Chapter 18

The return of Sanio millet in the Sine

Rational adaptation to climate evolution

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Introduction

Sanio millet[1] has reappeared in villages in the Sine, between Bambey, Diourbel and Fatick, since the mid-2000s. However, this long cycle millet had disappeared from farms in the northern half of Senegal in the 1970s because of the sudden decrease in rainfall. It was still present further south in the wetter regions of Saloum and beyond as far as the Casamance. As rainfall depths increased from the mid-1990s everywhere in Senegal (SALACK *et al.*, 2011), we put forward the hypothesis that this return could form a robust agronomic 'marker' of recent pluviometric evolution in central-western Senegal and show the ability of farmers to adapt rapidly and independently—i.e. without the support of agronomic engineering[2]—to changes in their environment.

However, although the climatic opportunity provided by the return of rainfall seems to be a necessary condition for the production of Sanio, it may not be enough to explain why Sanio is not chosen by all farmers, as it was in the past. Since the climate change theme has become an ordinary paradigm of science and public action, it has become commonplace to recognise that agriculture in Africa lacks financial and technological resources for adapting to climatic and environmental events (ADGER, 2006a and 2006b). But individual or collective adaptation is not new for African

1. 'Sanio' is the Wolof name for this millet variety. The Serer in the Sine call it 'Matye' (pronounced 'match').

2. After the dry decades, research has been focused mainly on promoting short cycle varieties with small demand for water.

farmers, who put up every day with precariousness (of resources and living conditions) resulting from variations and extreme climatic events. It is above all an inherent need in any strategy for the survival of the most vulnerable families. Thus, in the same way that the climate is probably not a sufficient condition for adaptation, poverty is not an absolute limit either. Adaptation (or the option of adaptation) responds to a complex set of constraints, opportunities and choices driven by farmers' pathways and capacity. The agricultural and cultural memory of the stakeholders and the system, famers' resources (land, labour and funds), the farming system used and professional influences can explain among other factors that considerable differences are observed in agricultural adaptation practices in the same climatic context and in a generally poor farming community.

Within the framework of the ESCAPE project (2011-2015), we examined the reappearance of Sanio millet in the Serer agricultural region between Bambey, Diourbel and Fatick in order to gauge its scale and to understand the different determinants, whether these were biophysical, economic or socio-cultural. First of all, we wanted to verify the role of the increase of rainfall in this process and evaluate the impact of climatic risks on the production of this crop. A sociological and agronomic survey was conducted on a sample of 1000 farms and completed by discussion with farmers and field observations. This gave an explanatory model of the return of Sanio on farms and an assessment of the areas used for the crop. Finally, we undertook a description of the dynamics of the sowing of Sanio using a spatial and historical analysis. The first local history of Sanio was reconstructed in order to examine the capacities and limits of adaptation to climate change of small family farms in this region of Senegal.

An agropastoral region with climatic and demographic constraints

Our study zone is in the Senegalese groundnut zone, south of the former Baol kingdom, and covers the north of the former Serer kingdom in the Sine and the administrative regions of Fatick (mainly), Diourbel, Thiès and Kaolack (BECKER and MBODJ, 1999; BECKER, 2014). The Sine area, population and society have been described at length since the independence of Senegal (PELISSIER, 1966; CANTRELLE, 1966; LERICOLLAIS, 1972) thanks in particular to a system of ecological, social and sanitary observation of 30 villages in the Niakhar administrative unit (DELAUNAY *et al.*, 2013) for over 50 years.

The region has a semi-arid Sudano-Sahelian climate. Temperatures are high (average 28.1°C in Bambey in 1980-2013) and rainfall is low (512, 474 and 546 mm respectively at Bambey, Niakhar and Fatick in 1980-2013), with precipitations mainly between mid-June and the end of September, with strong inter-annual variability in

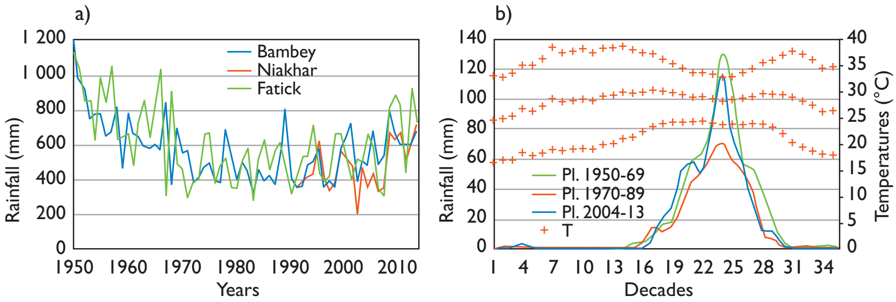

Figure 1.

Figure 1. (a) Evolutions of annual rainfall since 1950;
(b) average decadal pluviometry for the periods 1950-1969, 1970-1989 and 2004-2013
and maximum, minimum and mean temperatures at Bambey for the period 1990-2013.

quantity and distribution (Fig. 1a and 1b). The short rainy season, referred to as 'winter', means that only one crop cycle is possible each year. As everywhere else in the Sahel, rainfall decreased strongly at the beginning of the 1970s, falling from 719 mm in Bambey (780 mm in Fatick) for 1950-1969 to 478 mm (604 mm) during the next 20 years. The dry phase lasted for nearly three decades before a recovery of cumulated rainfall in the mid-1990, and in particular an improvement from August to mid-September (SALACK *et al.*, 2011).

The agropastoral system has kept its dominant original features for more than 50 years. The positions of villages and the first land clearance were preferably on flat areas of soil called *dior*. These are predominantly sandy soils with a permeable upper horizon and easy to plough and loosen. However, moisture retention and fertility are mediocre, generally leaving peripheral low-lying zones of sandy clayey '*dek*' soil (5 to 10% clay in comparison with 2 to 5% in '*dior*' soil). This soil is less present, more fertile and has better moisture retention capacity but is less permeable and hardens rapidly after rain. This land is used mainly for millet *(Pennisetum glaucum)*[3] and groundnut *(Arachis hypogaea)*, but crops also include sorghum *(Sorghum bicolor)*, cowpea *(Vigna unguiculata* subsp. *unguiculata)* and roselle (*Hibiscus sabdariffa*). Millet is a basic food crop while cash income is drawn mainly from groundnut, which also contributes to food supplies (grains, oil and stalks for livestock). In recent years income has been more frequently complemented by sheep and even cattle fattening and by other crops such as watermelon (*Citrullus lanatus*).

There are two types of millet—Souna and Sanio. They have been bred for several centuries to adapt to climatic uncertainties, soils and farmers' requirements (grain and straw). Souna millet[4] has a short cycle lasting about 3 months and is fairly constant as it has low photoperiod sensitivity. The cycle of Sanio millet is about a month to a month and a half longer and varies according to the sowing date as it is much more sensitive to the photoperiod. This character is adaptive to the date of the start of the rainy season (VAKSMANN *et al.*, 1996; KOURESSY *et al.*, 2008), enabling the plant to

3. Pearl millet has several names, including '*mil pénicillaire*', '*mil à chandelles*', '*petit mil*' and '*mil perlé*'.
4. ' Souna' is a Wolof term. The Serer word is 'Pod'.

Figure 2.
Figure 2. Photos of Serer land and agricultural practices.
Top to bottom and left to right: the country during the dry season; paddocking area; sowing with an animal draught seeder (groundnut here); emergence of millet; millet at about 1 month; Faidherbia albida *acacia and its fertilising effect; growing millet; Souna millet shortly before harvesting; groundnut shortly before harvesting; Sanio millet shortly before harvesting; Amadou Diouf, a Serer farmer in Nguayokhèm who has never stopped growing Sanio, holding a Sanio plant here; using an animal draught hoe to lift groundnut during the harvest; Souna millet stalks and the granaries in which they will be stored; storage of millet straw in stacks and cowpea stalks in baobabs.*

adjust its cycle length to that of wintering. Depending on rainfall, if they germinate early—that is to say in the first 10 days of June—the cycles of Sanio and Souna are some 135-140 and 95 days respectively, whereas if they germinate late at the end of July or the beginning of August their cycles last approximately 110 and 85 days. Sanio is taller (3-3.5 m in comparison with 2-2.5 m) and has more stems and straw than Souna but nevertheless the same quantity of grain, or perhaps a little less, with crop potential peaking at 3 tonnes per hectare under the best conditions (Dancette, 1983 a and b; Siéné Laopé *et al.*, 2010). In relation to this figure, it is useful to remember that farmers' millet yields in this region vary from 500 to 700 kg/ha (average figures for the last two decades) because of numerous constraints (low fertility, small fertiliser application, biotic attacks) in addition to rainfall deficits (Kouakou *et al.*, 2013).

Finally, Sanio differs from Souna in its aristate heads (Fig 3a): the term indicates the presence of long rigid awns (5 to 6 cm), also called beards, that protect millet spikes very effectively from attack by birds. Souna millet spikes do not have awns (Fig. 3b). The character is very useful at the end of wintering when Sanio millet is alone in the landscape and is thus a clearly visible target for millet-eating birds (*Quelea quelea*). This protection means that farmers can take their time and award priority to other agricultural work (groundnut harvest and postharvest operations) before harvesting Sanio. It should be added that Sanio grains are distinctly larger than those of Souna[5]. In addition to their exceptional adaptation to drought, Souna and Sanio millet are adapted to light, poor *dior* soils, even if Sanio also grows in slightly more hydromorphic *dek-dior* soils. Grain and straw production are completed by those of groundnut, grown in the same soils, and of sorghum that does well in *dek* soils. This agro-diversity is also a good feature for the staggering of farmwork.

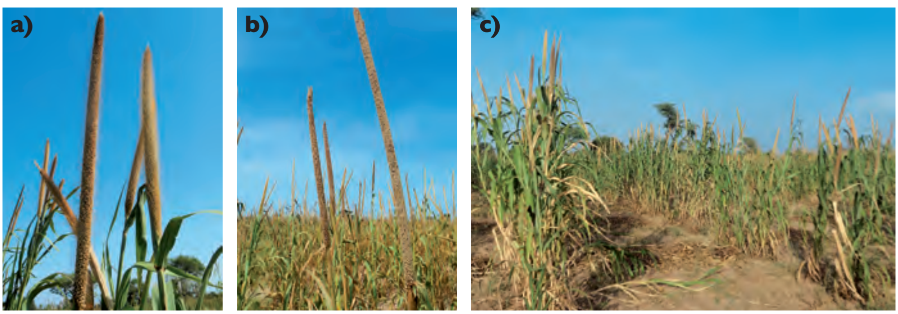

Figure 3.
(a) spikes of Sanio; (b) spikes of Souna; (c) rows of Sanio (after the harvesting of Souna).

Livestock are associated with crops in an agropastoral system that is exceptional in West Africa. Numerous herds and flocks belonging to sedentary farmers roam fields abandoned to grazing for varying periods during the dry season. Most then leave in transhumance in the rainy season and some are kept on local land in the rare fields where enclosed annual fallows are still used (Faye *et al.*, 1999). Livestock obviously benefit from crop residues too. The combination of crop and livestock farming maintains soil fertility without the need for long fallows. In fact, the maintenance of

5. This varies according to filling. Maximum weights of 1000 grains are 8 to 9 grams for Souna and 10 to 12 grams for Sanio. However, Sanio grains are often smaller than Souna grains because of the shortage of water at the end of the season.

fertility results from several complementary factors: 1) a grain crop with small requirements—millet, 2) the use of flock and herd manure either directly in paddocking or by the transport of manure and litter, 3) the use of domestic organic wastes, 4) respect of a grain-legume rotation generally combining millet and groundnut, 5) fallows and 6) the maintenance of afforestation with *Faidherbia albida* acacia whose nitrogen-rich leaves are cut for livestock or fall to the ground to create 'patches of fertility' (Fig. 2).

These complementary practices have contributed to the structuring of local land areas, with first a circle of fields ('*champs de case*') around dwellings. These are the most fertile as they benefit from domestic wastes and paddocking—especially of small ruminants—and possible manure application. Outside the circle are found other 'bush fields' with other fertility management methods in proportions that have varied in time and differ a little between villages. In addition, *champs de case* were traditionally managed with continuous monoculture of Souna millet while Sanio millet, together with groundnut and fallows, accounted for the majority of the arable bush fields and was a dominant feature of the landscape (LERICOLLAIS, 1972). This distribution gave the best management of food security. The omnipresence of tree and the fine mosaic of fields are the result of long, ancient fashioning of the landscape by farmers.

These practices and the use of animal draught seeders and hoes allowed annual use of almost all the agricultural land. This land thus ensured the maintenance of a growing population in spite of the (imposed) abandoning on one-year enclosed fallows from the 1970s onwards (LERICOLLAIS, 1972; GARIN *et al.*, 1999). Sine has thus long been described as one of the most densely populated parts of Senegal. In 1966, CANTRELLE (1969) estimated the population density in the Niakhar district to be 85 per km² (in comparison with 15 per km² for Senegal as a whole). In 2013, the population density in the 30 villages observed in the Niakhar district reached an average of 226 per km², with the density in three village exceeding 400 per km². However, seasonal migration has lessened the population pressure slightly since the beginning of the 21st century as, depending on the month, 6% to 11% of the population is temporarily absent from the villages (see Chapter 14).

In 1934, the colonial authorities launched a programme aimed at favouring the settlement of 'new lands' around Kaffrine by Serer from the Sine and the Saloum—reputed to be good farmers—while reducing pressure on the Sine areas that was already considered to be saturated. This idea was taken up and amplified after independence in the third 4-year plan (1969-1973). Thus from 1972 to 1980, the Senegalese authorities organised the movement of several thousand Serer families although they were deeply attached to their land even though it was densely occupied. These managed and then spontaneous population flows were not as intense as expected (5.3% of the families counted in 1976 in the Niakhar district had left to colonise the pioneer fronts of the 'new lands' of eastern Senegal between 1972 and 1987) but they contributed to release land and gain about 5 years of population growth in this district (GARENNE and LOMBARD, 1988). It is estimated that in the 2000s definitive departures totalled an average of 700 per year in the Niakhar observation zone (that has a population of more than 40,000). This emigration was mainly for nuptial and family reasons (see Chap. 14). Finally, the continuous and accelerated population increase has resulted in divisions of property when land is passed, with the sub-division of fields and necessitating technical innovation and farming potential. In the land at Sob (a village in the Niakhar observation zone), field size decreased from 1.23 ha (Lericollais, 1972) to 0.84 ha (the authors' calculation) between 1965 and 2012 (47 years), that is to say a decrease of a third.

In addition to the rapid growth of the population, climate is the most important macro-factor with regard to the evolution of Sahelian agrosystems. The climate shock of the 1970s thus strongly modified landscape and disturbed local areas. Shortage of rainfall resulted in a considerable decrease in the number of trees: in the village of Sob, the number of Faidherbia *albida*, a tree whose importance has been mentioned, decreased by nearly 34% from 1965 to 1985 (Lericollais, 1990). Likewise, the decrease of rainfall and the shortening of the rainy season resulted in the abandoning of Sanio millet. Lericollais observed that from 1965 to 1967 this formed three-quarters of the area sown with millet (Lericollais, 1972). After the major droughts of the 1970s, the crop disappeared almost completely from the Niakhar district.

Material and methods

Our analysis of the return of Sanio combined several methodological approaches, ranging from field observations to modelling using quantitative surveys and simulation. These aspects were completed by the gathering of statements concerning farmers' practices and motivation.

Study of the climate determinant in the return of Sanio

The role played by the climate in the return of Sanio was studied through its impacts on production by performing simulation of the growth and yields of Sanio and Souna during the period 1950-2013. This was performed using the crop development simulation model SarraH©CIRAD (Baron *et al.*, 2005; Dingkhun *et al.*, 2003) and the official rainfall records for Bambey (14°42'38''N; 16°29'00''W), Niakhar (14°29'10''N; 16°23'48''W) and Fatick (14°20'20''N; 16°24'20''W) and climatic data for Bambey. A single soil type was considered, with average available water capacity of 90 mm/m, as in this region millet is grown in sandy *dior* and *dior-deck* soils whose available capacity ranges from 80 to 100 mm/m (Affholder, 1995). The parameters used for the simulations of the varieties Souna and Sanio were those of Kouakou *et al.* (2013) and differed only in cycle lengths with, in particular, respect of the photoperiod sensitivity of Sanio described above. The criterion used in the simulations for the start of sowing was cumulated rainfall of at least 15 mm during two consecutive days. This is very realistic and close to farming conditions as millet is sown dry before the rains in this region at the end of May and beginning of June and germination takes place with rainfall of some 12 to 15 mm. Other sowing criteria were simulated and in particular that of SIVAKUMAR (1988)[6] but they did not cause any particular difference in the results.

Analysis of the social, economic and cultural factors associated with the return of Sanio

To gain information about social and farming logic and the driving forces that led Serer farmers to grow Sanio or not, our main work was a survey with a double questionnaire in 30 villages in the Niakhar district (i.e. within the framework of the IRD Niakhar Health and Demographic Surveillance System[7]), covering a random sample of 1,061 family farms (32% of the households under observation). Two questionnaires were submitted at each farm. A ‘household’ questionnaire was submitted to the head of the farm; this made it possible to set out the cropping system used in the 2013 rainy season. In addition, more than 45 questions concerned the growing of Sanio and Souna millet. An ‘individual’ questionnaire was then submitted to a farmer chosen at random among the farmers of the household who had cultivated at least one field during the three years preceding the survey. This questionnaire was focused on certain crops intended for sale, such as groundnut and watermelon, or for cattle fattening. Questions also concerned perceptions of the past and present climate and knowledge about climate change. The survey was conducted from December 2013 to March 2014.

The survey using questionnaires was completed by various focus groups and individual interviews that enabled us to better understand decision making processes and reasoning that were favourable or unfavourable with regard to the growing of Sanio. The group interviews also led to collecting information about the history of Sanio in the villages, its maintaining during the drought period and its distribution among Serer farmers and in the area. The main focus groups were held in the villages of Sob (March 2012), Ngayokhèm (November 2013 and October 2014) and Keur Ngane (November 2013).

The explanatory model of Sanio growing was developed using data from the questionnaire survey completed by information collected on a routine basis by the IRD Niakhar Health and Demographic Surveillance System. Analysis of the data was performed in two stages. The first consisted of developing a number of predictors. The number of persons old enough to participate in work in the fields (> 6 years old) and average duration of seasonal migration of adult men (15-55 years old) are two indicators developed by processing demographic data (Niakhar surveillance system). A cash poverty index was developed from household purchases of goods (food and non-food). The food poverty threshold was determined on the basis of the set of foods eaten by the household, with the size and composition of the latter taken into account.

6. Sivakumar defined a criterion for the successful sowing and establishment for millet consisting of a minimum of 30 mm rainfall during 3 consecutive days followed by no dry spell longer than 7 days during the next 30 days.

7. See DELAUNAY et *al.* (2013) for a description of the Niakhar Health and Demographic Surveillance System.

The non-food poverty threshold is based on the average consumption of non-food goods per adult-equivalent per day for households whose food consumption is close to the food poverty level. The total poverty line (food + non-food) is CFAF 479 in the Niakhar zone. Once this threshold had been defined, we valued the daily consumption of households to classify them on either side of the poverty line. The incidence of cash poverty was assessed at 52% in the Niakhar area.

To show that the increase in rainfall is a necessary condition but not sufficient for the growing of Sanio in the region, we assessed the effect of the characteristics of the farmer and his farm on the growing of this grain. Among individual and household variables, the model takes into account the sex of the farmer, his/her perception of the present climate, the past growing of Sanio millet by the farmer's father, the average duration of seasonal migration by the men of the household, the dominant caste of the household, the cash poverty of the household and the number of household members of working age. The farm variables considered were the labour available, the farm area owned, the borrowing of land, commercial production (watermelon and beef fattening) and the number of workers in the household with an income from a source other than farming. The model was tested using binary logistic regression with the Stata® 13.1 program (2014; Stata Corporation, College Station, Texas, USA).

The sample developed for the ESCAPE survey was designed to be representative of all the 30 villages monitored. However, the variable to be explained—growing Sanio millet—was found to be fairly rare in farming (as discussed below Sanio is grown by only 25.4% of the households surveyed) and very unevenly distributed among the 30 villages. The logistic model was subsequently found to be not robust enough (poor capacity of the mode to predict the farmers that had grown Sanio). We therefore performed an analytic correction of the sample by case-control sampling to increase the sensitivity of the prediction model. The numbers of farmers were knowingly balanced between those who had grown Sanio and those who had not. The model tested on the non-representative sample gives results that, as they are, cannot predict the use of Sanio. However, the capacity of the model to explain the choice of growing Sanio remains unchanged insofar as the coefficients associated with the explanatory variables are not changed. In fact, all the statistical inference concerning the coefficients remains valid: confidence interval, significance test and odds ratio (Rakotomalala, 2014). Finally, we cleaned the model data (analysis of residuals) by removing outliers and those that weighed on the model in an exaggerated manner (leverage points and influential points). The corrected and cleaned model was much more robust (Hosmer Lemeshow test) and its sensitivity increased from 19% before adjustment to 62% after this (Table 1).

Cartography of the present cultivation of Sanio and its spread

Sanio millet has always been grown in the south of our investigation zone, that is to say in zones that are naturally wetter. We thus wished to understand the dynamics of the reappearance and spread of Sanio in our study region, a drier area between

Bambey and Diourbel in the north, Fatick in the south, Fissel in the west and Gossas in the east. As the zone is larger (more than 1,000 km²), we defined a simple, rapid method to obtain reliable information about the presence and the date of reappearance of Sanio in this area. The work consisted of travelling along the roads and tracks in the zone and questioning farmers in each village, using a questionnaire with about a dozen questions. The geographic coordinates of the site were recorded by GPS in each case. The questions concerned 1) Sanio growing in the 2013 rainy season, 2) the year that it had reappeared in the village, 3) the advantages and disadvantages of Sanio as a crop and 4) the presence and names of farmers who had never stopped growing it. Although only a small number of questions were used, they enabled validation checking and the telephone numbers collected allowed certain verifications to be made. This 'light' geographic survey was conducted from April to August 2014. In all, we obtained information about Sanio growing at 240 locations in 2013. The double questionnaire survey conducted in the Niakhar zone also provided information about the dates of the resumption of Sanio growing in the 30 villages covered.

A crop that is possible again but still risky

The simulations performed during g the period 1950-2013 show that the decrease in rainfall meant that it was no longer possible to obtain even modest regular yields of Sanio during the 1970s and 1980s and almost the whole of the 1990s (Fig. 4a). Growing Sanio only started to be really possible again at the beginning of the 2000s. However, it has always been possible to grow Souna millet, but of course with a few very bad years. The water constraints on Sanio production decreased distinctly overall from the end of the 1990s but with poor performance in some recent years[8]. In contrast, it is observed that it has always been possible to achieve good straw production with Sanio. This biomass production is usually greater than that of Souna production (open field sowing using the same procedures) because its cycle is about a month longer and it is tall. Indeed, it is mainly the flowering and grain formation phases—that start roughly when Souna is reaching maturity—that can be subject in the zone to strong water constraints, depending on the earliness of the end of the rainy season.

These results correspond in all respects with the information provided by farmers (focus groups, interviews and surveys). Almost all explain that Sanio was no longer grown because its cycle was no longer compatible with the small rainfall that was concentrated in time—a little more than two months— in the 1970s, 1980s and 1990s

8. For example, in 2002 rainfall was historically low in the Niakhar zone with hardly more than 200 mm.

(Fig. 7b). According to the farmers again, the beginning of the 1980s seems to have been when Sanio was abandoned, doubtless as a result of a succession of poor crops during the 1970s. On the other hand, they observed that climatic conditions were favourable for Sanio again towards the mid-2000s. Thus, in the questionnaire survey of the Niakhar district, growers of Sanio stated that this millet variety reappeared in 2007 (on average) and that they had been growing it since 2009 (on average). Finally, 17% of these farmers stated that Sanio had never disappeared from the crops of their villages; two thirds (63%) of the farmers saying this live in the villages of Sass Ndiafadji, Ngayokhèm, Kalom Ndoffane and Diohine.

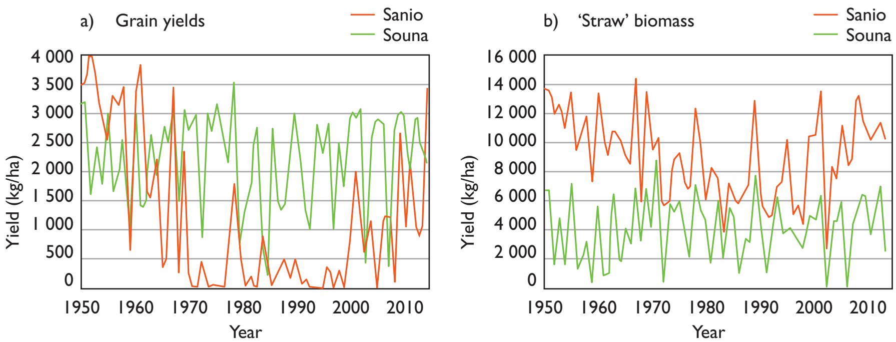

Figure 4.
Simulation of (a) grain yields and
(b) straw biomass (stems and leaves) in Sanio and Souna millet
during the period 1950-2013.

In addition to, and linked with, the climatic risk, farmers mention insect-related risks. Each of the two risks is mentioned in approximately 40% of answers to the question concerning the problems and disadvantages of growing Sanio (Fig. 5b). The farmers stress that insects damage Sanio especially in the years when rainfall ends early (the problem can also affect Souna millet but to a much lesser degree). The insects concerned are blister beetles (*Psalydolytta vestita* and *Psalydolytta fusca*) and earwigs (*Forficula senegalensis*) that suck and destroy ovules and grains. Most farmers say that losses can be considerably more than 50% of Sanio grain and some mention grain losses of 80% to 90%! Furthermore, questioned about the reason for the abandoning of Sanio, a few old farmers even mentioned 'the abundance of insects' before talking about the decrease in rainfall. Finally, in a few villages where Sanio had not yet been introduced but that are juxtaposed with villages that had started growing Sanio again, the farmers pointed out that insects tended to attack the crops of the precursors growing Sanio and even attacked Souna as well. According to these farmers, this is a strong constraint for the replanting (and distribution) of Sanio. Although we have not analysed the problem more deeply, it thus seem reasonable to consider that the pressure of these insects increased in the 1970s as one dry year followed another and the area under Sanio decreased and that this may have contributed to speeding up its disappearance.

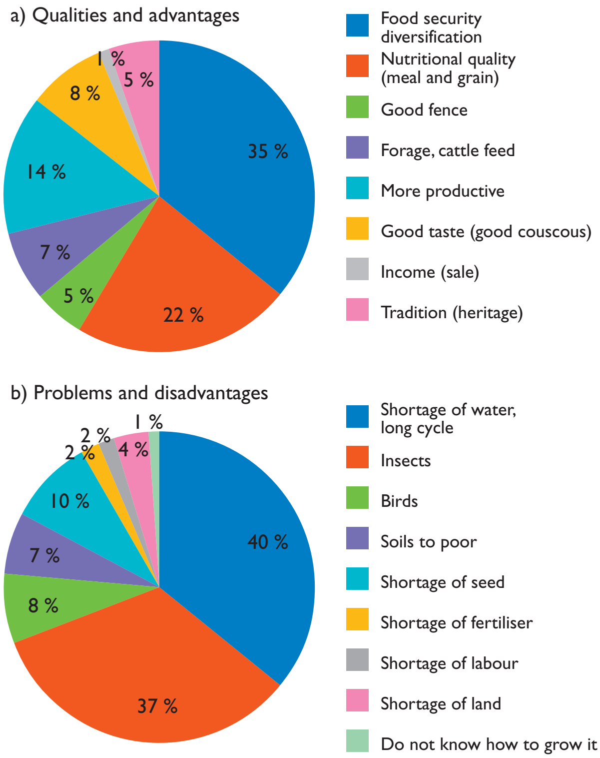

Figure 5.
Qualities, advantages and interesting features (a)
and problems, constraints and disadvantages (b) of Sanio mentioned by farmers
(% of times that the factor is mentioned; several factors may be mentioned)
(light geographic survey, ESCAPE 2014).

A crop whose qualities are appreciated and that is easy to grow but of no monetary interest

Sanio grain and stems have many qualities that are of interest to farmers. When asked questions such as ‘Why do you grow Sanio millet?’ or ‘What are the advantages of Sanio?’ in focus groups, interviews and surveys farmers always highlight the food quality of Sanio grain (and/or meal) and the quality of residues, more precisely of stems, saying that it tastes better, makes better couscous, is easier to digest and is more filling than Souna. We were also told that it is easier to eat uncooked after soaking in water (a method used by shepherds, who add sugar) than Souna and that this is more pleasant with Sanio because the grains are larger and tastier than those of Souna. But we were also told that Sanio meal, couscous and boiled grain kept less well during the winter (they do not last through the night once cooked) than those of Souna and so it was preferable 'to eat Sanio before the next winter', because 'it caused children's diseases during wintering'. There are thus clear differences between the grain of the two types of millet that farmers know well.

Sanio stems are much appreciated—more than those of Souna—for roofing and fences 'that last for a long time with Sanio'. They are also considered to be better as forage than those of Souna and 'almost as good as those of sorghum'. In addition, when farmers mention cultivation risks in the form of small yields or no crop at all in certain years they insist that 'there are always stems'. Finally, some farmers asked us whether it would be possible 'to have millets with the cycle of Souna for grain and stems like Sanio'—a clear summary of things.

The main and almost only weakness of Sanio are the problems mentioned above, that is to say risks linked to rainfall and damage by insects (Fig. 5b). More rarely, certain farmers also mention soil fertility weaknesses and say that Sanio millet needs fertile, more clayey soil (*dek* type) to give a good yield. Finally, even if this is little mentioned directly by farmers, another weakness of Sanio is that it is hardly a commercial crop and there is no prospect of income. It is true that this makes it no different to Souna as millet is mainly for on-farm consumption (only possible surpluses are sold, generally in small quantities on the local market) but this is no 'compensation' for the production risks.

To conclude, it should also be stressed that the renewed growing of Sanio does not involve any particular problems for farmers as no technical or technico-economic switch is involved, unlike watermelon, rice and even maize, and it does not have any particular labour requirements. Sanio can be sown dry like Souna using the same draught seeder and even simultaneously if the two are grown as companion crops (farmers first sow rows of Souna and then rows of Sanio) (Fig. 3c). Neither variety requires any particular inputs or pesticide treatment.

However, farmers recognise that they have certain difficulties in growing Sanio and consider it to be 'more tiring'. Indeed, the crop requires a return to the fields at the end of the season when the other jobs have been completed but the harvest is not in competition with the others. Some farmers say that a Sanio fields crop requires three hoeings instead of two, although others say the opposite a 'Sanio covers the ground well' and that 'this depends on row spacing'. It also appears that farmers harvest it in two passes, first to gather the best ripe spikes and then a second time. Finally, it seems that harvest is more difficult—'unpleasant'—as the spikes are aristate and could wound hands and especially eyes (the bristles become detached and can be blown) even though there are harvesting techniques in which the worker can protect himself and then remove the bristles easily by running the spikes on the ground. Women also pointed out that crushing Sanio is difficult and unpleasant if the bristles have not been removed before the storage of the spikes. There is no doubt that the lengthening of the working season and perhaps the comparatively hard harvest that explain why 89% of the farmers questioned in the Niakhar region said that Sanio requires a lot of labour. This is also said by farmers in interviews: 'It is tiring to carry on working hard late in the season when all the other jobs are finished'.

Finally, there are no particular problems even if growing Sanio again involves the discovery of a few 'new' hardships and lengthens the working season. All that is necessary is a supply of seed and to decide to devote land to it.

Continued Sanio cultivation areas from which seed has been distributed for 10 years

The Sanio distribution area (Fig. 6a) shows a recent distribution process that seems to be centred on two groups of villages where this variety has always been grown in spite of the decades of drought: the area around the village of Diakhao—former capital of the Kingdom of Sine—and the zone lying between the villages of Ngayokhèm and Niakhar. Sanio spread strongly from these two areas from the beginning of the 21st century, extending to the north (Bambey and Diourbel) and west (Fissel). Thus in 2013 it was grown in 61% of the 240 sites covered by our light geographic survey whereas it had been present at only 23% of the sites in 2000 (Fig. 6a).

We were surprised to observe the continued attachment to this grain in a large number of villages, with its uninterrupted presence mentioned for 45 of the 240 sites (19%) of our light survey (Fig. 6a) and in 14 of the 30 villages (47%) of the questionnaire survey, although this was conducted in one of the two areas (Fig. 6b). However, very few farmers in these villages continued to sow Sanio. In Ngayokhèm, where four out of five farmers (78%) were growing Sanio again in 2013, we identified only three farmers who had grown and conserved it during the dry decades.

The few farmers who continued to grow Sanio in spite of shortage of rainfall refer to extraordinarily simple reasons and techniques. Amadou Diouf, a Serer farmer in the village of Ngayokhèm who said that he had always grown Sanio, explained that he always sowed a minimum of a few rows of Sanio between rows of Souna and that he always had enough seed for sowing again in the following year without having to search for another source of supply. His grain production was rarely sufficient for consumption but 'there were the stems' that are 'very good for fencing' and there was always the hope that 'there might be good production again one day'. Even if no farmer put it this way, their statements—like that of Amadou Diouf—indicate strong attachment to this millet variety whose qualities they firmly recognised.

Of course it is possible that in some years farmers had to obtain Sanio seed from the south, either by going to purchase it or by gifts or exchanges with farmers—relatives or not—in the Saloum or the 'new lands'. But the strategies described by Serer farmers show their determination not to lose traditional millet varieties.

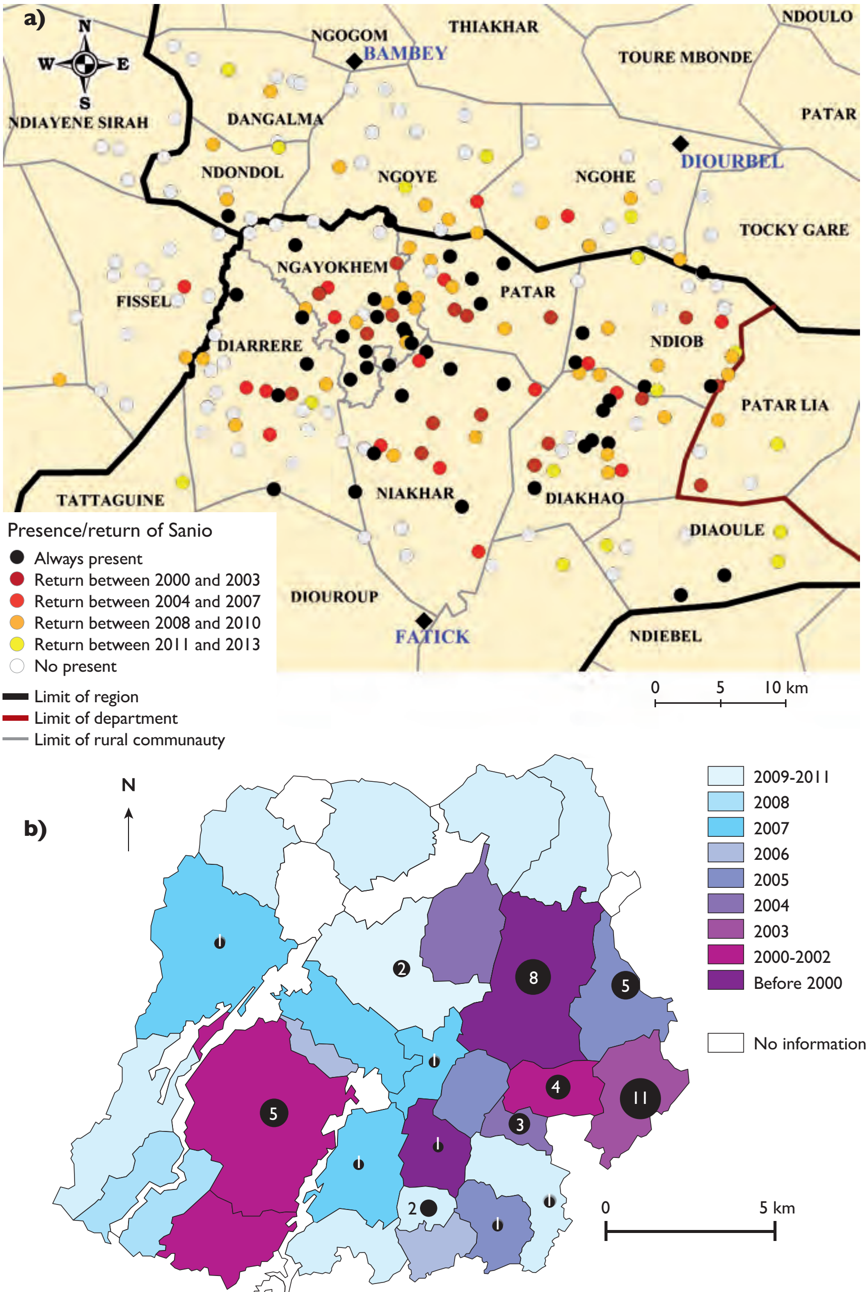

Figure 6.
(a) The presence and year of return of Sanio in the region (light geographic survey, ESCAPE 2014);
(b) year of recent resumption (after 2000) of Sanio growing in the villages
in the Niakhar zone and villages identified as having always grown this crop
(the number of persons surveyed who made this declaration is indicated in black circles
(questionnaire survey, ESCAPE - 2013/2014).

The recovery of rainfall: a necessary condition but not enough for the recovery of Sanio

In the Niakhar survey zone, 270 of the 1,061 farmers questioned (25.4%) chose to grow Sanio in 2013. However, only 89 (14%) of the 630 fields concerned by Sanio were sown with Sanio alone as a field crop. The majority were sown with a combination of Souna and Sanio with fewer rows of Sanio, generally with 1 row of Sanio to 5 rows of Souna. Thus in 2013 Sanio was only grown on 2.8% of the farmed area in the Niakhar zone and formed 7.3% of the area under millet. Sanio as a sole crop was grown only on 1.2% of the farmed area (Fig. 7a). For growers of Sanio (25.4% of farmers using 28% of the area), Sanio was on 10% of the sown land and on 27% of the area devoted to millet as sole cropping as a field crop concerned 29% of the fields sown with Sanio while it was combined with Souna in two fields in three. As in the past, Sanio is generally sown in bush fields (85%) and in sandy soils (75%) with little or no manure (86%). These figures show that the return of Sanio is still uncertain and fragile and that it is mainly grown in association with Souna.

There is no doubt that sufficient rainfall staggered over nearly four months is needed to achieve a Sanio millet yield to allow regular consumption by the household. And in fact the spread of Sanio among farmers only started after the recovery of rainfall at the beginning of the 2000s. However, although all the farmers and villages in the Sine are subject to the same climatic conditions and although most have observed the recent increase in rainfall depths (see Chap. 4), they have not all resumed Sanio growing or taken it up again with the same intensity. The return of the rains has increased the number of strategies available for farmers but without imposing choices.

The heterogeneity of cropping behaviour is first of all geographic. As is shown in Figure 7b, in 2013 not all the villages in the Niakhar district covered by the survey have undertaken Sanio growing in the same way. Overall, the majority of the villages in the south (12/21) have grown Sanio in above-average proportions (26%). In the 21 villages in the south, an average of 43% of the farmers grew Sanio in 2013 while in the north (9 villages) the proportion fell to 5.5%. In the south, Sanio growing decreases in intensity along an east-west gradient, reminiscent of the dynamics of the penetration of this millet variety in the Niakhar district (Fig. 6b). The villages in which most Sanio is grown are located mainly around Ngayokhèm and Sass Ndiafadji. The villages in the north, where little Sanio is grown, adjoin the historic territory that used to be the Kingdom of Baol (where Wolof presence is more marked). Clayey soils are more common in the zone, beef fattening is an important activity, non-agricultural work with a cash income is more common and all linked with seasonal migration, and stronger Mouride influence.

As between villages, clear differences are seen between farms. The global logistic model of the factors associated with Sanio growing in 2013 (Table 1) shows first of all that at the beginning of the 21st century growing Sanio is for some people a heritage and memory, that of men and women and the agrosystem. Thus nearly twice as many farmers whose fathers had grown Sanio in the past grew it than farmers who did not have this family tradition (OR = 1.78; p = 0.014). This cultural dimension also appears when Sanio growing is analysed according to the main caste of the household. Thus growing Sanio is significantly more widespread among 'noble warriors' than among 'farmers' (OR = 2.88; p = 0.0001) and it is less frequent among 'griots' (OR = 0.13; p = 0.008). These correlations should be seen as the trace of pre-colonial division of labour that forms the basis of the caste system (C. A. Diop, 1960). The noble warriors were the guardians of tradition and land

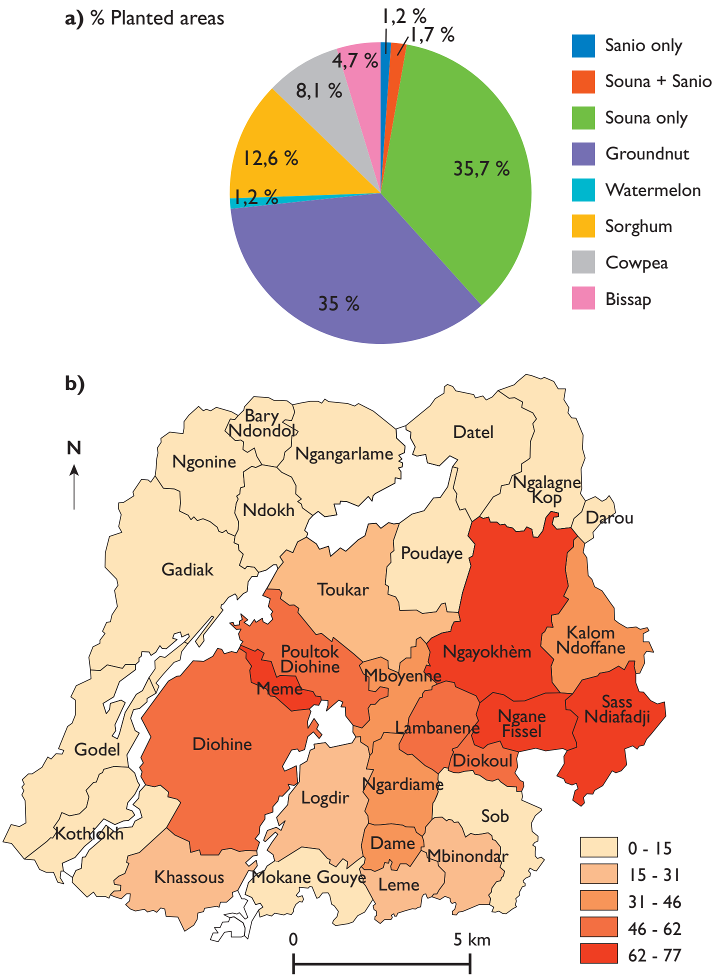

Figure 7.
(a) Percentages of planted areas by crop in 2013 (questionnaire survey, ESCAPE - 2013/2014);
(b) proportion of farmers who grew Sanio in-2013 (questionnaire survey, ESCAPE - 2013/2014).

while for reasons of their function as keepers of oral tradition (history, genealogy) the griots were excluded from agricultural activities. Finally, it is noted that the fewer of the men in the household have made long stays outside their territory (seasonal migration), the more the household in question is likely to grow Sanio (OR = 0.997; p = 0.035).

However choosing Sanio also—and above—all depends on land resources. It is more commonly grown when the farmer has sufficient land (OR = 1.16; p = 0.001), and Sanio growers have an average of 4.9 ha against 4.2 ha for the others. In addition, more farmers who borrowed land in 2013 sowed Sanio than the others (OR = 1.73; p = 0.0011). These features are corroborated clearly by farmers, who explain that they do not replace fields of Souna by fields of Sanio and that 'before growing a field crop of Sanio you have to have enough fields of Souna' to cover household food requirements and also have available land.

As has been mentioned above, although farmers consider that 'Sanio' is a crop that requires more labour as, in particular, it makes the agricultural work season longer, shortage of labour does not seem to be a significant obstacle to the crop (Table 1) as neither the size of households nor the return of migrants to help with crops during the rainy season increase the chances of growing Sanio. This is doubtless related to the fact that the extra work involved in the Sanio crop does not coincide with work on the other crops. However, it is noted that the number of persons who can help with agricultural work (6-year-olds and over) is significantly greater in the households where Sanio has been grown (9.4 persons) than in the other households (8.8 persons).

Absolute poverty (food or monetary poverty) is generally considered to be a barrier to adaptation to climate change. However, in the present case in which adaptation (i.e. growing Sanio millet) is reactive and consists of profiting from a climatic opportunity, monetary poverty is far from preventing it and in fact favours it (OR = 1.95; p = 0.002). This counter-intuitive relation can only be explained by the fact that growing Sanio requires no additional investment and no particular technical resources.

Finally, it is observed that households managed by women grow less Sanio than those managed by men (OR = 0.53; p = 0.023).

Applying similar modelling to the 21 villages in the south of the observation zone shows overall the same causal relations as in the overall model (Table 1) but with a noteworthy difference: growing Sanio may compete with other agropastoral production. Thus beef fattening reduces the chances that a farmer might choose Sanio (OR = 0.91; p = 0.030). Likewise, there is little chance that the same farmer will grow watermelon and Sanio (OR = 0.52; p = 0.052). This is explained by the need to reserve a field for watermelon[9]. Indeed, when he can a farmer opts for the economically most profitable choice. The options—in contrast with Sanio—beef fattening and watermelon (both for the sale of production)—doubtless explain

9. Indeed, watermelon is sown at the end of August/beginning of September so that growth profits from rainfall and fruit development takes place under dry conditions using soil moisture. It is not possible to grow watermelon after Souna (or groundnut) and even less after Sanio.

Table 1.
Analysis of the factors associated with Sanio growing by farmers in the Sine.
Logistic regression applied to 1,061 farms
(questionnaire survey, ESCAPE - 2013/2014).

	Modèle global		**Modèle villages sud**	
	Odds Ratio	**P>z**	**Odds Ratio**	**P>z**
Number of observations (total ;Yes ; No)	(518 ; 257 ; 261)		(501 ; 246 ; 255)	
Did the farmer's fther grow Sanio?	1.779	0.014	1.931	0.005
Sex of the head of the household	0.527	0.023	0.535	0.029
Number of adults who returned to the village during the last rainy season	0.860	0.572	0.750	0.290
Proportion of workers with extra-agricultural income	0.942	0.558	1.027	0.799
Proportion of adult household members managing one or more fields	1.002	0.962	1.066	0.058
Beef fattering	0.956	0.302	0.910	0.030
Watermelon	0.664	0.284	0;515	0.052
Area in hectares	1.157	0.001	1.117	0.009
Number of persons old enough to participate in farmwork (6-year-olds and over)	0.996	0.894	0.974	0.360
Borrowed lan	1.726	0.011	1.886	0.003
Average duration of seasonal migration by adult men (15-55 years old)	0.997	0.035	0.999	0.472
Majority caste of members of the household				
Farmer	Ref.		Ref.	
Tiedo	2.884	0.000	1.234	0.361
Griot	0.127	0.008	Pas d'observations	
Monetary poverty	1.946	0.002	1.489	0.058
Constant	0.395	0.128	0.626	0.453
Pseudo-R2	0.121		0.069	
Roc curve	0.717		0.676	
Hosmer-Lemeshow test (prob. value)	0.703		0.814	

why the households that are the least poor in monetary terms are those that grow Sanio least (Table 1). Questioned about the reasons for Sanio being particularly strongly present at Ngayokhèm where watermelon was not grown, in contrast with the neighbouring village of Sob, farmers at Ngayokhèm clearly pointed out the financial advantages of watermelon over Sanio and added that unfortunately 'the large urban markets for watermelon have been taken by the people of Sob where all the lorries stop now without wanting to go any further'. And several of them added that they would stop growing Sanio if there were other more profitable options among crops.

Conclusion : adaptation to climatic evolution whose future remains uncertain

The recent spectacular return of Sanio in the Serer landscape of the Sine is clearly a 'marker' of the recent evolution of rainfall observed in Senegal and West Africa (SALACK *et al.*, 2011; SÈNE and OZER, 2002; OZER *et al.*, 2003). Indeed, it is clearly the return of rainfall, especially at the end of the rainy season, which makes it possible to grow this relatively long-cycle millet again in a semi-arid area from which it had practically completely disappeared after the major droughts of the 1970s and 1980s.

Its steady, very large geographic spread throughout the last decade is explained by the fact that it is easy to grow if land is available for it and by the recognised qualities of its grain and stems. It thus appears as an adaptation to the climate that draws benefit from long rainy seasons by giving farmers a new option in their cropping strategies. But Sanio growers are also aware of the considerable climatic risks involved in production, to which are added pest risks. Reintroduction is thus being handled cautiously and without compromising the food balance of households. Thus no farmer is replacing Souna by Sanio and the farmers growing Sanio (especially as a single field crop) are those who still have land available after sowing Souna. In addition, Sanio does not bring in income. So as is shown by the small areas devoted to it in spite of its presence on a growing number of farms, it is still a secondary grain crop—far behind Souna (and sorghum).

A parallel must be made here between the recent expansion of watermelon in certain villages in the Sine and elsewhere, and of maize and upland rice in the Saloum and in Casamance. Like Sanio, watermelon makes it possible to benefit from fairly rainy ends of seasons. So it has appeared in the Sine. But unlike Sanio it is a delicate crop that requires investment in seed, inorganic fertiliser, pesticides (essential) and apparatus (sprayers) and good technical skills. In return, it gives substantial returns on a market that is nonetheless very volatile and a priori becoming saturated.

Further south, especially in the Saloum around Nioro du Rip, maize has developed spectacularly thanks to increased rainfall while Sanio is practically totally absent. Maize had decreased very strongly in the region since the 1970s and is now grown on 25% of the area devoted to grain crops—with Souna millet being dominant—and has even become integrated in local food habits (eaten mixed with millet). Farmers grow it intensively using ploughing (increasingly with a tractor) and purchasing certified seed of improved short-cycle varieties (80-90 days), or even hybrids, and using large amounts of fertiliser. For this, they benefit from active farming associations and the development of an increasingly well-organised sector supplying agroindustries in Dakar, enabling increasing replacement of imports by local production.

Finally, still further south, upland rice is developing strongly, once again because of the increase in rainfall and also because of strong demand for this grain in Senegal—still relying too much on imports—and the distribution of 80-90-day early varieties of the NERICA type. Upland rice production is even starting to spread to the Saloum.

The return of Sanio millet, like the increase in watermelon and the development of maize and upland rice—all made possible by the recent increase in rainfall—shows the tremendous capacity of farmers to adapt rapidly to changes in their environment, sometimes even before accompaniment by the research sector, by always seeking to profit from all opportunities but never taking risks that would endanger their food security, which remains based on Souna.

The future of Sanio is uncertain for the same reasons. Its presence will probably decrease if other more profitable opportunities arise and even more certainly is rainfall were to decrease again. To enhance its maintenance, the development of a small '*Matye*' sector based on grain quality and its traditional image could be developed. But given the uncertainties weighing on the climate in the Sine, this could be of more benefit to farmers further south. There remains the possible solution, requested by farmers, of developing 'Sanio with a shorter cycle' that would reach maturity after 3 months (like Souna) and have the much appreciated features of the aristate heads, nutritive and tasty grain and excellent forage stems and straw of '*Matye*'.

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