume rice) and the fact that the country does not produce enough rice, Senegal depends on imports from other countries – especially Thailand, Vietnam and Brazil. Therefore to understand the complexity of relationships between climate variability and food security, it is also important to consider climate trends in other countries.¹⁰

Market dependence and seasonality

Households across most of the country are highly dependent on markets for their food security. To understand potential impacts of climate on markets, it is important to examine the seasonality of dependence on markets. This section examines these seasonalities for households that are millet producers (which are predominantly located in the groundnut basin) and for households that are rice producers (which are predominantly located in the Senegal River Valley and in Casamance) by identifying the proportion of households that are self-sufficient, those that produce a surplus (and sell their food), and those that purchase food in order to meet their household food requirements throughout the year.

The proportion of millet-producing households that are self-sufficient is relatively stable between November and April following the harvest. Similarly, the proportion of households that are net sellers of millet increases between October and January – this suggests that the vast majority of households that produce millet use it for own consumption. In contrast, the proportion of households that become net buyers of food is highest in the lean season, between July and September. During this period, between 70 and 80 per cent of households that produce millet become dependent on markets for their food requirements. In addition, around 10 per cent of millet-producing households depend on markets throughout the entire year (Figure 26).

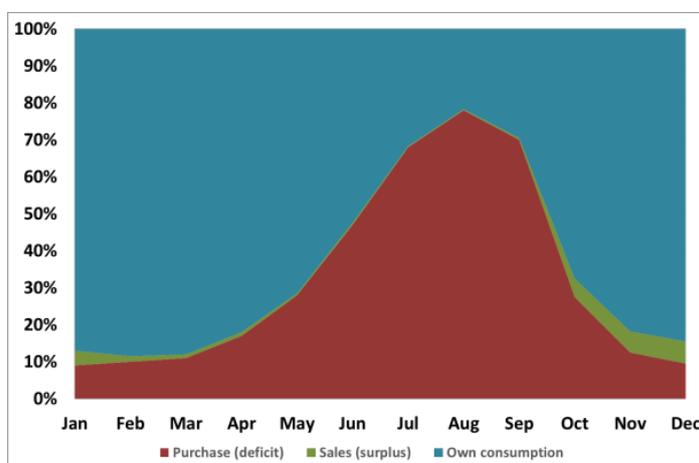


Figure 26. Seasonality of household market dependence for households that are millet producers. [Source: WFP, 2011]

There is therefore a strong element of seasonality in market dependence. This problem is further complicated by the fact that physical access to markets is difficult in the lean season in certain parts of Kaolack and the groundnut basin due to floods once the following rainy season starts.

¹⁰ While an analysis of climate and rice production trends in countries that export rice to Senegal would help provide a more comprehensive picture of vulnerability to climate risk, the focus of the present analysis is on vulnerabilities based on climate variables at the national level.

Rice-producing households account for approximately 20 per cent of all households interviewed in the Comprehensive Food Security and Vulnerability Analysis, and are principally located in the Senegal River Valley and in Casamance. In contrast to households that produce millet, those that produce rice are more dependent on markets throughout the year. Rice-producing households become net buyers from April until October, and are mostly self-sufficient for five months after the harvest (Figure 27).

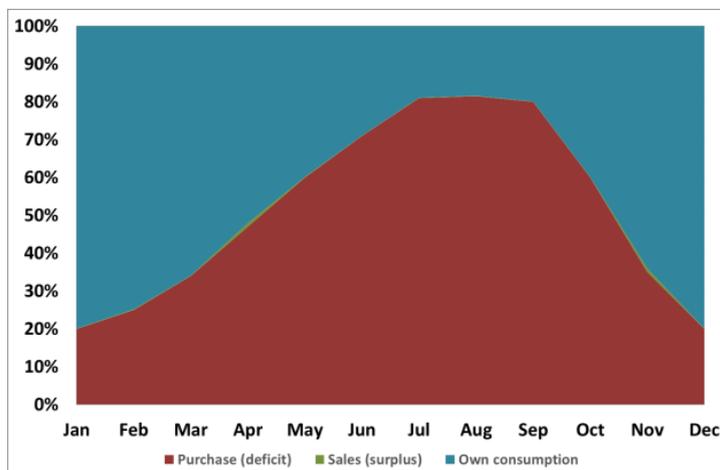


Figure 27. Seasonality of household market dependence for households that are rice producers. [Source: WFP, 2011]

Households that produce rice appear to be in areas of Senegal where there is little variability in rainfall during the growing season. Moreover, as rice-producing households are mostly dependent on markets for their food requirements, they are vulnerable to climatic variability in Thailand, Vietnam and Brazil (the largest suppliers of rice in the country).

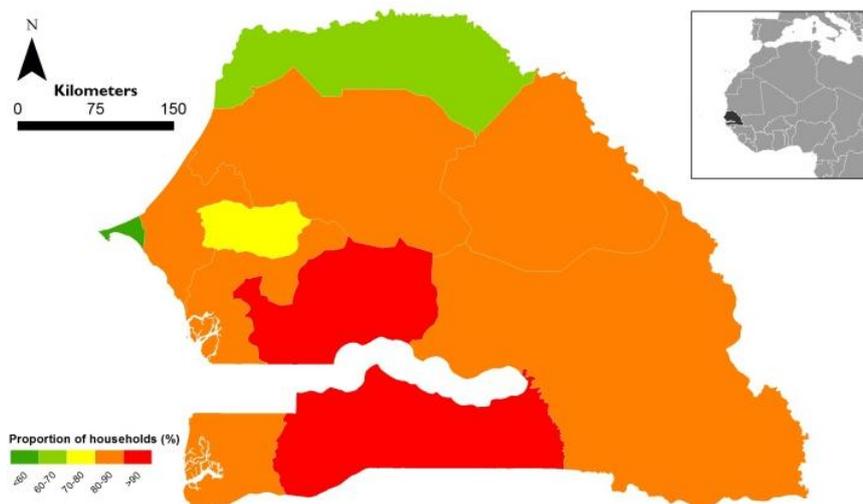


Figure 28. Proportion of households that reported having difficulties in meeting food requirements in August, 2010 [Source: WFP, 2011]

The foregoing analysis suggests that market access is a key component of food security in Senegal, and that dependence on markets is highly seasonal. According to the results of the CFSVA, apart from Dakar, Saint-Louis and Diourbel, more than 80 per cent of households across Senegal reported having difficulties in meeting their food requirements in August – at the peak of the lean season

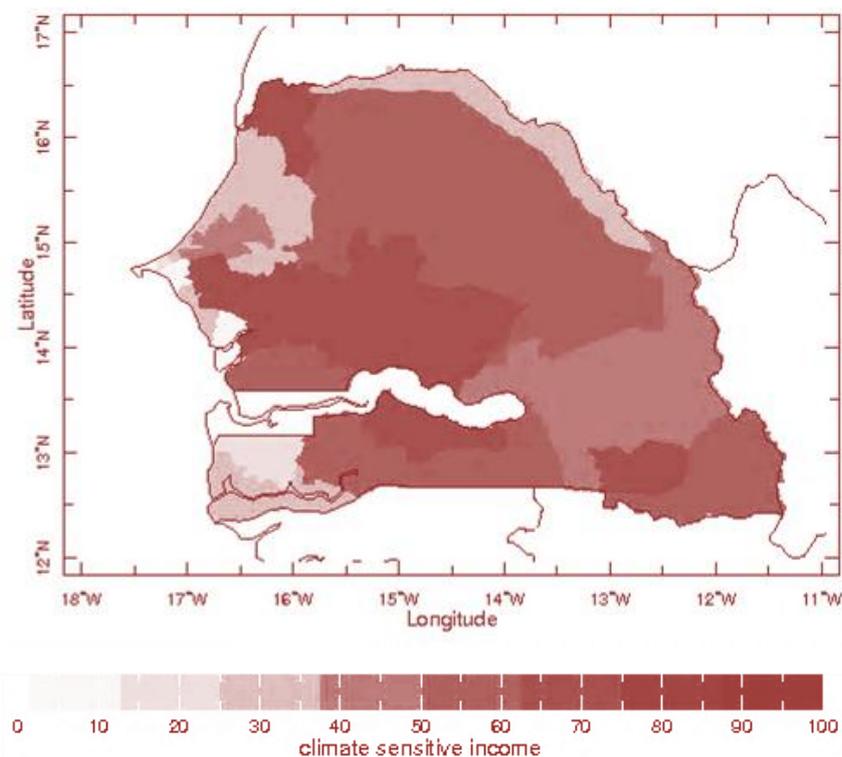
(Figure 28). Households in Kaolack and Sédhiou are particularly vulnerable during this period. In Kaolack, in particular, where aggravating climatic factors coincide, climate variability could further exacerbate food insecurity trends.

Under climate change, two inter-related impacts could affect the ability of households to access food during key months. First, if the **lean season intensifies due to climatic variability** (for example, the onset of the rainy season could be delayed) it is likely that households would have to purchase more of their food during the lean season. Second, under a scenario of increasingly erratic rainfall, **extreme climate events such as floods could destroy or severely affect infrastructure**, reducing the ability of households to purchase food. Infrastructure is a key aspect, especially in the southern parts of the country where access to markets is critical for ensuring household food security.

Income sources

Across rural Senegal, there is high dependence on income from climate-sensitive activities such as subsistence agriculture, cash crops, livestock rearing, *marâchage* (vegetable growing), and daily agricultural labour.

Figure 29 shows the percentage of income obtained from climate-sensitive activities by livelihood zone. The map highlights that income in the groundnut basin and the Niayes horticulture zone along the coast north of Dakar is highly climate-sensitive. Given that rainfall variability is highest in central Senegal, and that aggravating climatic factors are concentrated in this region, incomes in the groundnut basin are highly sensitive to climate.



Income source	Climate sensitivity
Subsistence agriculture	Changes in rainfall patterns will likely affect the quantity and quality of water available for agriculture. Erratic rainfall patterns could reduce the length of the growing season as well as yields, with negative impacts on incomes and food security.
Cash crops	Changes in rainfall patterns will likely affect the quantity and quality of water available for agriculture. Erratic rainfall patterns could reduce the length of the growing season as well as yields, with negative impacts on incomes and food security.
Livestock rearing	Changes in rainfall patterns will likely affect the quantity and quality of water available for livestock consumption. This would affect livestock health, with potential impacts on the quality of meat and milk. Erratic weather patterns could also render livestock more vulnerable to diseases.
Maraichage	Changes in rainfall patterns will likely affect the quantity and quality of water available for agriculture. Erratic rainfall patterns could reduce the length of the growing season as well as yields, with negative impacts on incomes and food security.
Agricultural labour	Agricultural labour is likely to be affected by seasonal and long-term changes in rainfall patterns. Labour availability under climate change is likely to become unpredictable, potentially lowering income for agricultural labourers.

Figure 29. Climate sensitivities of income sources. [Source: WFP, 2011]

The majority of rural households in Senegal depend on at least two activities for their income: only 15 per cent of households depend on one activity, whereas 41 per cent have two main sources of income and 44 per cent depend on three or more. This suggests that rural households have diversified their livelihood activities as a strategy to minimise the impact of climate variability and other external factors on their poverty levels. In contrast, the majority of urban households depend on one (43 per cent) or two livelihood activities (40 per cent) and only a minority (18 per cent) depend on three or more activities.

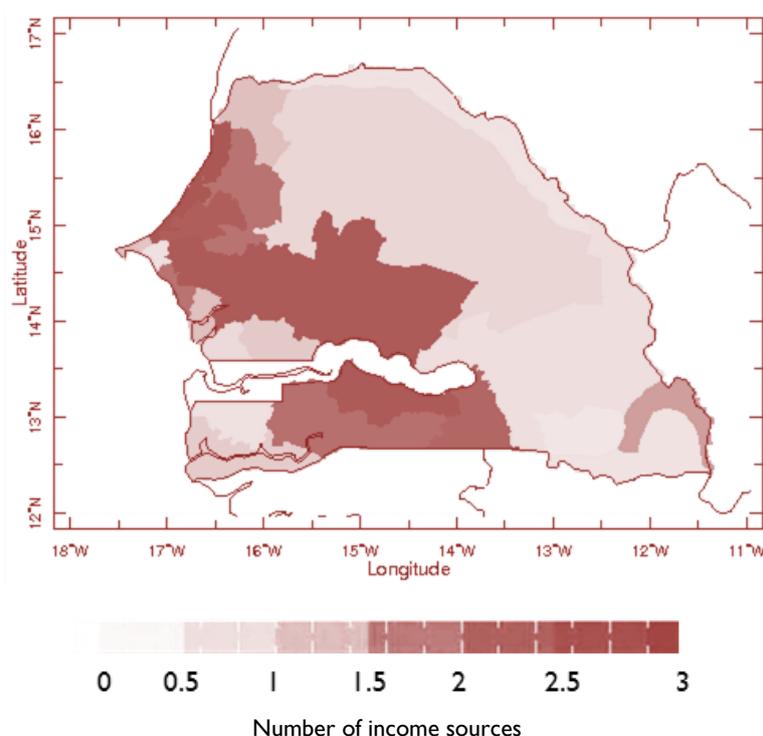


Figure 30. Number of income sources by livelihood zone. [Source: WFP, 2011]

Figure 30 shows the number of income sources by livelihood zone for both rural and urban households. The map highlights that households with the highest diversification of income are located in central, western, and southern Senegal. In southern Senegal it is likely that income diversification has been a strategy to reduce the impacts of poverty and conflict (Evans, 2007). Across western and central Senegal, empirical data suggests that diversification of income sources has been a strategy to minimise the impact of the drought that lasted from the 1960s until the 1980s (Ben Hammouda et al., 2010; Tacoli, 2011).

Climate-related shocks and coping strategies

In terms of climate-related hazards, Senegal is particularly vulnerable to droughts and floods resulting from both long-term climate variability and erratic rainfall patterns.

Rainfall has changed significantly over the 20th century in Senegal, which helps explain patterns of vulnerability in the country. The Sahel-wide reduction in seasonal rainfall that occurred between the late 1960s and the mid-1990s resulted in fewer rainy days, a shorter rainy season and longer dry spells (Le Barbé and Lebel, 1997). In the absence of sufficient publicly available records of daily precipitation, 31 shows the number of number of years (out of 30) in which there were over 450mm of rainfall during the rainy season (between May and October) between 1941 and 1970 (top) and 1971 and 2010 (bottom), allowing for millet production. The climatological trends suggest that smaller parts of the country receive enough rainfall to grow millet. However, recent data suggest that from 1990 onwards there has been an increase in precipitation suggesting a reversal of the drought conditions experienced between the 1960s and 1980s (Giannini et al., 2012).

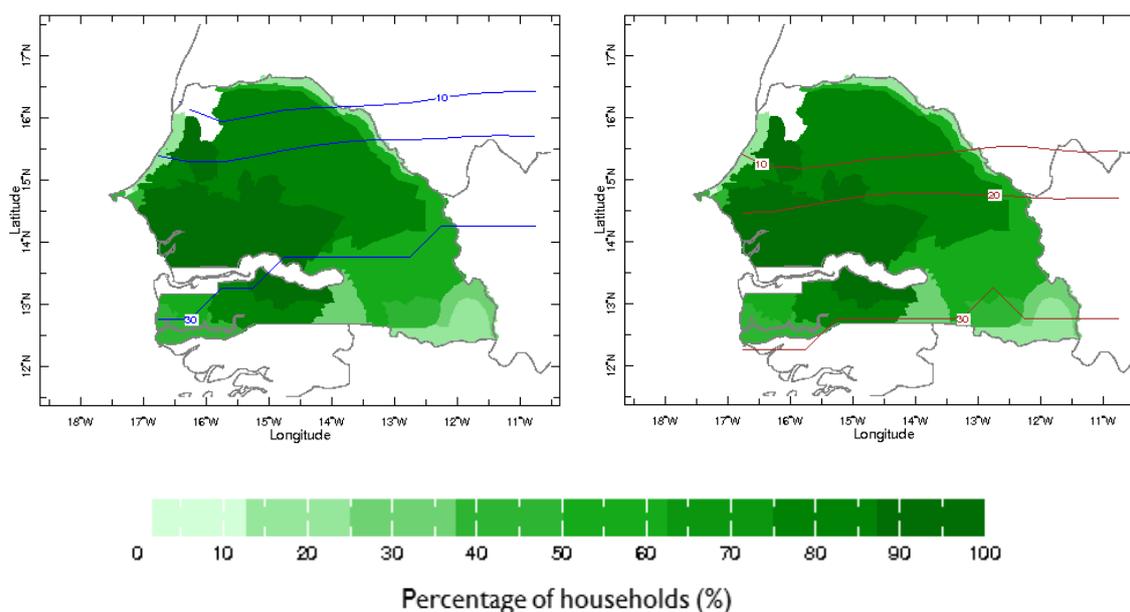


Figure 31. Per cent of households growing millet and number of years in 1941-1970 (top, blue) and 1971-2000 (bottom, red) receiving at least 450 mm of rain between May and October [Sources: WFP, 2011 and WCRP, 2012]

In addition to long-term trends, households are also affected by inter-annual variability. Using data from the CFSVA, it is possible to map areas where households have reported insufficient rainfall in 2009, the year prior to the survey. As Figure 32 shows, the majority of households reporting insufficient rainfall were located in the southwestern parts of the country (particularly in Ziguinchor and Kolda).

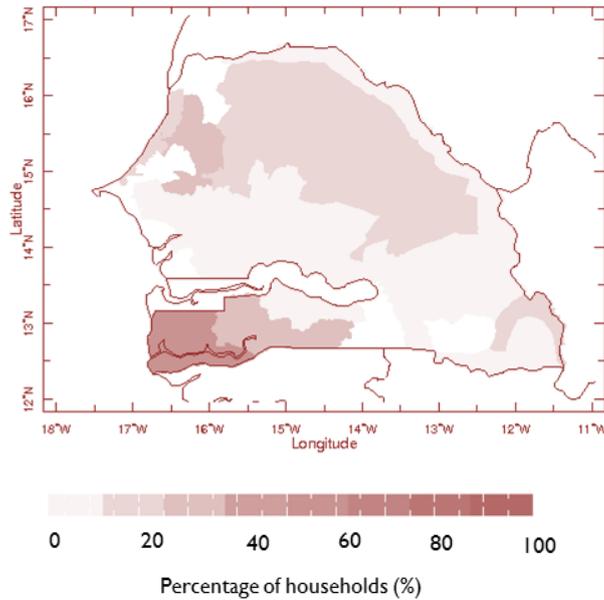


Figure 32. Percentage of households reporting insufficient rainfall in the rainy season. [Source: WFP, 2011]

Survey data correlate well with actual precipitation data. Figure 33 shows precipitation anomalies during the rainy season (May-October) in 2009 with respect to the rainfall climatology between 1983 and 2011 (left) and with respect to rainfall during 2008 (right). The maps show while 2009 was a wet year in Casamance in the long-term climatological sense, it was in fact dry with respect to the previous year.

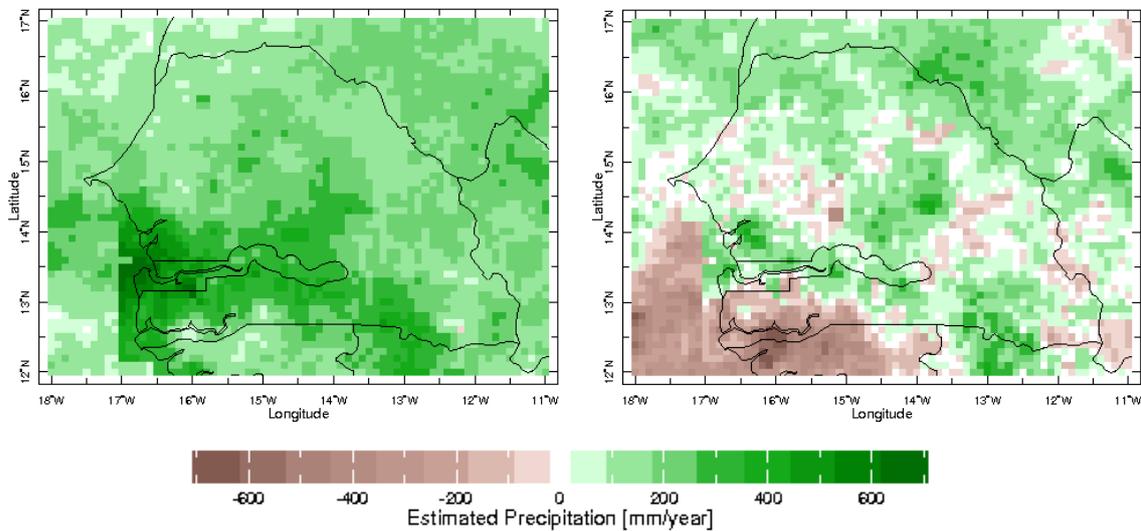


Figure 33. May-October rainfall anomalies with respect to climatology (1983-2011, left) and with respect to 2008 (right). [Source: FEWS/ARCV2, 2012]

Rainfall variability and livelihood indicators

Rainfall statistics¹¹ for the period May-October 2009 also appear to be strongly correlated with livelihood indicators measured in the CFSVA: coping strategies index, food expenditure, food consumption score, and wealth index¹² (Table 3).

¹¹ The rainfall statistics used in Part II are also used here: total rainfall, first onset, true onset, and dry spell length for 7, 10, and 15 days.

Table 3. Spatial correlation between rainfall statistics and livelihood indicators using the classification into 7 agro-ecological zones. To gauge significance, the 5% level for a sample with 5 degrees of freedom is 0.754

Rainfall statistic	Livelihood indicator					
		Coping strategies index	Food expenditure	Food consumption score (poor/very poor households)	Wealth index (poor households)	Wealth index (very poor households)
Total rainfall		-0.93	-0.83	0.97	0.90	0.78
First onset		0.61	0.82	-0.67	-0.85	-0.93
True onset		0.61	0.75	-0.75	-0.84	-0.89
Dry spell (7 days)		0.67	0.61	-0.89	-0.78	-0.64
Dry spell (10 days)		0.64	0.60	-0.82	-0.65	-0.55
Dry spell (15 days)		0.38	0.18	-0.32	-0.11	0.05

The negative correlation between total rainfall and the coping strategies index suggest that a bad rainy season results in a higher dependence on food-based coping strategies. In contrast, the positive correlation with the food consumption score suggests that higher rainfall results in larger diet diversity and quantity. The correlation between rainfall total and wealth index is weaker for very poor households compared to poor households – this suggests that very poor households are more vulnerable to non-climatic factors such as conflict than poor households.

A delayed onset of the rainy season and dry spells also appear to affect livelihood indicators. For example, a delayed onset of the rainy season is strongly correlated with higher proportion of cash income spent on food as well as a lower food consumption score. A dry spell of 7 or 10 days, too, appears to affect food consumption negatively and is linked to higher use of food-based coping strategies.

The results show a very strong correlation between rainfall variability, especially rainfall total, and livelihood indicators suggesting that for the poorest households, rainfall is a key determinant of livelihood outcomes.

¹² The **coping strategies index** measures the frequency and severity of coping strategies used during a shock, such that a higher number indicates that a household tends to depend on food-based coping strategies. **Food expenditure** measures the proportion of cash income spent on food items. The **food consumption score** is a composite index which measures diet frequency and diversity, such that a higher number indicates better diet diversity and frequency at the household level. Finally, the **wealth index** measures the well-being of households according to ownership of non-productive assets.

Part IV: Managing climate risk

Despite significant food assistance efforts over the last decades, food security remains an important issue in Senegal. Climate risk, particularly droughts and floods, affects livelihoods and exacerbates environmental degradation, poverty, and food insecurity. Policies to tackle risks at different spatial scales are required to manage the negative impacts of climate on livelihoods and food security.

The negative effects of lack of and erratic precipitation might have been countered by adaptation measures taken by vulnerable populations, such as the slow change in choice of crops (including the substitution of barley with other crops) or planting dates. Such gradual adaptation measures occur at small spatial scales and cannot be captured by the models used in this analysis, which used de-trended data. In this context, the reported impacts of climate on food security should be interpreted as the expected impact in the absence of adaptation measures (cf. Lobell and Field, 2007). The scale of adaptation therefore adds a level of uncertainty in estimating climate impacts on food security.

A number of policies to address climate risk can be highlighted:

Mainstreaming climate risk management into development and food security strategies

One of the key messages of this analysis is that climate variability is a hunger risk multiplier, exacerbating current vulnerability trends. As such, it is difficult to isolate climate impacts on food and nutrition. Therefore, managing climate risk should not take place in isolation but should be integrated into broader development plans, food security and poverty reduction strategies, and national adaptation plans (NAPs). *Integrating climate risk management* structures into broader development pathways offers a cost-effective manner of addressing multiple development challenges, while accounting for the emerging risks posed by climate variability and change. For instance, social protection and safety nets offer critical platforms and vehicles for investing in risk management for the most vulnerable and should become a policy priority.

Innovative strategies for climate risk management: The R4 Rural Resilience Initiative

WFP, Oxfam America, and partners are working together to strengthen the food security of vulnerable farmers through the R4 Rural Resilience Initiative. In Senegal, R4 will enable poor farmers to enhance their food security and livelihood by managing risks through four inter-related strategies: improving natural resource management (community risk reduction), accessing microcredit ("prudent" risk taking), gaining insurance coverage (risk transfer), and increasing savings (risk reserves).

Scaling up risk management is critical in view of a changing risk environment characterised by increasing risks as well as larger numbers of people exposed to these risks. Successful scaling up should be implemented at the community level, as well as at the national, regional and global levels by adapting successful experiences and best practices in resilience building.

Focus on the most vulnerable

This analysis highlights that all rural livelihood systems in Senegal are highly sensitive to climate given their dependence on rainfall. Recent climate trends show that climatic conditions that aggravate food security are concentrated in the central parts of the country (Kaffrine, Koumpentoum, northern Tambacounda, and southern Matam). These regions experience irregular rainfall patterns during the

rainy season, erratic start of the rainy season, and long dry spell length that could affect crop production. Climate projections suggest that these trends could continue over the next few decades.

In this context, strategies for *livelihood and income diversification* are critical to ensuring resilience against more intense climate-related risks. For example, migration (both seasonal and permanent) has become an important source of household income for at-risk populations. Increasing voluntary labour mobility is a low-cost, low-regret approach that contributes to the adaptive capacity of communities through networks that are used to exchange goods, services and information while also giving at-risk populations the opportunity to adapt based on their needs. Support to additional income sources, such as wage labour, skilled non-farm activities and forest management can lead to improved livelihoods.

Landscape transformation through land rehabilitation can offer a long-term solution to climate risks. For instance, the Great Green Wall Initiative responds to the combined impacts of land degradation and drought on rural livelihoods by expanding sustainable land and water management practices in highly sensitive environments in order to rehabilitate degraded landscapes and support vulnerable livelihoods in these regions. Similar activities might also support disaster risk management at the community level through, for example, construction of disaster mitigation infrastructure such as embankments, dikes, and check dams, as well as construction of infrastructure to enhance access to facilities such as roads and mountain trails.

Further, landscape management could also contribute to effective flood risk management through the expansion and refurbishment of irrigation and water storage infrastructure, capacity building for water-efficient cropping practices, and adoption of flood-resilient crop varieties.

Manage uncertainties associated with climate change

One of the key characteristics in terms of climate risk in Senegal is that both droughts and floods may occur in the same growing season (as in 2012), with potentially devastating impacts on livelihoods and food security. Strategies to address climate risk should focus on developing capacities to better analyse and anticipate risks. For instance, the introduction of early warning systems and contingency plans can support climate risk management and food security strategies. Investments should also be made in strengthening analytical tools such as early warning systems, and risk assessment and monitoring systems to enhance detailed and up-to-date vulnerability assessments.

Africa Risk Capacity

The African Risk Capacity (ARC) is a specialised agency of the African Union designed to improve current responses to drought food security emergencies and to build capacity within AU member states to manage drought risks.

ARC is an African-owned, continental index-based weather risk insurance pool and early response mechanism, ARC offers an African solution to one of the continent's most pressing challenges. By bringing together the concepts of insurance and contingency planning, ARC aims to create a new way of managing weather risk by transferring the burden away from African governments, and their vulnerable populations who depend on government assistance, to international financial markets that can handle the risk much better.

Senegal has recently joined this initiative, with the national meteorological service (ANACIM) providing support with data provision and analysis.

Integrate climate change adaptation and mitigation efforts

Addressing climate impacts on the most food insecure requires a twin-track approach which incorporates adaptation and mitigation efforts. Where possible, initiatives to address climate impacts should also aim to reduce greenhouse gas emissions through mitigation activities – such as reforestation –, and low-carbon development – through renewable energy systems. Such initiatives should also ensure that the poorest and most vulnerable communities are not negatively affected.

Part V: Conclusions

Food security is highly sensitive to climate risk in Senegal. Recent climate-related events and trends — including the 2011/2012 food security crisis in the Sahel — have highlighted the potential impact of climate-related events on crop production, access to markets, and income from climate-sensitive activities.

Rainfall is the key climatic variable affecting food security and livelihoods in Senegal. The analysis presented here shows that rainfall is highly variable across the country, and throughout the year. High rainfall variability at seasonal, inter-annual and multi-decadal scales characterizes climate change in Senegal, and is the key contributing factor to vulnerability.

The analysis suggests that food security indicators in Senegal, including agricultural production, food consumption score, expenditure on food, and coping strategy index, are closely linked to climate variability. The impact of these climate trends could likely be offset by adaptation measures at the community level including selection of alternative crops, application of fertilisers and livelihood diversification—but the magnitude of these effects is uncertain and difficult to quantify.

Historically the most discernible impact of climate has been that of precipitation on crop production. The main crops (rice, millet, groundnuts, and sorghum) are highly sensitive to changes in annual precipitation patterns, so that crop production is lower in years with lower rainfall. Crop production is especially responsive to rainfall variability in the groundnut basin. The results also indicate that climate trends may have contributed to some variations in food prices, although the results are less conclusive due to the influence of imports on food prices. Our analysis suggests that insufficient rains translate into a bad harvest, which leads to a decreased supply, and high consumer prices.

An analysis of livelihoods reveals that climate risk may affect diet quantity and quality (dietary intake and diversity), both through direct impacts on food production (availability) and indirect impacts on markets (access). Given the high reliance on markets, two inter-related climatic impacts could affect the ability of households to access food during critical months. First, if the lean season intensifies due to climatic variability (for example, the onset of the rainy season could be delayed) it is likely that households would have to purchase more of their food during the lean season. Second, under a scenario of increasingly erratic rainfall, extreme climate events such as floods could destroy or severely affect infrastructure, reducing the ability of households to access markets to purchase food. Infrastructure is a key aspect, especially in the southern parts of the country where access to markets is critical for ensuring food security.

Similarly, across most of Senegal, income sources are highly climate-sensitive: subsistence agriculture, cash crops, livestock rearing, maraîchage (vegetable growing), and daily agricultural labour are the main sources of income. The proportion of income that comes from such climate-sensitive source is highest in central Senegal. Aggravating climatic factors are concentrated in this region, suggesting that incomes in the groundnut basin are highly sensitive to climate.

The high sensitivity of food security in the country requires a set of targeted interventions to enhance climate risk management, including through drought and flood risk management, asset creation, social protection, capacity development, and enhancement of early warning systems and monitoring capacities.

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