Case Study 4: Senegal Adaptation and Mitigation Through "Produced Environments": The Case for Agriculture Intensification in Senegal

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1 Introduction

For the last 15 years, discussions and debates on the debilitating effects of climate change have become increasingly intense. The stress has been on securing emission reductions by industrialised nations which are the biggest polluters, as it is incumbent on them to show leadership by taking tangible steps to honour the commitments made under the Kyoto Protocol, which came into effect in February 2005. Because the focus has been primarily on mitigating the effects of greenhouse gases, comparatively little attention or human and financial resources have been given to dealing with vulnerability and adaptation strategies. Mitigation and adaptation are, however, increasingly being treated as equally important with many new initiatives aimed at combating climate change approaching the issue from a sustainable development point of view, which would, wherever possible, seek to combine the two.

This case study looks at one example of how adaptation and mitigation can be usefully combined in a way which enhances incomes and diversifies livelihoods of the poor while also securing benefits for biodiversity, gender equality and carbon sequestration. The case study describes how a pilot farm in Niayes, Senegal, launched in the 1970s, has evolved over time to address significant variations in climate change. The farm had to adapt to the production conditions formed by successive droughts and a drying climate (with isohyets drifting southwards); this entailed selecting irrigatable crops, planting dense perennial *haies* (edges) to act as windbreakers and tracing the passageways and perimeter of plots. These windbreakers fight wind and hydric erosion and provide fuelwood for cooking. This vegetation generated a microclimate conducive to increased production of fruit and vegetables, thereby paving the way for enhanced export income. The innovations and adaptation

Figure 1: Map: Senegal's Position in the Western Sahel

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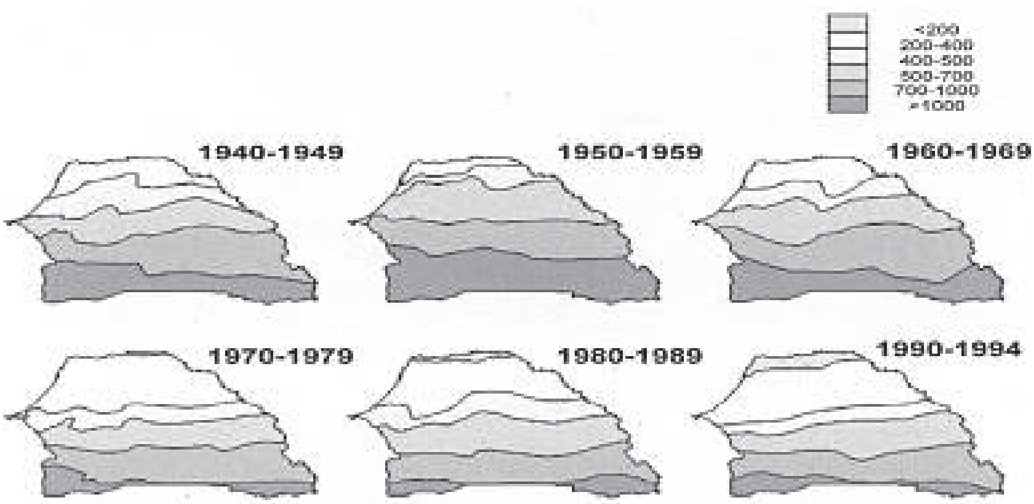
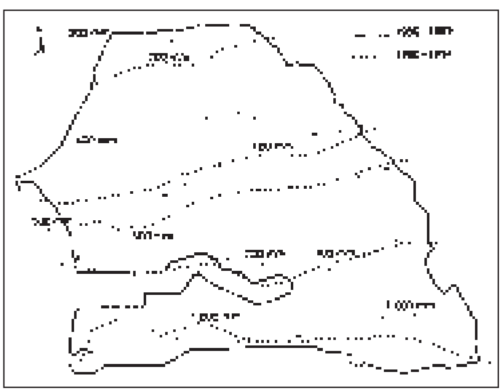
Figure 2: Rainfall Changes from 1940 to 1994



Source: Direction de la Météorologie Nationale, Senegal.

Figure 3: Isohyets Based on Averages from 1980–9 and 1990–4



Source: www.reseau.crdi.ca/fr/ev-27906-201-1-DO_TOPIC.html (accessed June 2005)

practises tried in Sébikotane, Senegal consisted of developing an original and integrated way of managing the environment for the benefit of modern, efficient agriculture. This case study recounts that success story and explains how it could be replicated elsewhere in the Sahel and farther afield.

The case study is structured to provide background information on Senegal's history, climate and socio-economic conditions in section 2. The institutional and policy processes relevant to climate change are set out in section 3. The core of the case study describing the agricultural innovations in Sébikotane is set out in section 4. The last two sections set out lessons for key actors, directions for future research and the key conclusions.

2 Senegal's climate and socio-economic conditions

2.1 Climate and physical description

Senegal is a small country in Africa lying at the westernmost tip of mainland Africa, Senegal covers 200,000 km^2 between 12° and 17° northern latitude and 11° and 18° western longitude. It is bordered to the north by Mauritania, to the southeast by Mali, to the south by Guinea and Guinea Bissau and to the west by the Atlantic Ocean (see Figure 1).

It has an estimated population of 10 million. It is ranked as one of the world's Least Developed Countries (LDCs). Since 1970, it has been in the clutches of a chronically severe economic situation, into which it first plummeted with the first big drought in 1972 (Box 1) and the oil recessions of 1973. Climatically, it is mostly Sahelian. Its main assets are its Atlantic coast and its peoples' acknowledged dynamism, ingenuity and capacity to adapt.

Senegal is a flat country with the only elevated relief being the volcanic Cap Verde peninsula, Thiès "cliff" and the foothills of the Fouta Djalon mountain range on the border with Guinea, where the four rivers that meander through the country (the Senegal, Gambia, Saloum and Casamance) have their sources.

Box 1: Senegal and Recent Droughts

As with other Sahelian countries, Senegal was hit hard by the recurring droughts of the 1970s and the consequences of climate change. The country's development was hamstrung by a combination of external factors (global economic environment) and internal ones (climate). As a result, it slid into being one of the Least Developed Countries (LDCs) in 2001 and drew up a Poverty Reduction Strategy Paper (PRSP) in 2002.

Adverse global economic conditions (oil recessions) and the radical transformation of geopolitical relations (with the eastern and western blocs no longer so eager to foster allies among poor countries) accentuated the effects of the degradation of the physical environment, which was the main asset of the country with a poorly educated population that was excessively dependent on its natural resources and agricultural output.

Senegal's coastal front along the Atlantic runs for 700 km and is only interspersed by some rocky parts along the Cap Verde peninsula and the region of Thiès. A stretch of fertile interdunal depressions runs along the northern coast from St Louis to Dakar; this area is known as Niayes and it is highly favourable to vegetable growing thanks to maritime trade winds. On the other hand, the coast to the south of the Cap Verde peninsula is split by the Toubab Dialaw cliffs and then by the Saloum mangrove, where stretches of water run through the land like a maze, giving rise to ten small islands. Further to the south, the subtropical zone of lower Casamance has very dense vegetation and rice fields and fruit and palm trees. Meanwhile, the country's inland area features a semi-desert plain, where pastoral farming is practised.

The main climate types in Senegal are, from north to south, per year:

- Desert-like Sahelian climate, where annual rainfall does not exceed 350 mm
- Dry, continental Sahelian–Sudanese climate, where annual rainfall range is 350–700 mm
- Cooler and drier Sahelian–Sudanese climate, where annual rainfall is 700–900 mm
- Sudanese climate, with an average rainfall of 900–1,000 mm
- Sudanese–Guinean, which is characterised by heavy rainfall of about 1,000–1,200 mm.

This climate is marked by two distinct seasons:

- A rainy season from June to October, which features a hot and humid monsoon wind from the St Helena anticyclone
- A dry season from November to May, where the prevailing northerly wind (maritime trade winds from the Azores anticyclone and the Harmattan from the Libyan anticyclone).

As will become clearer in the case study, Senegal's winds play a critical role in the productivity of its agricultural system.

From 1940 to 1994, Senegal endured eight of its ten driest ever years on record. The first big drought hit the country in 1972, inaugurating a cycle of declining rainfall that struck further cruel blows in 1976, 1979, 1982, 1983, 1984 (the record low), 1985 and 1986. Since the big drought of 1972, one of the main features hit by climate change has been water resources. Rainfall has dropped by 30–40 per cent over the last three decades and in the space of just four years, isohyets have shifted significantly to the south. Coastal areas have not been spared. The drastic drop in groundwater tables, which is due to the southward shifts of the isohyets has wiped out a lot of plant cover and thereby aggravated wind erosion.

Vulnerability to climate chance and not just climate change itself, has become a factor that cannot afford to be ignored. The Cap Verde peninsula is highly sensitive to erosion and now risks losing 50 per cent of its beaches. Elsewhere, the Saloum estuary is vulnerable to flooding, particularly around the delta area, and is liable to lose over half of its ecosystems by 2050. This would have a severe impact on the development of socio-economic activities in the country.

2.2 Socio-economic situation

For a long time, Senegal was the world's leading producer of groundnuts – but massive production of this crop, and this crop alone, created serious damage to its soil resources. It tried to diversify by

Table 1: Some Socio-economic Data on Senegal

Economic indicator	2004 GNP	US$4.7 billion; US$602 *per capita*
	GDP *per capita* 2003	US$635.70 *per capita*
Agriculture	Arable land (2001)	3,800,000 ha; 19%
	Irrigated land (2001)	76,000 ha
Population	Annual growth (2003)	2.5%
	Rural population	51,1%
	Urban population (2003)	48.9%
Distribution (2001)	Agriculture	70%
	Industry	15%
	Services	15%
	Population in 2025	16,900,000
	2002 life expectancy	52.9 years

promoting tourism and fishing but crop-growing retained a hugely significant place in the economy, with pastoral farming being less widespread. Most of the people active in agriculture operate in a host of sub-sectors that perpetuate relatively inefficient traditional practices. Almost all crops (95 per cent) are dependent on rainfall, which is irregular and often insufficient; furthermore, the technology used is often very basic, using obsolete production systems.

It has been demonstrated that poor groups, communities and individuals are more vulnerable to the effects of climate change, with the most vulnerable being those living in areas afflicted by drought and other phenomena connected to climatic variability and change. This is why adaptation strategies are so urgently needed.

The extent and impact of the disasters that Senegal has endured or will suffer in the future have and will affect agriculture production, including live stocks. Given that they are so dependent on crops, both the authorities and the population in general eventually accepted that an alternative to rain-based agriculture had to be developed due to rain lasting barely three months from July to October. The government has sought to encourage irrigation-based agriculture and, in particular, horticulture for the nine months of the year without rain.

Since some 60 per cent of Senegal's population works in the agricultural sector, the PRSP aims to conjure the conditions for accelerating growth. The strategies to be implemented will make it possible to boost gross domestic product (GDP) from agriculture by removing the obstacles currently faced by farmers and bolstering economic security for the poorest (small landholders).

According to the 2002 census, Senegal's population was 9,956,202. This rose to 10,127,809 in 2003. The country's GDP is US$600 *per capita*, and debt servicing accounted for 70 per cent of this GDP in 2000, as compared with 86.2 per cent in 1994. A total of 53.9 per cent of Senegalese households lived below the poverty line in 2001, as opposed to 57.9 per cent in 1994. Accordingly, Senegal was classified as a Least Developed Country (LDC) in 2001 and drafted its PRSP in April 2002.

3 Key institutions and policy processes

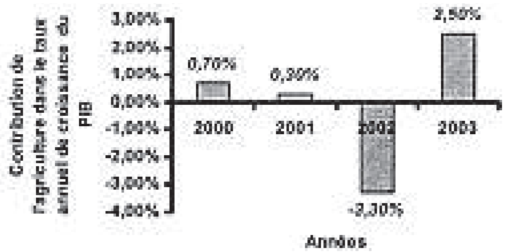
This section describes the key documents relating to the environmental policies, programmes and plans relevant to assessment of the vulnerability and adaptation options for the country, focusing, in particular, on its agriculture.

The Environmental Code (Law No 2001– 01 of 15 January 2001) forms the basic systems of references for environmental protection and management in Senegal. The country's environmental plans and strategies, listed below, constitute a fundamental part of its environmental policy.

3.1 The National Environmental Action Plan

The National Environmental Action Plan (PNAE) was drawn up in 1997 and was one of the initiatives

Figure 4: Agriculture's Contribution to Annual GDP Growth



Source: Ministry for the Economy and Finances (2004).

taken by the Senegalese government in the wake of the Rio Earth Summit in 1992. The PNAE is an overall strategic framework that aims to ensure harmony between all the policies across different sectors that relate to natural resources management and planning. One of its key objectives is to ensure that environmental considerations are taken into account in all social and economic planning. This plan was approved by a national forum and adopted by a ministerial council. The PNAE provides the umbrella for the National Strategy, the National Action Plan for Preserving Biodiversity, and the National Action Plan to Combat Desertification.

3.2 Senegal's forestry action plan

In 1981, Senegal launched the Forestry Development Guideline Plan (PDFF) which provided a forestry management scheme. The plan outlined mid- and long-term action strategies designed not only to propel a dynamic for conserving forests and natural areas but also to stimulate substantial growth in public investment in this sub-sector. Since the national and international context was subject to constant change, this plan was updated via a Senegalese Forestry Action Plan (PAFS) in 1993. This PAFS is currently being reviewed because the forestry board has become aware that it needs to adopt more participatory approaches and attitudes since the causes of deforestation and natural resource degradation are more a consequence of the overall complexity of management systems and practices than merely with the headline act of cutting wood. The goal is now to ensure that rural forestry, which covers forestry, agriculture and pastoral farming, helps boost natural resources productivity while preserving ecological balance.

3.3 The Biodiversity Conservation Strategy and Action Plan

The Biodiversity Conservation Strategy and Action Plan (1999) forms part of the Senegalese government's efforts to pursue both effective macroeconomic management and effective natural resource management by redressing and maintaining the balances that are crucial to the sustainable development of the country.

3.4 Poverty Reduction Strategy Paper

Senegal presented its Poverty Reduction Strategy Paper (PRSP) to the International Community in April 2002. It identifies public authorities' spheres of intervention and the results that guide these interventions. The strategies to be applied are designed to boost gross domestic agricultural product by removing the barriers currently impeding small farmers and providing economic security for the most vulnerable of these small farmers.

3.5 The National Programme to Combat Desertification

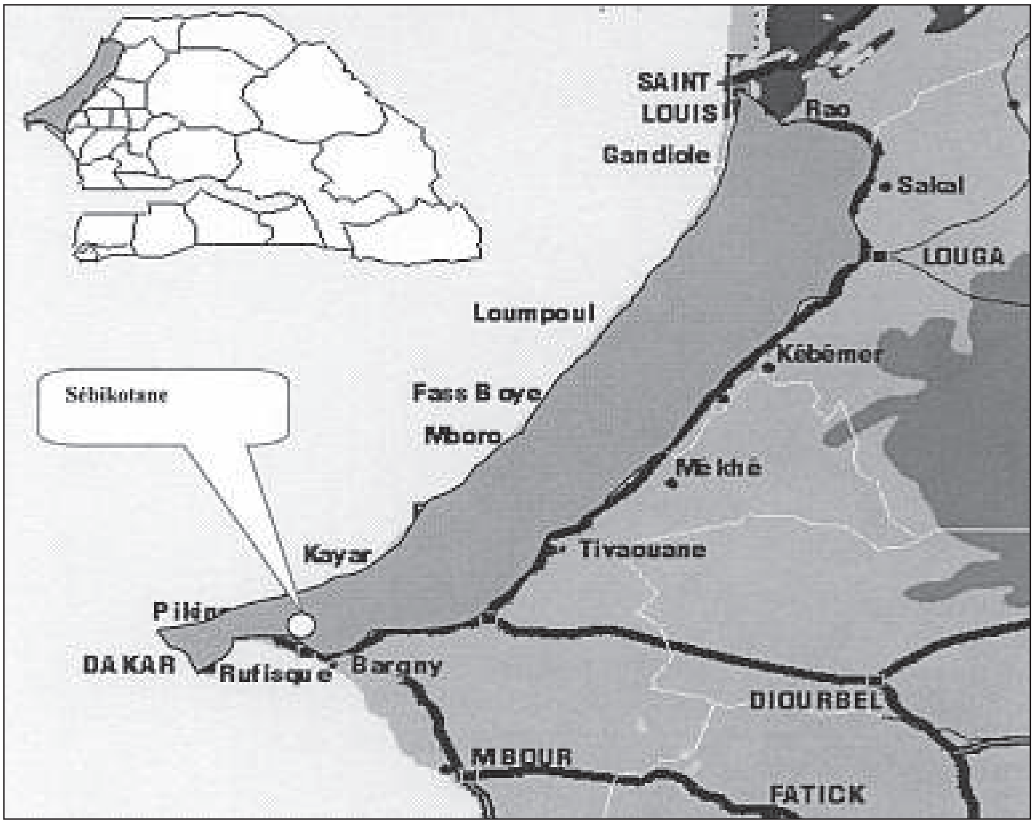
This is the main instrument for implementing the United Nations Convention to Combat Desertification (CCD) at national level. A study carried out in 1984 as part of national land management planning found that 47 per cent of soils are of poor quality or are totally unsuitable for agriculture, while a further 36 per cent is subject to desertification-related factors that restrict its productivity. As part of efforts to achieve sustained agricultural growth (thereby boosting food security) and better manage natural resources, the government undertook actions to reflect the provisions of the CCD. These included: fighting erosion, regenerating soil, combating salting of soil, restoration of depleted land (reforestation, soil restoration and rest, deferred grazing), imposing regulation on resources use (legislation on exploitation of woodland, fauna and sea resources) and rationalisation of wildlife and fish resources.

3.6 Senegal's Initiative under the UN Framework Convention on Climate Change

Initial National Communication

In accordance with Article 12 of the United Nations Convention on Climate Change, which requires parties to supply 'a national inventory of anthropogenic emissions by source and absorption by sinks of all greenhouse gases', Senegal produced

Figure 5: Location of Site Covered by the Study: Sébikotane



Source: IDRC (Centre de recherches pour le développement international, CRDI). www.resean.crdi.ca/fr/ev-27906-201-1-DO_TOPIC.html

its first national greenhouse gas inventory in May 1994 on the basis of data from 1991.

The Initial Communication updates this inventory to reflect 1994 data. It also highlights the vulnerability of water resources, agriculture and coastal zones and puts forward strategies for coping with the effects of climate change. This Initial Communication was submitted to the international community in 1997. The second is scheduled for 2006.

National Implementation Strategy (NIS) on Climate Change

Drafted in 1999, the National Implementation Strategy (NIS) of the United Nations Framework Convention on Climate Change (UNFCCC) may not be mandatory given Senegal's commitments arising from the UNFCCC (such as the national communication), but is intended to demonstrate to the international community how the country intends to incorporate climate change concerns into its overall social and economic development policy. For domestic policy purposes, the NIS gives guidelines for improving adaptation to climate change. These include:

- Boosting the efficiency of irrigation
- Improving practices for working the soil
- Letting land lie fallow
- Promoting use of new seed types
- Conducting R&D to improve genetic materials.

Still in the agriculture sector, the objective of the National Action Plan and Strategy for conserving biodiversity is to ensure that this issue is taken more into account by production activities and programmes.

The National Climate Change Adaptation Programme (NCCAP)

As a result of decisions taken by the conference of the Parties in 2001, LDCs can prepare National Adaptation Programmes of Action (NAPAs) as ways of communicating their urgent adaptation needs. The purpose of the National Climate Change Adaptation Programme (NCCAP) is to identify sectors most at risk to the effects of climate change, devise implementation projects along participatory lines and raise funds for carrying out these projects. Launched in April 2004 and due to be ratified in June 2005, Senegal's NCCAP identifies and focuses on four main sectors: agricultural production, coastal zones, water resources and tourism and fishing.

Climate change vulnerability studies carried out in Senegal have focused on these four main sectors. The studies highlighted that climate change has significantly hampered all of these spheres, since Senegal, as with other Sahelian countries, has endured 17 years of recurring drought. The evidence points to a chronic situation, which has embedded an almost irreversible desertification process that is wreaking havoc with the country's ecosystems and livelihoods. As a result, agricultural yields have declined, tree-clearing is continuing apace, rural populations are sinking further into poverty and are consequently migrating to urban areas where they generally find little or no income. In financial terms, the impact of climate change has been put at several hundreds of billions of CFA francs, since agriculture is the main occupation of most of the active population, and due to its mainly rudimentary level, is heavily dependent on rain.

Forecasts for the Cap Verde peninsula and the Niayes region suggest that climate change could cause the sea level to rise by 7–4 cm by 2050. This figure could reach 19–94 cm by 2100. Meanwhile, purely empirical evidence indicates that the agricultural losses caused by drought diminished GDP significantly between 2000 and 2002.

4 Successful integration of environmental production into agricultural production in Sébikotane (Niayes)

4.1 Case study area

The pilot farm documented here is located in the Niayes area in the Sébikotane locality, in the peri-urban zone of Dakar. The zone presents the double avantage of its proximity to Dakar (with its various infrastructure to support production) and its large area of land which is known for its favourable agricultural potential .

4.2 The genesis of intensive agriculture in Senegal

The years 1971–2 saw the creation of the country's first large horticultural farm, BUD Senegal. This was the fruit of cooperation between the Senegalese government and the Dutch food company BUD Holland. The farm covered 1,000 ha in the Niayes area (see Figure 5) and in the space of just a few years (from the beginning of the 1970s) made Senegal the biggest exporter of fruit and vegetables out of the EU–ACP (African, Caribbean and Pacific) group of countries. Thousands of people – including youths, women and both rural and urban dwellers – were introduced to, and employed by, this new agricultural system.

Five years later in 1977, BUD Senegal, whose managers were all expatriates, encountered problems and after administrative restructuring, another farm was set up on the same land and was run by Sen-Prim, which had a Senegalese manager. This farm operated well for ten years (1978–88) before going bust and being replaced by Seproma, which was run by former BUD Senegal technicians. Seproma only lasted one season. In 1990, a group of former BUD Senegal workers took up the reins, this time with the support of a private local agricultural company.

In effect, a series of players (expatriate then national executives, then technicians and then workers) attempted, on the same land, to show that horticulture could become the engine of Senegalese agriculture. Several explanations have been put forward for the failures of these players. Somewhat inevitably, most fingers have pointed to management shortcomings – but the truth lies elsewhere! The fact is the lack of rain during drought years caused massive loss of vegetation and, therefore, left soil bare. Once good rainy seasons returned the soil was swept away, reducing much of Senegal to desertified conditions. The system of farming had not taken into account the vulnerability of sensitive market-orientated crops to the dessicating effects of wind and the drop in night-time temperature resulting from lack of wind protection. It is hardly surprising then that yields plummeted. Niayes is exposed to brutal sea winds, which had hitherto only swept through a small section of the mainland

Box 2: Origins of the Niayes Wind Protection System

The production systems currently used by farmers in Sébikotane are not directly derived from traditional practices even though they have been entirely mastered and appropriated for years now. Rather, the systems were designed by a team of specialists (including an agricultural engineer*) from the Systems and Prospects department of the organisation ENDA-TM. Windbreaks play a crucial role in these systems, offering systematic protection from wind for crops, restricting potential evapotranspiration and providing solid support in organic material that is conducive to soil fertility.

*The system is primarily the brainchild of Moussa Seck, member of ENDA Syspro.

but, with the vegetation gone, could now reach right across the Cap Verde peninsula and the southern coast. This intensified the effects of the winds.

After assessing the impact of previous agricultural policies, farmers quickly understood that practices had raised neither output nor income, nor their living conditions. In fact, due to the aggravating effects of droughts, these practices had severely depleted their prize assets: the natural resources. It was essential that a new form of agriculture be explored.

4.3 The adaptation story: "producing" an environment as part of sustainable modern agriculture

This case study describes innovations introduced in Sébikotane which have been so successful they have taken on legendary status in Senegal. The story began with the conceptualisation of a "third-generation" production system by a non-governmental organisation (NGO), ENDA-TM, which focused on "producing" an environment conducive to intensive agriculture that could take root in the emerging Senegalese agricultural system. Traditional production systems are known as "first-generation" systems and the systems overseen by state bodies were "second-generation" systems and did not focus on the environment or on intensive agriculture. The "third-generation" system differed from its predecessors by including an environmental production aspect – which it treats as absolutely fundamental (Box 2). What is revolutionary about the system is that it conceives of a way of "producing" the environment rather than merely protecting or conserving it.

A new analysis of problems created by climate change

As a result of climate variations since the 1970s, the area in which the Sébikotane farm is located has become ecologically and geographically hostile to agriculture, especially market gardening, its principal land-use. Why? The analysis by ENDA focused on wind erosion as one of the principal factors that had previously been neglected despite the fact that the Niayes region is an area through which many winds (Harmattan and trade winds) sweep through. The average monthly speed of these winds in Dakar ranged from 2.9 m/s in September to 5.3 m/s in March during 1980–97 (UNEP/UNESCO/UN-HABITAT/ECA 2003). Given Niayes' coastal location, these speeds are most likely even higher, making open country agriculture particularly difficult. It became critical, therefore, to find an alternative solution that would protect soils and restore lost productivity.

Niayes is exposed to brutal sea winds which had hitherto only swept through a small section of the mainland but with the vegetation gone the effects are intensified and could now reach right across the Cap Verde peninsula and the southern coast (see map) (Lycée taiba/ics de mboro 2005).

Sébikotane's new "environment production" system

The "third-generation" agricultural system is designed to promote a system of agriculture that is appropriate in a context of climate change and also secures higher yields, biodiversity benefits while improving the lives of women and girls (through reduced time spent collecting fuelwood). The system is rooted in a combination of four basic factors: technical, environmental, economic and social.

Natural techniques for intensifying production

With an output rate of 1 ton/year, it would take Sahelian farmers in general, and Senegalese ones in particular, 100 years to produce 100 tons from a single ha – unless they could extend their holdings to 100 ha by cutting down yet more trees. This is, quite obviously, a tremendously low productivity rate and is totally inconsistent with the urgent need to feed, clothe, educate and invest in themselves and their children. Accordingly, how to produce more is the first question farmers ask themselves. It takes Sahelian farmers 5, 10, 20 or 100 years to produce as much as farmers elsewhere can produce in just 12 months. Some Western farmers can grow 800 tons of tomatoes per ha/year. But how could Sahelian farmers reduce production time and increase arable space without cutting down more trees?

Agricultural intensification does not necessarily mean using more chemicals or machinery. It can be more straightforward than that: it is possible to achieve satisfactory annual production/ha simply by increasing crop cycles and diversifying to use crops such as vegetables that naturally give high yields. For example, two successive sowings of potatoes and cabbages can yield a cumulative output of 60 tons, and this is only one possible combination.

Moreover, Sahelian farmers must learn to use and apply irrigation, fertilisation and crop protection on a daily basis. To meet its pressing food needs, Africa has to compensate for its technological lag. Pluvial production systems are dominant in Africa, accounting for some 94 per cent of agricultural systems, while just 6 per cent of the continent's arable land is irrigated. Yet in terms of agricultural GDP, eight of the top 12 most productive countries in Africa are in dry or arid zones. Egypt, where it hardly ever rains, is the most productive country in the continent, simply because it production relies exclusively on its 3 million irrigated hectares. Contrast this with Nigeria, the continent's second biggest producer: it pursues pluvial hectares over 30 million ha – ten times as many as Egypt. In third place comes Morocco, which has just 1.3 million ha, but irrigates them.

It has frequently been demonstrated that irrigation is a precursor to technological development. In other words, irrigated farms are more favourable and more receptive to technological innovation (seeds, fertilisers, machines etc.)

Sébikotane's agroforestry system has been successful precisely because it is rooted in effective production techniques. In addition to the quickset hedges that lend the farm a distinct shape, the practice of contour cropping creates a microclimate that stimulates production. All the farms are irrigated, with particular emphasis being placed on drop irrigation, which is very economic with water and labour and has the added merit of fertilising while it irrigates (fertigation). Other irrigation methods used are sprinklers and ploughed furrows.

"Producing" the right environment

As far as producers are concerned, these are the factors that create conditions for optimal production. Given that it is possible to identify and define the environment, and to preserve, degrade or conserve it, then it should also be perfectly conceivable to produce it, so long as we know what it consists of. When we say there has been environmental degradation, what exactly has been degraded? If we are talking about natural resources, then we may mean that plant cover, and consequently the entire ecosystem of which it is part has been degraded. Therefore, if we can intelligently and realistically simulate plant cover, then we can erect windbreaks, offset hydric and wind erosion and positively alter the microclimate, rendering the environment a productive factor for agriculture.

Windbreaks planted in well thought-out and linear fashion make it possible not just to trace the physical perimeter of a farm, including distribution roads, but also to delineate and protect crop plots. This whole system constitutes the productive environment and confers on the new ecosystem the capacity to boost production. That is why we may say that designing and implementing such a system is tantamount to 'producing' an environment and, simultaneously, turning the environment into a producer. This releases a raft of components and complex relations between the various actors and factors within the freshly created ecosystem, leading to a food chain, habitat and substrate of biotic and abiotic elements including animals, plants, micro-flora, temperature, humidity and sunshine.

On this basis, the farmer can then devise the rules for selecting and developing the biotic and abiotic factors that yield the most benefit and minimise those that harm production – while maintaining appropriate balances to embed a sustainable system.

Gearing agricultural production towards local and export markets

Produce consists mainly of fruit and vegetables mostly for selling. Depending on target clientele, the produce is either packed (in boxes or trays) for external markets or sold in bulk on the local or subregional market. Farmers achieve average yields of about 20 tons per ha, and sometimes as much as 50 tons for speculative crops such as tomatoes. This means that farmers' income is 20 times higher than when they used pluvial agriculture system. Average gross income per ha can reach 3 million CFA francs (US$6,000). What's more, when produce is packed and exported, extra added value and jobs are created (in packaging – by sea, road and air – processing and marketing).

Social benefits: training a new generation of farmers

Some 80 per cent of Senegal's population is younger than 35. The droughts of the 1970s and 1980s impacted heavily on rural incomes, and one of the major consequences of this has been the flight of young men towards cities, where they seldom find jobs, and leaving disproportionately large numbers of women in the countryside. Agriculture in Senegal is confronted by two challenges: to boost productivity by increasing investment in farms, and to attract young people back as they are more likely to absorb the information needed to use new technologies.

This new generation of Senegalese farmer was trained and inspired in Sébikotane. They have thrust themselves into horticulture and the most demanding export markets possible. Men were the first, but women have quickly followed suit and not only have they become farm-owners but they also continue to carry out the tasks traditionally assigned to women, such as sowing, weeding, harvesting, packing and processing.

This movement constitutes a shift towards the formation of a genuine socio-professional community and citizenry. Their production systems represent a considerable stride ahead of traditional methods and are closer to high-yield modern methods, with the crucial addition of being environmentally sound. These new players are forging a place for themselves in Senegal's economy, since they are an indispensable link in the production chain, covering everything from the provision of inputs to packaging and transportation. They are generally organised into economic interest groups (EIG) or small or medium-sized businesses and are recognised as such by the state.

5 Lessons from Sébikotane adaptation innovations

The "third-generation" Sébikotane production systems have dramatically overhauled the way agriculture is practised in Senegal. The new system has earned the institutional recognition of the Senegalese government through the adoption of the "Sénégal Agricole" programme. It has also been the subject of an array of media reports, features, memoirs and theses and social events. These have covered spheres such as agriculture, pastoral farming, natural resource management, climate change, the rural economy, access to markets, infrastructure development, water and irrigation and decentralised cooperation.

5.1 Technical innovations

Techniques have been considerably overhauled from traditional methods. From rudimentary beginnings in 1985, the system now harnesses some of the most sophisticated techniques in existence. The level of technical achievement does vary between farms, but in general it is accurate to say a new breed of modern farms has emerged in the country. For example, the use of drop irrigation systems is now widespread. Similarly, packaging systems are getting more and more advanced, as is necessary in order to comply with the raft of standards and norms imposed by the international market. With such enhanced techniques, improved productivity quickly followed: cherry tomato yields reached 120 tons per ha in open country and carrots, cabbages and potatoes all exceeded 30 tons per ha. Finally, farmers have become increasingly aware of the importance of planning effective spatial layout of their farms so that they are harmoniously integrated into the natural landscape, though it is true that there are still a large number of traditional farms to be converted to this way of thinking.

5.2 Environmental benefits

Avoiding deforestation and increasing energy production

Sébikotane's third-generation production system uses windbreaks requiring the production of some 19 tons of wood/ha. This is mostly procured from planned cutting of the windbreaks every two years, a practice designed to prevent them from competing with crops. This means that in addition to producing food, this system generates a surplus of wood that can then be used as cooking fuel. This is in contrast to traditional production systems, which use natural wood for cooking the food they produce (Box 4).

It is slowly becoming impossible to fetch fuelwood and charcoal as reserves are reaching

Box 3: Providing Energy Needs

Fifty years ago, an ample supply of wood lay just 50 km from Dakar: now you would have to travel 600 km, which demonstrates the extent to which increasing population, food needs and cooking requirements are connected. The Sébikotane production system provides a long-term solution for fighting wood-clearing and the detrimental effects of climate change.

In the future it will become ever more difficult to fetch wood and charcoal in the greater Dakar area as ligneous resources dwindle. It is vital to now start applying solutions to the rising food and cooking needs.

exhaustion point. Annual food production in Senegal is around 2.5 million tons, while annual wood consumption stands at 3 million tons, meaning it takes 1.2 tons of wood to cook 1 ton of food produced. Moreover, we also need to factor in the consumption of imported food produce and other forms of cooking fuel such as gas. It is therefore of paramount importance that production systems "produce" the environment rather than degrade it by cutting down yet more wood.

A related development comes from a study (Gueye 2001) that assessed the quantity of carbon in the juice of the fruit of the cashew tree. This can be obtained by fermentation and measurement of an amount of ethanol mixed in with cellulose to produce gel fuel for cooking – this could replace charcoal, fuelwood and non-renewable natural gas and thus could save thousands of hectares of woodland from being cleared, since all that is required is the juice rather than the tree itself.

Enhancing carbon sequestration

The first assessment of carbon stocks in agro-food systems carried out by ENDA Syspro was in 1998 (Bakayoko 1999). Owing to technical and methodological difficulties, the measurement taken then concentrated solely on aerial biomass. The stocks of carbon sequestered in the aerial parts of the windbreaks was gauged at 13.46 tons/ha in a five-year-old plot and 1.19 tons/ha in a one-year-old plot. The average amount of carbon stocked in crops was 4.17 tons/ha for green beans and 1.935 tons/ha for tomatoes.

> In June 2003, ENDA Syspro carried out further measurements (Na Abou 2004) using the mathematic models described below. These take account of both the epigeal (*leucaena leucocephala*) and root part of the windbreaks. This study shows that Sébikotane's agroforestry systems sequester on average 15 tons of carbon/ha (root and aerial biomass) in five-year-old plots. This study, taking account of root carbon, was the first of its kind in Senegal. The amount of detected carbon stocks is the same as that occurring in natural prairie and tropical savannah ecosystems according to a study conducted by Cairns and Meganck (1994). If we take a ton of carbon to be worth US$15, the sequestration made possible by Sébikotane's agroforestry system is worth US$45 million to Senegal, a figure that is in addition to the revenue from agricultural output.

The Kyoto Protocol rules for international carbon trading under the Clean Development Mechanism were designed to deter rich polluting countries from buying their way out of politically difficult domestic emission reduction through investing in developing countries' forests. While this concern was legitimate, it may be that the balance has not been struck in favour of the South, particularly those countries, like Senegal, that can help take measures that avoid deforestation and sequester carbon.

This imbalance has led ENDA Syspro to devise an operational model for future regime changes that can accommodate choices by countries about whether to reduce or sequester that are guided by the type of carbon they have (fossil or non-fossil).

Fossil carbon refers to carbon stored in fossil fuels (hydrocarbons and coal) and in sedimentary rocks formed deep underground over millions or billions of years. *Non*-fossil carbon is the carbon in living plant and animal organisms. Stocks of non-fossil carbon are estimated at 2300 ± 350 Gt (Giga tons), including carbon in vegetation (550 ± 100 Gt) and soil carbon (1750 ± 250 Gt); thus, plant and soils have about three times as much carbon as the atmosphere, which only contains 760 Gt. Carbon stored in living organisms accounts for less than 1 per cent of carbon on Earth.

> The agricultural systems previously described sequester an average of 15 tons of non-fossil carbon, thanks to the windbreaks. This does not include the sizeable stocks in organic matter in the soil (6 per cent). Of all the stocks existing in nature, only non-fossil carbon (in plants and soil) and fossil carbon (in fossil fuels) can be accessed by man.

Extracting just 15 per cent of fossil carbon stocks (hydrocarbons and coal) would double carbon content in the atmosphere. The degradation of 33 per cent of non-fossil carbon would be equally far-reaching. It can be seen, therefore, that the issue of anthropogenically induced climate change relates to the balance between *fossil carbon* and *non-fossil carbon*.

> This shows that it is crucial to give priority importance to curtailing emissions of fossil carbon and sequestering those of non-fossil carbon. The experience of Sébikotane could prove to be highly note-worthy in this regard.

Some countries in the North possess large tracts of forest coverage (which constitute carbon sinks) and would like to acquire credits for these in order to help comply with their commitments entered into under the Kyoto Protocol. If this wish was granted, it would be to the detriment of attempts to reduce carbons emissions – and without such reductions there can be no long-lasting and equitable fight against climate change.

As for Southern nations, 70 per cent of their emissions are non-fossil (heating wood, agriculture, materials etc.) so they should attach most importance to carbon sequestration rather than emission reduction (which, by contrast, is what the industrialised countries must focus on). Such an approach would safeguard the principle of equity between North and South.

In conclusion, the following environmental lessons can be drawn from Sébikotane:

- In the Sahel, especially in Senegal, adapting the agricultural sector to climate change entails instilling "complementary substitution" of rain-based agriculture for irrigated agriculture, which is less dependent to climate fluctuations and can be practised all year round.
- In addition to protection and restoration, it is possible to "produce" the environment. Accordingly, the environment should be treated as a factor of production along with fertilisers, inputs and production techniques. This is the main lesson of this study.
- Desertification is, therefore, not irreversible and solutions (adaptation) to the problems linked to climate change are possible.

5.3 Food security and livelihood diversification

In China, vegetable production has caught up with and overtaken cereal production – and yet China is the world's highest producer of cereals. India, which has one of the biggest populations in the world, is making similar efforts to increase vegetable production. In Senegal, vegetables have the additional merit of helping overcome Senegal's chronic food deficit. Due to their diversity and high yields, they are ideal for compensating for poor cereal yields. Vegetable production promises rural-dwellers genuine opportunities to boost income thanks to the good market prices (twice as high as for cereals) and the capacity to increase production cycles in a single year – this is crucial when we consider that 60 per cent of Senegal's active population work in the agricultural sector, including pastoral farming, forestry and fishing, but that this sector only contributes 20 per cent of GDP. There is now ample evidence to prove that farmers, whether urban or rural, who use irrigated systems and market gardening fare better that those practising pluvial agriculture.

5.4 Additional social benefits and lessons

The use of windbreaks to neutralise the harmful effects of many years of drought and accompanying deforestation and erosion, has enabled many kinds of individuals and producers to prosper. Hundreds of new workers have been attracted to the area, improving the way they are organised and forging links with various development partners to secure support and funding. The lives of women and girls has been improved due to lessening the burden of fuelwood collection.

The social lessons that can be drawn include the following:

- The reluctance of local populations to adopt agricultural innovations was due to the failure of previous adaptation strategies. However, the successful testing of the third-generation production systems encouraged populations to appropriate new techniques.

- Applying this success story on a wider scale should be accompanied by strong support to build peoples' capacities to help them develop in a systematic way a new and efficient producton system.
- One key factor in the success of Sébikotane was the fact that the workers involved were young and had a relatively high level of education.
- To tackle rural depopulation, it is essential that all the various links in the production chain (input sale, packing, processing, transport etc.) are performed in rural areas rather than in cities.
- It often takes a long time to learn how to use this system properly: this result was only achieved after 15 years. And the national "Sénégal Agricole" programme has not yet got under way, even if all of its various components have already been applied on an experimental basis. This means development interventions and measures must be longer than the current 3–5 year cycle.

5.5 Mainstreaming implications: getting high level political and institutional backing

The expectations and involvement of politicians and donors can be critical in ensuring long-term success and scaling up. The appropriation of this experiment by Senegalese decision makers (notably through 'Sénégal Agricole') will make Senegal an environmental producer rather than an environmental consumer. Political decision makers should also take part in regional, even continental, forums to spread the word of this experience of adapting to climate change and furthering sustainable development and stimulate exchanges at continental and, indeed, Western level. But to do so requires them to be made aware of the sources of climate-related vulnerabilities and practical ways in which these can be reduced.

The 'Dakar Agricole' international conference held in Dakar on 4–5 February 2005 enabled ENDA Syspro, the inventor of this production system, to launch a discussion on a new way of planning agriculture at both local and continental level.

The involvement of political decision makers is essential if promising experiences are to be sustained and replicated elsewhere. Attracting such involvement means capitalising and spreading the word on activities and positive results. This was achieved well in Sébikotane, where the communication strategy was steered by ENDA Syspro and brought attention to the concepts that underpinned the new production systems and made all concerned aware of the need to ensure they were long-lasting.

The lessons drawn from several years of experience and experimentation at Sébikotane are:

- Donors are more likely to support an activity if it has already proved its reliability. The visits of leading figures from the World Bank, the Food and Agriculture Organization (FAO) and UNDP to Sébikotane are of huge benefit in this regard, since they resulted in promises of support for this form of sustainable agriculture.
- The government's involvement means funding is more readily available. NGOs can design programmes and then enlist the backing of the state and development partners to ensure they are applied more extensively.
- In spite of the clear ecological and economic benefits to this system, it would still be of great value to allocate a specific budget to encouraging farmers to adopt it – given that so many of them are so poor. Indeed, for a certain period, the US Agency for International Aid (USAID) offered incentives of 40 francs for each tree planted in Niayes. Sébikotane farmers planted many for their windbreaks and quickly exhausted USAID's budget.
- To ensure sustainability, private operators must seek funds from private institutions such as banks, credit unions etc. so that public coffers are only dipped into for collective utilities.

The results of the interest taken by national and international decision makers have been numerous and tangible and should go some way to ensuring the continued success of the initiative.

- In 1995, the European Union funded the construction of a road paving the way for 8,000 ha of land, thereby connecting production and consumption zones. In light of the massive contribution (80 per cent) this zone makes to the country's figures for fruit and vegetable exports, the Prime Minister gave the go-ahead in 1997 to drill six boreholes for Niayes farmers.
- The German Corporation (KFW) and the Senegalese Agency for Infastructure (AGETIP),

with the help of ENDA Syspro, enabled producers to build a packing plant to promote exports by small producers.
- The President of the World Bank visited Sébikotane farms and afterwards promised to help fund exports to the tune of US$8 million. Producers in this zone now earn some 15 billion CFA francs from exports.
- Local and regional banks, such as the African Development Bank (ADB) and the West African Development Bank (WADB), plus credit and savings institutions, are now working in tandem with the government and other partners to raise more funds to support production and exportation.
- The development of Sébikotane farms has had a knock-on effect and similar initiatives are now sprouting all over Senegal, especially in the river valley where, moreover, greater water and land resources are available.

6 Future research issues

'Sénégal Agricole' is a wide-ranging scaling-up programme jointly devised by ENDA Syspro to be applied over 33 sites in all 33 departments of Senegal. Deploying "environmentally productive" methods across 300,000 ha should make it possible to sequester some 4.5 million tons of carbon over five years, five times Senegal's total net emissions in 1995. This case study has examined part of the Sébikotane experience relating to the new system.

Further work could examine a number of issues in more detail, for example the distributional issues (who benefits most and least) and the different roles played by different actors, particularly the role of the poorest and most vulnerable groups. This would be a far from redundant question if it emerged that the vulnerable and impoverished people involved in the innovative and efficient production systems in Sébikotane did not earn more from these activities than they could earn from other endeavours – since we surely then would not be dealing with an adaptation initiative with a meaningful community dimension. We need to know whether the improved productivity and profitability of Sébikotane would mean that workers earn more or that more people are employed. In either case, we need to objectively evaluate the benefits to poor individuals, groups and communities. These issues are important because scaling up may involve problems or expose weaknesses not yet examined.

The case study also raises other salient questions. For instance, in the Sahel, where countries must absorb rapid demographic growth and are undergoing radical urbanisation, it may be useful to perform an analysis of the constraints and opportunities presented by the experiment described here and determine how applicable they may be to other greater urban areas. Why? Because the specific conditions relevant for the success of Sébikotane may not pertain elsewhere. Issues that are important to note are that Sébikotane is in the natural hinterland into which the greater Dakar agglomeration will spread and following the recent administrative reform in the name of growing decentralisation in Senegal, it is officially classed as an urban commune. This means the pressure on land will grow from urban sprawl introducing increased competition for land and potentially more conflicts over agricultural activities, especially those that require large tracts of land.

Also, while it has been possible in Niayes to adapt agriculture to cope with drought conditions, no solution has yet been found to the problem of salt ridge intrusion due to dwindling groundwater tables. Similarly, in order to protect the coastline, the government, with backing from development partners, planted a 200 m-wide cluster of trees and vegetation along 150 km in Niayes. Since it lies by the coast, Niayes is exposed to a host of risks related to climate change (such as drought, dwindling groundwater tables, salination, coastal instability etc.) these problems of "success" need to be examined in more detail.

There is also ample scope for further in-depth study of Sébikotane to determine which of the innovative aspects could best be combined with more traditional agricultural practices. For example, some well-documented traditional Serère production systems in the Sine region (cf. Pélissier 1966) are already held up as examples of complex, time-honoured systems that struck a respectful balance with their environment by combining crop rotation, wood-growing and the use of humus to restore soils that deteriorate on a cyclical basis but is then left to rest through fallow periods and pastoral farming that produces manure. These production systems demonstrated they were well capable of coping with the colonialists' policy of intensively cultivating groundnuts and the populations' need to continue growing subsistence crops. The villages that engaged in this practice used to plant *Faiderbia albida* trees to complement other agro-pastoral activities. The *F. albida* enhanced soil fertility and meant the land did not have to lie fallow for extended periods, and the cluster of trees provided animal feed and wood. Concomitant pastoral farming meant there was a ready supply of milk, meat and manure, with the latter being used as fertiliser for crops such as peanuts, millet, cotton and *niébé* beans.

In this way, the example of Sébikotane could be invoked to help update traditional good agricultural practices by rendering them more efficient (thanks to scientific research) and enhancing the technologies used and harnessing social innovations. These innovations will ensure that any profits made are invested in underprivileged groups, who are the most vulnerable to the harmful effects of climate change.

The positive results achieved in Sébikotane could also inspire plans for urban agriculture in a bid to eradicate poverty. We are quickly reaching the time when cities will be home to the majority of Senegal's population, and as these urban areas sprawl, less and less arable land becomes available and sources of pollution proliferate, a fact that damages peoples' health and thus impedes their ability to produce. Yet issues relating to urban poverty and peri-urban agricultural systems are under researched.

7 Conclusions

The objective of the Linking Climate Adaptation Project of which this case study is a part, is to identify climate change adaptation strategies led by disadvantaged, vulnerable communities, particularly those that have succeeded.

It is obvious that in the specific case of the Sébikotane initiative, the production systems devised by ENDA Third World's ENDA Syspro team appears to successfully combine the goals of adaptation, mitigation and biodiversity conservation. Examples such as these should be supported by the NAPA process as ways in which climate change, seen as current and future variability, is addressed simultaneously. To summarise, the main lessons from the Sébikotane case study are that it is both possible and desirable to link attempts to adapt to climate change to efforts to mitigate emissions and sequester carbon. The former are the concern of communities who are well capable of observing that the effects of climate change exert a direct impact on their living conditions. As for the latter (mitigation/ sequestration), their value to communities is less obviously apparent since they relate mainly to the wider environment and the commitments of Northern governments. Accordingly, the main reason they could be of interest to local communities is because they could generate sustainable livelihoods through income diversification, through better energy production and enhanced biodiversity benefits.

For this to happen, climate change concerns must be reflected in all sectors of economic life in the country. This will prevent any recurrence of the obstacles that previously impeded the growth of productive, appropriate agriculture. Adapting agriculture to climate change must be tied in with other developmental problems that aim to reduce vulnerability to current and future climate change.

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