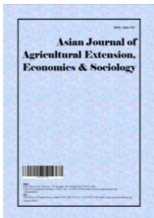

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Drought-tolerant Varieties as an Adaptation Strategy in the Context of Climate Change: Insight from Maize Production Systems in Benin

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Previous studies suggested that maize is set to become a cash crop while ensuring food security better than any other crop. However, climate change has become one of the key production constraints that are now hampering and threatening the sustainability of maize production systems. We conducted a study to better understand changes here defined as adaptations made by smallholder farmers to ensure food security and improve income through maize production in a climate change context. Our results show that maize farmers in northern Benin mainly rely on traditional seeds. Drought as abiotic stress is perceived by farmers in many agro-ecological zones as a disruptive factor for crop production, including maize. When drought is associated with pest damages, both the quantity (i.e. yield) and the quality (i.e. attributes) of products/harvests are negatively affected. The adverse effects of drought continue to reduce production in different agro-ecological zones of the country, because of the lack of widespread adoption of tolerant varieties. The study suggests actions towards the production of drought-tolerant maize seeds, a promotion of seed companies, the organization of actors and value chains. Apart from climate change, the promotion of value chains is also emerging as one of the important aspects to take into account to sustain maize production in Benin.

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1. INTRODUCTION

All countries in West and Central Africa are severely affected by the highest climatic variability ever recorded during the 20th century, both in intensity and duration [1,2]. A change in rainfall patterns manifests this variability. Rainfall decreases are intensified during the 1980s and 1990s [3]. This leads to a degradation of the environment and reductions of crop yields [4]. Cereal crops such as maize, which yields have steadily dropped from year to year, seem to be the most affected by this climatic variability.

Smith et al. [5] predicted that maize will become a cash crop and provide food security better than any other crop. In northern Benin, for example, maize ranks second after cotton as both a subsistence and cash crop. According to the Ministry of Agriculture, Livestock and Fisheries (1997-2017), land acreage for maize production at the country-level increased from 600 000 ha in 1997 to 1 100 000 ha in 2017. Unfortunately, the average yields stagnated between 1150 and 1250 kg/ha during the same period. According to Thirtle et al., [6], each 1% increase in agricultural productivity in Africa reduces poverty by 0.6%, and the 1% increase in production lowers the number of people living with less a dollar a day of 6 million.

The interest for investigations in northern Benin is explained by its diversified agricultural production, based on maize, and its very low agricultural productivity. This weakness in productivity could be explained, among other things, by the decline in soil fertility and the use of inappropriate cultivars (seeds, cuttings, etc.). Farmers in northern Benin mainly rely on traditional seeds. Such seeds are, however, considered as resources with limited potential that contributing largely to the low productivity of traditional farming systems [7]. In other perspectives, they are associated with a form of autonomy that contributes to household food security and the renewal of agro-systems [8]. Improved varieties are often more productive but overly criticized for being very demanding in mineral fertilizers and specific pesticides which are often challenging to acquire and sometimes quite expensive. Improved varieties are also viewed as presenting organoleptic qualities that do not always meet the nutritional requirements of the producers and/or consumers.

With climate change, drought is increasingly perceived by farmers in many agro-ecological zones as a disruptive factor in crop production, including maize. Associated with the damage of the pests, drought negatively affects both the quantity (i.e. yield) and the quality (i.e. attributes) of products/harvests. To sustain the production systems, adaptations to deal with drought are required. In that prospect, most of the initiatives focus on improved seed varieties with varied cycles. These include extra early or intermediate cycles. Only a few varieties are actually drought tolerant. The results achieved so far are mixed while the adverse effects of drought continue to reduce production across the agro-ecological zones of the country.

Against this background, our main research question is: How is maize produced to in times of climate change to cope with drought? We conduct a socio-economic and agricultural analysis of maize production in the context of climate change in Benin. We further highlight the potential role that drought-tolerant varieties might play as an adaptation strategy to climate change in general and particularly to drought.

2. METHODOLOGY

2.1 Study Area

Our data are collected in the municipal areas of Kandi and Tanguiéta. These areas are of the departments of Alibori and Atacora, respectively, in the north of Benin. They are well-known in maize production. According to statistics from the Ministry of Agriculture analyzed over ten years, the average annual land acreage for maize production in Kandi and Tanguiéta is 18,000 ha and 3,000 ha, respectively. On the other hand, both areas are at very high risks as long as drought risks are concerned.

The population of Kandi is up to 95,206 inhabitants compared to 54,719 inhabitants for Tanguiéta (National Institute of Statistics [9]. The female population represents 51% and 50% in Kandi and Tanguiéta, respectively. The social organization is made up of several ethnic groups; the most important in Kandi are the Bariba, the Mokolé, the Dendi, the Peulh and the Boo. In Tanguiéta, the main ethnic groups are the Otamari, the Berba, the Biali, and the Gourmantché. These different ethnic groups have a long agricultural tradition and have been engaged for several years in the production and marketing of animal and crop products.

In these areas, rainfall changes dramatically from month to month and significantly affects agricultural production. Kandi records an average rainfall of 1100 mm per year compared to 1000 mm for Tanguiéta. The rains used to start in the second half of May. They are maximum in August and September, with about twenty rainy days. While the good distribution and the correct level of rains create the conditions for a good agricultural year (Lericollais, 1999), the rains for a few years seem irregular.

2.2 Sampling

We conducted surveys in each of the municipal areas with key informants, specifically with the municipal managers of agricultural production. Sixteen villages (eight per municipal area) were selected based on criteria such as maize production, accessibility and ethnic and socio-cultural diversity.

In each village, village chiefs and key informants such as public and private agricultural extension officers, farmers' organization officials, health workers, were surveyed. In addition to these categories of informants, 150 farmers (75 per municipal area) were randomly selected and interviewed.

2.3 Data Collection and Analysis

Our data relate to the characteristics of farms, types of maize seed varieties used, the sources of seeds, experience and perceptions in relation to the risks of drought, the strategies to cope with drought. These data were collected by combining individual and group in-depth interviews with key informants.

We use descriptive statistics through frequencies, means and standard deviations to understand the distribution of our key variables of interest. In addition, the t-test is used to compare the municipal area or the users and non- users of improved seed varieties.

3. RESULTS

3.1 Agricultural Production System

3.1.1 Relative importance of main crops

In terms of land acreage, maize and cotton are the main crops, each occupying about 33% of the land under cultivation by each respondent. They are followed by cereal associations (sorghum, maize, millet, etc.), legumes (peanuts, cowpeas, soybeans, Bambara groundnut, etc.), sorghum, the maize-sorghum complex, peanuts, etc. Crops association remains a practice for all the survey respondents. In each farm, there is an average of three associations. The most common types of association are maize + sorghum and cereals + legumes.

The practice of crops association in general and particularly maize + sorghum association is guided by the concern to intensify and improve labour productivity. Maize + sorghum association allows farmers to protect themselves from bad harvests and to have a sufficient grain reserve to feed the family.

Unlike cotton production, maize production has increased in recent years. The general upward trend in maize production could be explained by the increasingly common use of inputs (fertilizers, herbicides and improved varieties).

3.1.2 Use of inputs

About 11% of farmers purchased improved maize seeds. This low percentage of users as several explaining factors. One of them is linked to the low purchasing power of the majority of farmers. Indeed, about 67% of farmers are poor. On average, 10,500 XOF (USD 17.84) are spent on the purchase of maize seeds, which corresponds to 40 kg, the amount needed to plant 2 hectares. Another cause is linked to the low coverage of the national territory by the public services responsible for supplying seeds to farmers. Only a few seed groups (three for all of northern Benin) produce maize seeds and sell them to farmers. This source of supply is supplemented by National Agricultural Research Institute (INRAB) and the Regional Center for Agricultural Promotion (CeRPA) which provide, through their decentralized structures, improved seeds of maize. The main source of maize seed purchase to date remains the market which represents 30% of the sources of supply of improved maize seeds.

The varieties purchased are DMR, QPM, PISSABACK, TZBSR, EVDT-97STR. Seed purchases are spread over a period of four months, from the middle of the dry season (March) to the start of field work (July).

3.1.3 Cultivated maize varieties

In each of the six villages, farmers cultivate both improved and early varieties. Among the cereals grown in the study area, maize has become the dominant cereal (44% of the area sown with cereals) followed by sorghum which occupied the first rank for about fifty years.

Over 85% of farmers cultivate local varieties or improved varieties whose introduction escapes the collective memory and which are therefore considered to be local varieties. About 70% of producers have given up yellow varieties with a long cycle (4 months) which no longer adapt to current rainfall conditions. Yellow varieties are still used in the Fulani community especially. This socio-cultural category cultivates maize on land that has benefited from organic manure. The Kamboessé and Pisabark varieties have been given up by more than 95% of farmers, due to the unavailability of seeds. Also, the extra early variety (TZEE) has been given up by 80% of farmers because of its poor yield. The DMR variety seems to be the best variety with a utilization rate reaching 80%.

The cultivated maize varieties are intended for various uses or purposes. The varieties Lazare, Kamboessé, EVDT-97STR, TZEE and TZPB-Y are mainly used for food in households. The varieties QPM (Faaba), TZL and TZB which are white in color and have a good level of yield and preferable attributes (color and shape of the grains), are cultivated preferably for commercial purposes. The variety of DMR is produced for both food and commercial purposes. The set of criteria generally used by farmers for the choice of varieties includes color, yield, maturation cycle, starch level, organoleptic characteristics, size of plants, etc. The farmers surveyed do not cultivate hybrids. 100% of farmers say they cannot identify the difference between hybrids and open-pollinated varieties.

3.1.4 The main constraints affecting the cultivation of maize

Despite its development, maize production remains subject to several constraints. The most important is drought (Fig. 1). According to the respondent farmers, drought is manifested through the delay in the rain, pockets of drought, the decrease in rainfall, the poor distribution of rain. In addition, this key constraint is followed, in order, by weed infestation, damage caused by animals, the decrease in maize prices and the large increase in input costs.

3.1.5 Criteria for maize varieties selection

To adopt the varieties of maize, farmers rely on several criteria (Table 1). The first three criteria that guide their choices are yield, drought resistance and crop cycle, respectively. The use of several criteria in the choice of varieties sometimes generates very diverse maize fields. This diversity has several functions. It also allows the holder to donate, barter or sell maize seeds.

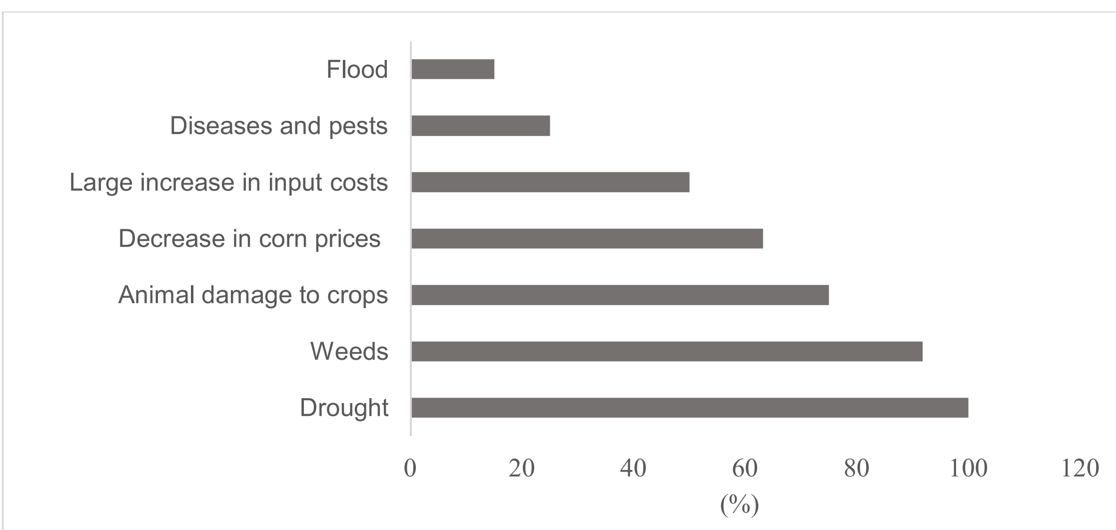

Fig. 1. Constraints to maize production

Table 1. Criteria for choosing the best maize varieties

Criteria for maize varieties selection	% of farmers
Potential yield	45.7
Drought resistance/performance in times of poor rainfall	32.3
Crop cycle	12.0
Performance on poor soils	4.0
Grain size	2.0
Flood resistance	2.0
Taste of the meal	1.3
Resistance to disease and rot	0.7

3.1.6 Sources of seeds

The maize seed system is a mixed one. It combines the formal with the informal and allows farmers to have access to improved seeds as well as local seeds. The most important formal sources are seed groups, research services, government projects, extension services. The formal seed system is headed by the National Institute of Agricultural Research of Benin (INRAB). The Department of Quality Promotion and Packaging of Agricultural Products (DQPC) is responsible for certifying the quality of seeds. The informal source seems to be the most used and is fueled by self-supply from harvests, donations, barter and purchases on the local market.

3.1.7 Land acreage for maize production

We explore the relationships between land acreage for maize and the use of improved varieties. As a general trend, farmers who allocate larger areas to a particular crop tend to be market-oriented. However, the improved varieties are intended for the market, while the local varieties are intended for self-consumption. The areas allocated to the cultivation of improved varieties by non-adopters are approximately twice larger (3 ha) than those used by adopters (1.5 ha) (Table 2). Using improved varieties of maize is a strategy used by farmers to increase their agricultural income and face the drought constraint.

3.2 Perception of Risk Control Strategies Related to Maize Production

The perception of the risks associated with growing maize varies according to the level of prosperity of the farms. Up to 70% of wealthy farmers perceive the cultivation of maize as very risky compared to less than half (28%) of the poor who have the same perception. About 61% of poor households consider the cultivation of maize to be risky, compared to about 36% for the rich. There are more poor farmers (12%) than rich farmers (3.4%) who consider the cultivation of maize low risk.

To reduce risks, maize farms use different strategies. The strategies used vary according to the level of prosperity or, sometimes, are almost identical regardless of the level of prosperity (Table 4).

For example, the rich uses mainly improved varieties. This is explained by the high cost of seeds of improved varieties. Improved varieties are also used by poor but in low proportion compared to rich. It appeared that the using of improved varieties is one of the key strategies to reduce the risk in maize production. According to the poor farmers, they diversify mainly their production. Besides, as well as the poor accumulate goods in the same proportions, make non-agricultural diversification to be able to face possible risks.

4. DISCUSSION

The use of drought-tolerant varieties of maize is a strategy for adapting to climate change. As a result, the majority of farmers use improved varieties because they are drought tolerant. Even if farmers continue to use local varieties, they combine improved varieties and the average area cultivated in improved varieties is significantly higher than that of the local variety.

In the current climate change conditions, the perception of profitability is not sufficient to know whether or not the proposed improved varieties will be adopted. Taking into account the three dimensions, namely agronomic, economic and social dimensions, could prove to be almost important. Indeed, the objectives of the farmers and their rationality can be very different from those of the scientists. Farmers take risk into account and have multiple objectives that do not

Table 2. Comparison of average maize areas (adopters and non-adopters)

Maize area	Number of farm	Maize area (ha)	Standard deviation
Improved varieties users	40.0	1.5	1.8
Non-users	110.0	2.9	3.8
Student's t test parameters	t = 2.91 ; ddl = 148, *P* = 0.004		

Table 3. Perception of risk related to maize production

Risk of maize production	Rich farmers	Poor farmers
High risk	69,96	27,59
Average risk	35,61	60,92
Low risk	3,42	11,59

Table 4. Relative importance (%) of production risk reduction strategies according to the level of prosperity

Strategies	Poor	Rich
Using of improved varieties	21.1	46.0
Diversification of agriculture	34.1	18.7
Non-agricultural diversification	13.0	9.2
Accumulation of goods	18.8	18.7
Participation in government programs and NGOs	3.3	1.9
No action	3.3	1.9
Early sales	3.3	1.9
Use of chemical and organic fertilizers	3.2	1.9

necessarily include maximizing profit. They make complex decisions about how to allocate their scarce resources in light of the relationships between different activities.

A meta-analysis performed by Roudier et al. [10] revealed maize production in West Africa is subject to the effects of climate change. These authors added that the negative impact of climate change would intensify by the time. Roudier and al. [10] indicated maize productivity has decreased by 18% in West Africa. According to Lobell et al. [11], the decreasing in productivity is around 3.8% worldwide. They suggest the implementation of adaptation strategies to ensure people's food security [11,10]. In general, crop farmers perceive climate change and develop strategies through the diversification of crops, the adjustment of farming practices and the agricultural calendar [12,13,14]. Our results support that farmers choose improved varieties of maize that are drought tolerant. Political interventions should, therefore, facilitate access to improved drought-tolerant seeds for small producers for improving food security. In West Africa, there is a weak policy in supporting the maize seed system. This explains the use of informal sources for seed supply. This same observation was made in the south of Benin by Floquet et al. [15] who note the seeds come from friends, the local market and brought back from migration. Unlike yam seeds, inheritance and exchange of maize seeds are rare [16]. In the current climate change context, a considerable effort must be made in the field of varietal improvement and the supply of maize seeds.

5. CONCLUSION

We analyze maize production systems in the context of climate change with a case study of northern Benin. Our study shows that in addition to the diversification of crops, the readjustment of farming practices and calendar, producers use improved varieties of maize. The choice is made in order to favor improved varieties which resist drought. According to the respondent farmers, DMR is the best-improved variety in this context. To minimize risks and conserve varietal biodiversity, local varieties of maize are also used. In addition to climate change constraint, the main shocks that affect the cultivation of maize are the damage caused by animals, the increase in the price of inputs and the decrease in the price of maize. Efforts must be made to improve the accessibility and quality of seeds, as well as the management of soil fertility using appropriate technologies. Our results support the use of drought-tolerant varieties of maize as a strategy for climate change adaptation. There is a need for more research to better understand the factors behind the adoption of drought-tolerant maize varieties.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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