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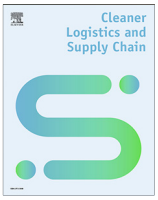

Towards a sustainable production of maize and soybean in the department of Borgou

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ABSTRACT

In Benin, as in most sub-Saharan African countries, people continue to rely primarily on low-productivity agriculture for livelihood and employment. Producers are faced with significant logistical challenges whilst managing their harvest. We empirically investigated the situation of the producers of maize and soybean in the department of Borgou. This research is aligned with the United Nations' Sustainable Development Goal 2, zero hunger, and 12, sustainable consumption and production. Workshops brought together delegates from producer groups of the Borgou department, researchers in agronomy and management, rural development technicians from the non-governmental organization named Eclosio and the regional union of maize and soybean producers of Borgou-Alibori. The exchanges led to the development of a survey questionnaire. Then, direct and personal interviews was conducted with maize and soybean producers in their preferred language based on the questionnaire. The main objective of this paper is to support strategic choices towards a sustainable production of maize and soybean in the department of Borgou. Results show the need to finance agricultural campaigns, use warehouses, and have a transparent and trustworthy space for farmers and buyers to negotiate fair prices.

1. Introduction and context

According to The Food and Agriculture Organization estimations, 95–115 kg/year/capita of food is wasted in Europe and North America, whereas 6–11 kg/year/capita of food is wasted in sub-Saharan Africa and South/Southeast Asia (Gustavsson et al., 2011). While most of the food waste and loss occurs at the consumer stage in developed countries, most occurs at the production stage in developing countries (Gustavsson et al., 2011). The World Bank (Zorya et al., 2011) highlights the importance of post-harvest losses in cereals in sub-Saharan Africa. Moreover, Delgado et al. (2021) identify critical loss points along the value chain of five staple crops in six developing countries. More precisely, the authors point out that losses depend on factors beyond the farmgate, such as lack of adequate storage capacity and market volatility. On the demand side, the predominance of large numbers of non-market farmers in developing countries strongly limits the ability of farmers to respond to price incentives (Owusu et al., 2021). On the supply side, the commercialisation of agricultural products suffers from a lack of resources and access to markets and market information.

The objective of this research is to better understand the profitability of maize and soybean production in Borgou department, Benin. As the aim of this paper is intended to support strategic choices, a Political, Economic, Social, Technological, Environmental, Legal (PESTEL) analysis, based on a literature review, describes the environment to identify the main factors capable to influence the market. Based on the results, a Strengths, Weaknesses, Opportunities and Threats (SWOT) is performed to address the strategic capacity of the maize or soybean producers, in order to be competitive on the considered market. This study aims to highlight the problems associated with the management of the supply chain linked to maize and soybean production in Benin and propose solutions to participate in the socio-economic development of this territory. It allows progress towards the objectives of achieving locally-controlled food security and sustainable livelihoods for most of African farmers while considering the importance of implementing sustainable development agenda.

The remainder of the paper is structured as follows. Section 2 presents the characteristics of the study area. The methodology is explained in Section 3 and the hypotheses are stated. The empirical results are then described in Section 4 to provide an overview of the

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responses obtained. Section 5 constitutes the discussion of the results; the hypotheses established are tested to define whether statistical relationships in the collected data support them. We present our conclusions in Section 6 along with potential leads for future research.

2. Study area

We begin by describing the situation in Benin before focusing on the Bourgou Department.

The Republic of Benin is a low-income and food-deficit country (World Food Programme, 2020), as 9.6 % of the population is food insecure while chronic malnutrition affects 32 % of young children (Secretariat, 2017). The agricultural sector is of paramount importance for the strengthening of Benin's economy as it contributes an average of 32.5% of the gross domestic product, 75% of export revenues, 15% of state revenues, and provides around 70% of jobs (INSAE, 2013). The main cash crops are cotton (41.9% of export earnings in 2015), cashew nuts and oil palm; while the main food crops are yam (Degla and Sourokou, 2020), cassava and maize. Agriculture is registering an increase in cereal production; however, this increase is mainly due to the expansion of cultivated areas, while agricultural yields are lagging behind overall. The currency in Benin is the West African CFA franc, pegged to the Euro at 1 € = 655.957 XOF. For this reason and because Euro is one of the most traded currencies, Euro is used in this paper.

According to Secretariat (2017), Benin's strategic development orientations as defined in the Government's Action Programme and the Growth and Poverty Reduction Strategy consider the agricultural sector as a lever in the fight against poverty. However, the allocation of public resources to agriculture remains low, amounting to about 6.5% of the national budget. Furthermore, a disproportionate distribution compounds the low level of resource allocation. Moreover, implementing sustainable, modern and competitive agriculture based primarily on small farms, in a context of weak state intervention, is a political choice. The main actions envisaged relate to increasing agricultural production and diversifying agricultural sectors by creating an institutional framework favouring access to credit and the creation of favourable conditions for public–private partnerships (The World Bank, 2022b). For instance, the warrantage is a storage technique in a collective warehouse (SOS Faim, 2016). The producers receive a warrant from the microfinance structure following the deposit in a warrantage shop of a certain quantity of goods against the granting of a loan. This warrant records the value of these goods for a financial guarantee on all the goods. These goods are stored and maintained in the warrantage shop to limit damage until the producer decides to sell them at an opportune time (generally a lean period) to repay the debt he has contracted with the microfinance structure.

The average size of the farms is 10 hectares (UNDP, 2015). Benin adopted a land code in 2013 to establish a unified land title to put an end to land insecurity by treating rural land (objects of rights established or acquired according to custom) in the same way as registered urban land (Secretariat, 2017). Note that according to Akuffo (2009), the label -customary law to describe indigenous African law- and custom has emerged in the colonial period to describe the customary rules and practices. In a typical customary law, land is communally owned by the community or family and individuals have rights of possession (Akuffo, 2009). According to this law, an individual cannot sell land and cannot be dispossessed of their landholding (Gebeye, 2019).

Among the PSRSA (2017)'s objectives ("Plan Stratégique de Relance du Secteur Agricole", Strategic Plan for the Revival of the Agricultural Sector), one goal is to increase the current level of maize productivity since maize is by far the most consumed cereal in Benin, being far more consumed than rice and sorghum. In addition to this maize sector, there are emerging sectors such as soybean production (Hounhouigan et al., 2020).

A part of the harvested food is kept for producers' needs. The remaining part is distributed, stored and transported for commercial purposes. Road transport is the dominant mode for the domestic transport of goods and passengers. However, road infrastructures are often dilapidated (Lihoussou, 2017). The rural tracks network is severely lacking, and many areas are landlocked during the rainy season. The access to production and border areas is therefore inadequate (Lihoussou, 2017).

The farm inputs are provided through capital and labour. The activities involved in agriculture, such as harvesting food from crops, mobilise 44.3% of the working population regardless of gender (FAO, 2018b). However, the lack of profitability pushes young rural people to exodus, with the hope of better living conditions in big cities such as Parakou where they are trapped in precariousness, delinquency and banditry (Ahohounkpanzon, 2020). Due to the financial burden of motorisation, many producers join together Cooperative of Agricultural Machinery Users (CUMA). These CUMAs helped producers with large areas to carry out ploughing operations by minimising the impact of purchasing expensive farm equipment (Dayou et al., 2021). There are few producers who have their own tractors, especially with the strategy put in place by the government to facilitate access to tractors via the Territorial Agency for Agricultural Development (Dayou et al., 2021).

Furthermore, mobile phone use in sub-Saharan Africa has increased over the past decade (Asongu and Odhiambo, 2018). The mobile phone has brought new possibilities to the continent (Lihoussou, 2020). Particularly in rural Africa, mobile phones have represented the first modern telecommunications infrastructure of any kind. They have reduced communication costs, which improves economic development. Among the development benefits of mobile phones and mobile banking, agricultural waste is eliminated through the mitigation of constraints and demand–supply mismatches (Aker and Fafchamps, 2015) and the increase of business opportunities (Mishra et al., 2011). In sub-Saharan African countries, the effect of mobile technologies is positive and significant (Myovella et al., 2020).

At the marketing level, men are present among wholesalers and collectors; whereas retailers are predominantly women. Artisanal processing of maize derivatives reinforces women's reputation in the local valorisation of the product by supplying urban centres with a variety of services, such as street cuisine, and products such as food products derived from or associated with maize at markets or in street kitchens (FAO, 2018b). Soybean products are mainly processed into cheese (FAO, 2018b). Food waste, if any, is an organic material used to feed livestock such as chickens.

These food supply chains are dependent on soil conditions and environmental characteristics such as temperature and precipitation. Their inputs are provided through capital and labour and involve various stakeholders: the producers, the supervisory structures which control the quality of seeds, health organizations, tractor operators for ploughing, seed sowers, the Agriculture Departmental Direction, the Non-Governmental Organization (NGO) named Eclosio, microfinance structures that support producers through loans, the network of certified seed companies in Benin and SODECO (Société pour le Développement du Coton) which is the formal structure for supplying agricultural inputs to producers and informal resellers of inputs imported from Nigeria and Ghana. The import, manufacturing and use of pesticides (phytopharmaceutical products) on Beninese territory are subject to authorisation. Moreover, Benin is developing national regulatory frameworks for fertilisers and seeds, in line with the West African Economic Monetary Union (WAEMU) provisions in this area.

To support strategic choices, a PESTEL analysis identifies the main factors capable to influence the market in Benin. Based on the literature review, support from NGOs and academic experts, and by the problem owners (producers), the key factors to perform a PESTEL analysis (Johnson et al., 2017) are identified. Subsequently, our analysis, summarised in Table 1, was validated by the experts and producers.

Table 1
PESTEL analysis related to the agricultural sector.

Favourable elements	Unfavourable elements
	Political
• Stable democracy (The World Bank, 2022) • Political support: Government's Action Programme and the Growth and Poverty Reduction Strategy (Secretariat, 2017) • Strategic Plan for the Revival of the Agricultural Sector (PSRSA, 2017) • Institutional framework favouring access to credit (Fiamohe et al., 2021) • Favourable conditions for public–private partnerships (The World Bank, 2022b; SOS Faim, 2016) • Territorial Agency for Agricultural Development (Agence Territoriale de Developpement Agricole, 2022)	• Low allocation of public resources to agriculture, about 6.5% of the national budget (Secretariat, 2017) • On average, 1% of agriculture and food specific expenditure disbursed in Benin is related to storage infrastructure (Baborska et al., 2020) • Weak state intervention (Secretariat, 2017), • Road infrastructures are often dilapidated (Lihoussou, 2017) • Rural tracks network is severely lacking (Houngbadji, 2022)
	Economic
• Solid economic outcomes between 2016 and 2019, with average real GDP growth of 5.5% (The World Bank, 2021b) • Reduction in food imports (The World Bank, 2021a) • Growth in market share (UNDP, 2015) • Increase in cereal production (UNDP, 2015; PSRSA, 2017) • National Plan for Agricultural Investment (PSRSA, 2017)	• Economic activity slowed to 6.4% in 2019 (The World Bank, 2021b) • Financial capacity (self-financing) (World Food Programme, 2020) • Price fluctuations (Owusu et al., 2021)
	Sociocultural
• Collaborative economic system (Dayou et al., 2021) • NGOs (Go Africa, 2022) • Food and Nutritional Security (World Food Programme, 2020) • Women empowerment (UN Women, 2021; Baborska et al., 2020)	• Land access issue (Jayne et al., 2014) • Poor standard of living (World Food Programme, 2020) • Dietary habits (Secretariat, 2017) • Population growth (The World Bank, 2022) • Young rural people exodus (Ahohounkpanzon, 2020) • Gender inequality (Walther et al., 2019)
	Technological
• Mobile phone (Asongu and Odhiambo, 2018; Myovella et al., 2020) • Mobile banking (Aker and Fafchamps, 2015)	• Digital divide (Benin, 2019) • Lack of network coverage in certain areas (nPerf, 2022) • Level of education and digital literacy (Benin, 2019)
	Environmental
• Agro-ecological transition (JINUKUN, 2014)	• Poor soil fertility (Kihara et al., 2016) • Global warming: the projected increases in temperature and precipitation are likely to exacerbate the challenges already faced by agriculture (Ministry of Foreign Affairs of the Netherland, 2022) • Dependence on chemical inputs (Bendjebbar and Fouilleux, 2022; Dossa and Miassi, 2018)
	Legal
• Land code since 2013 to establish a unified land title (Secretariat, 2017; Akuffo, 2009; Gebeye, 2019) • Certified seed companies (Diallo, 2018) • Formal structure for supplying agricultural inputs (Amegnaglo, 2018) • Authorisation needed for phytopharmaceutical products (Houngla et al., 2019) • National regulatory frameworks for fertilisers and seeds under development (Djagba et al., 2019)	• Informal resellers of inputs imported from Nigeria and Ghana (Djohy et al., 2018) • Black market (Balogun, 2021)

Central Benin is an area of humid forests and savannahs, with an average rainfall of 1 200 mm per year on which the sector is strongly dependent. Most of the cultivated land in the centre and south is devoted to the production of food crops and cotton (Secretariat, 2017).

This research focuses on the Borgou department (Fig. 1). According to the United States Department of Agriculture JINUKUN, 2014), the largest plots of farmland are in Borgou; in this departement 53% of households are engaged in crops or gardens for food. The primary sector of the economy occupies 66% of the population (INSAE, 2013). Most farmers produce using simple techniques and man-powered tools. There is, thus, low mechanization and agricultural productivity remains low by international standards (Diao et al., 2010).

According to INSAE (2013), the Borgou department has 83 275 agricultural households, of which 5% are headed by women (Table 2); cereal production corresponds to 63 712 ha sown to soybeans and 153 152 ha to maize in 2018.

Yam, maize and soybeans are the three products most cultivated by farm households in almost all the communes of the Borgou department. Sorghum, mil, fonio are also cultivated in many communes (INSAE, 2013). Table 3 represents the distribution of maize and soybean.

The Borgou department suffers a severe disadvantage in terms of socio-economic infrastructure (Secretariat, 2017). Regional institutions such as the Economic Community of the West African States (ECOWAS), the WAEMU, the Inter-State Committee for Drought Control in the Sahel and their donors, have highlighted the role of storage systems in food security and market regulation. Support for local warehouses, considered the first line of defence in the event of a food crisis,

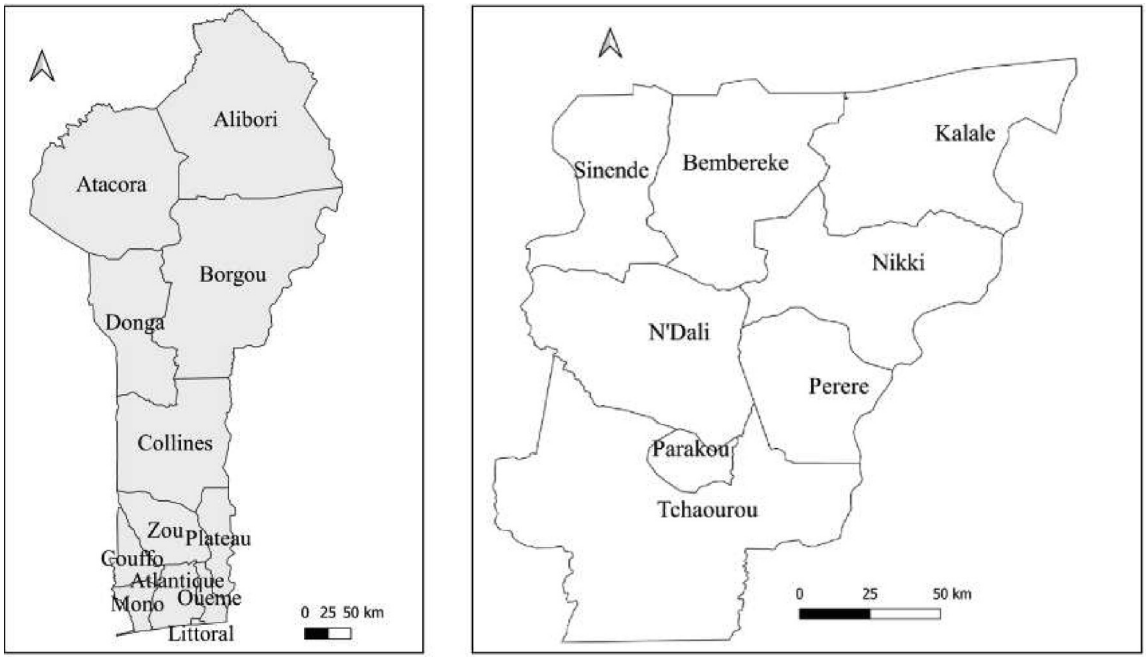

Fig. 1. Left: map of the departments of Benin. **Right:** focus on the Borgou departement. Own composition based on shapefiles from https://data.humdata.org/dataset/benin-administrative-boundaries.

Table 2
Distribution of agricultural households.

	Bembéréké	Kalalé	N'dali	Nikki	Parakou	Pérèrè	Sinendé	Tchaourou	Total
Household	10 441	13 444	9 414	11 492	4 447	6 703	7 031	20 303	83 275
Man	9 706	12 892	8 976	11 061	4 226	6 474	6 617	19 351	79 303
Woman	735	552	438	431	221	229	414	952	3 972

Source: INSAE (2013)

Table 3
Percentage distribution of maize and soybean in the Borgou department.

	Bembéréké	Kalalé	N'Dali	Nikki	Parakou	Pérèrè	Sinendé	Tchaourou
Maize	37	24.1	14	8.6	8.2	2.8	50	6.2
Soybean	5.5	9	15	27.1	3	17	5.7	5.7

Source: Adapted from INSAE (2013)

is explicitly retained in the storage strategy of the ECOWAS, as is the strengthening of collecting, storage and marketing capacities of producers' organisation, in regard with market regulation.

3. Methodology

In November 2019, several workshops and seminars brought together delegates from producer groups of the Borgou department, researchers from the Faculty of Agronomy, the School of Management and trainee students from UP, rural development technicians from the NGO Eclosio and the Regional Union of Corn and Soybean Producers of Borgou-Alibori (URP-BA). These technicians provide producers with technical training on how to sow, care for seeds, and conserve and store products. The exchanges made it possible to state the hypotheses and draw up a survey questionnaire.

3.1. Hypotheses

In this section, the hypotheses are stated.

3.1.1. Access to land

Jayne et al. (2014) study rural land access in Africa. Evidence indicates that access constraints are becoming increasingly critical for smallholders and that such constraints are growing over time. Indeed, the amount of land under customary tenure declines while populations within customary tenure areas increase. The first workshop outcomes also highlight that the main factor influencing production is the difficulty of accessing land. All the farmers stressed this land access issue, especially for women, a real sociological problem in Borgou. According to the producers, the vast majority of land is inherited, which means one has to travel long distances to find new land to cultivate. Moreover, population growth tends to link existing cities to existing villages, considerably reducing land under cultivation. The agricultural technicians from the NGO Eclosio and URP-BA support these remarks by raising other causes of land insecurity, such as the sale of fields for funeral ceremonies or the purchase of a motorbike taxi. The hypothesis concerning the access to land (Table 9) are:

- *H1: The majority of the land is inherited.*
- *H2: The access to land is more difficult for women than for men.*

3.1.2. Standard of living

To assess the standard of living, questions related to cooking fuel, drinking water, housing and assets are asked. They are indicators of the Multidimensional Poverty Indices (MPI) developed in Alkire et al. (2011). The respondents are also asked to provide their educational level.

- *H3: The majority of producers are deprived of assets.*

The meal of most Beninese is often composed of basic foods (cereals, roots, tubers) accompanied by a sauce, the composition of which varies according to economic means. In general, quantity is more important than nutritional quality. Certain preparation and cooking methods lead to a significant loss of nutrients and contamination of the food (The World Bank, 2017). Eclosio and its partners have been working on these aspects for nearly five years in the communes of N'Dali and Tchaourou, through awareness-raising on diversification of production, food hygiene, culinary demonstrations, processing and conservation of fruit and vegetables, and the promotion of local family gardens. The government has also developed a strategic document: the National Plan for Agricultural Investment and Food and Nutritional Security.

3.1.3. Capital

Producers borrow money from microfinance institutions and informally from individuals in return for a share of the harvest. For warrantage, the producer must not exceed 80% of the price of the product at the time of storage, which lasts between three to four months. While warrantage is a life-saving system that has helped stem several problems in the agricultural supply chain, it has its limitations in terms of capacity. In Benin Cajù, the repayment period is one year with an interest rate of 5%, with land titles as security. There are other structures with various conditions such as Agri-Finance, ASF with an interest rate of 2%. The following hypothesis is tested:

- *H4: Producers borrow money to finance their farms.*

The questions asked, Table 10, were used to analyze the respondent's financial situation.

3.1.4. Production

Since Ahohounkpanzon (2020) highlights young rural people exodus and, according to Adegbola et al. (2020), a large part of the labour force of rural population in Africa is engaged in agriculture, we test the following hypothesis:

- *H5: Agricultural sector lacks in workforce.*

Crop production in smallholder farms in sub-Saharan Africa is limited by poor soil fertility that results from continuous cropping (Kihara et al., 2016). The questions related to crop allocation are summarized in Table 13. The hypotheses to test are:

- *H6: Local agriculture has become very dependent on chemical inputs i.e fertilizers, herbicides insecticides.*
- *H7: The vast majority of the area of the fields are under cultivation.*
- *H8: The area under maize decreases in favour of the area under soybean.*

They are followed by questions about the quantities harvested for improved maize and soybean, local maize and soybean, maize and soybean with and without inputs. The answers are expressed in 100 kg/ha. The producers are also asked to assess their production costs: How much does it cost you to produce one hectare of maize and soybean? We are also interested in the workforce (Table 11), sourcing (Table 12) and flows (Table 14).

3.1.5. Distribution

Coulter and Onumah (2002) clarify the role of warehouse in sub-Saharan Africa. The rapid removal of food from farmers to regulated centralised warehouses can significantly decrease storage losses, especially when using improved shelf-life. Focusing on pre-harvest losses is key (Sheahan and Barrett, 2017). Warehouses can also serve as a means of guaranteeing credit for liquidity-constrained farmers; farmers who cannot access financial services may store their grains as a form of in-kind savings (Stephens and Barrett, 2011). Storing grain in a warehouse allows avoiding the postharvest losses suffered by grain stored in the farm under less favourable conditions. However, if it fails to command a price premium on the market, the smallholder will be better served to sell his grain at harvest or store it on the farm. The establishment of a centralised commodity exchange based on negotiable receipts' trade could promote the agricultural value chain's modernisation. Such advancements would benefit all growers of grain, including smallholders (Miranda et al., 2019). Mutiga et al. (2019) study the concept of local grain production and banking system in maize growing areas of East Africa and its participation in provision of facilities that ensure that the harvested grain is appropriately handled and tested prior to storage under the custody of a warehouse receipt system.

Some bags are kept in the collective premises for speculative purposes. According to (Adegbola, 2010), bags are put on boards, in their small attics or bedrooms in their home.

- *H9: Storage is done individually on personal premises.*
- *H10: Warehouses are needed.*

3.1.6. Sales

Buyers usually come from the city. Note that Cluster N'Dali comes to fix the prices and acts as an umbrella organisation to group the products for purchase. There are also resellers and warrantage.

- *H11: Most of the producers sell their products to wholesalers.*

Van den Broeck et al. (2017) study rice smallholder farmers in Benin. Their results show that the bulk of smallholders prefer to market their produce under a contract compared to selling it individually. Contracts with complete restrictions on herbicide and pesticide use reduce the likelihood to be accepted. To comply with these restrictions, farmers require significant monetary compensation. Their preferences regarding certification remain mainly economically driven. If contract-farming in staple food sectors could be sustainable, as documented for the rice sector in Benin in Maertens and Vande Velde (2017), more farmers might benefit. Maertens and Vande Velde (2017) find that contract-farming results in expansion of the rice area, intensification of rice production, increased commercialization of rice, and higher farm-gate prices, and ultimately in rice output growth and increased household income. This trend is confirmed by (Arouna et al., 2021). However, Ton et al. (2018) show that conditions that may predict farmers' income effects from the contractual arrangement vary according to crop type. Also, as many contract farming arrangements imply adopting specifics inputs, crops, and horizontal coordination, more experimentations with varying service packages would help better identify the package components and contextual conditions that drive effectiveness in each contractual arrangement. Furthermore, based on a dataset covering various maize contract farming schemes in the Upper West region of Ghana, Ragasa et al. (2018) show that these schemes contribute to technology adoption and productivity growth, but not always to profitability, and therefore limited potential to reduce poverty.

- *H12: Most of the producers have a sales contract for one of their agricultural products.*

Walther et al. (2019) assess the effects of income and gender on informal social networks in the rice value chain in Benin, Niger and Nigeria. They show that, based on data collected from actors in the rice network, the richest are those who have established abundant ties within and beyond their community. This is essentially true for men. Women producers and retailers occupy the ends of the value chain whereas the largest profits are related to storage and wholesaling rather than processing.

To assess the ability to exchange information, the questions are: Do you have a mobile phone? Is it important? Have your farming activities been seriously affected by unforeseen circumstances?

- *H13: Most of the producers have a mobile phone.*

3.2. Data collection

In the interest of efficiency and reducing the use of paper, an app for Android and React was implemented to collect data. A model-view-controller software design pattern was used to develop user interfaces, and an opensource structured query language, in this case SQLite, to store data. The app was tested with the producers attending the seminar organised in November 2019. A presentation and training on data collection tools and preparation of fieldwork were given to the participants.

The surveys were conducted in December 2019 and in January 2020, i.e. in the middle of the harvest. The rural development technicians from Eclosio or URP-BA, in charge of the communes, had planned the meetings by mobilising the producers. The technicians stressed that in order for women to feel comfortable, they should be represented and interviewed by women. In each selected village, a three-stage procedure was performed.

Single focus group The commonly spoken language in Borgou is Bariba. First, the technician introduces the delegation. Then, the team leader explains the research's objectives and the processes. Upon the producers' request, certain aspects of the study are detailed. A discussion takes place to ensure that the survey process is understood. This interactive discussion of all participants and a team of facilitators as one group in one place has been identified by Nyumba et al. (2018) as a single focus group. According to the authors, focus group methodology was used to explore the contribution of indigenous knowledge to agriculture and climate change adaptation, such as (Somanje et al., 2021) in Ghana.

Direct and personal interviews The team conducts direct and personal interviews using the questionnaire on smartphone. The application collects the producer's responses. The target is people above 20 years old who own a maize or soybean farm and live within the study area. A translator assists producers who do not speak French. Table 4 shows the distribution of respondents in the eight communes of the Borgou department. At least three villages per commune are visited. Several administrative divisions are involved in each of the 25 surveyed villages in our study. These are all villages where the support agents of the NGO Eclosio and the URP-BA work. The advantage is to ensure the mobilisation of the farmers before the arrival of the interviewers team.

Visits to storage facilities The investigators' team requests a visit to the premises used to store the products under the producers' guidance and the heads of producer groups.

4. Empirical results

After cleaning the dataset of any inconsistencies in the entries, 287 questionnaires are analysed thanks to RStudio.

4.1. Socioeconomic characteristics of the respondents

The proportion of men is 81.5%, women are overrepresented in our sample (Table 2), due to our communication. However, decisions on key agricultural activities are made by several members of the household for 95% of the respondents. Almost all of them were married (95%). Some respondents are married to several women: 33 of the male respondents state to be married with two wives, 12 with three wives, and three men with four wives.

A household is composed of a person or group of persons, whether related or not, who live together in the same housing unit, share common living arrangements, recognise the same person as the head of the household, eat together and are considered a single unit. The median of the household size is 10, with a maximum size of 88 (Fig. 2). The classification by Ward's method (Ward, 1963) suggests three main classes, the smallest has a household size $\leqslant 10$(153 respondents) and the greatest a household size $\geqslant 40$for 10 respondents.

In terms of the participants' age, the highest proportion of participants was 40–50 year-old (27%). The number of years of experience is greater for men (Fig. 3).

Agriculture is considered as a business for 68% of the men and 77% of the women. Agriculture is the main activity 81% of the men and for 68% of the women; the respondents earn income from a variety of non-farm sources, 21% declare to combine two activities (they are mainly involved in livestock activities or are workers).

4.2. Access to land

The majority of the respondents (79%) have inherited their land, 3% leased and 2% purchased it, 8% state the "other" option. The remaining respondents combine inherited, purchased and leased options. Our sample supports $H1$, since the majority of the respondents have inherited their land. On average, the area of the field is 16.2 ha (median = 10 ha). The classification by Ward's method (Ward, 1963) suggests three main classes, the smallest with an area of the field $\leqslant 22$ha (228 respondents of which 52 women) and the greatest with an area of the field $\geqslant 80$ha for 5 men, 3 of them located in N'Dali. Fig. 4 shows the distributions of the fields' area according to gender. The men represent most of the respondents and have a larger area of fields than women (Student test conducted with a confidence level of 95% results in a p-value < 0.001). The access to land is more difficult for women than for men, $H2$ is thus supported.

The majority of the respondents (69%) states that their field's area is not enough. Only 6% of the respondents rent, of which one woman rents 1.5 ha and another 2 ha. On average, the rented field area is 6.45 ha (median = 3 ha) at, on average, 31.59 € per ha, with a standard deviation of 18.98 €.

4.3. Standard of living

The floor is composed of natural materials or rudimentary materials for 34% of the respondents. In addition, 93% are deprived of cooking fuel, they have to collect firewood to cook. All the visited villages

Table 4
Distribution of farming households' respondants.

	Bembéréké	Kalalé	N'Dali	Nikki	Parakou	Pérèrè	Sinendé	Tchaourou
Our survey	42	32	50	38	18	20	41	46
Total (INSAE, 2013)	1150	1378	1141	878	657	666	1739	1495

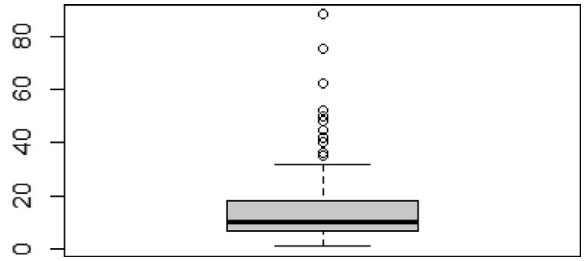

Fig. 2. Household sizes.

had a well. Fig. 5 shows that 39% of the sample represented has no education (66% of women).

Farm families are not only agricultural producers but also consumers. Regarding the general situation of the household, around:

- 12.5% can afford to buy certain expensive products such as a TV, a fridge or a motorbike (Group G1).
- 42% have enough money for food and clothes and save a little, but not enough to buy expensive things like a TV, a fridge or a motorbike (Group G2).
- 37.5% have enough money for food and clothing (Group G3).
- 9% do not have enough money for food (Group G4).

So 87.5% of the respondents are deprived of assets (*H*3 is supported). Agriculture is the only source of income for 36%; it contributes to the household's livelihood for 92% of the sample and is an essential contribution to household's consumption (95% of the respondents); that is mainly subsistence. Their motivation of farming are: gaining money from the sale (87%); family consumption needs (82%); children's schooling (72%) and main activity (43%).

The studied household's general situation can be explained (p-value < 0.001) by the commune; the areas such as the area of the field, the area under maize or soybean, number of ha owned. All these explanatory variables are strongly correlated. It is also linked to the distance to market (p-value < 0.001), whether or not farmers considered their activity as a business (p-value < 0.01) and to the storage location (p-value < 0.001).

4.4. Financial aspects

The possibility of obtaining credit is considered important for 90% of the respondents.

*H*4 is supported since 63% of the respondents borrow money to finance their farms. However, more women (47%) are self-financing than men (35%). By order of importance, the main microfinance structures that support producers through loans are CLCAM (Caisse Locale de Crédit Agricole Mutuel), PADME (Projet d'Appui au Développement des Micro-Entreprises), SIA'SON, PEBCO (Promotion de l'Epargne à Base COmmunautaire) and Benin Cajù (whose main objective is to strengthen and broaden cashew value chains).

Producers are paid via cash transfer (97%) exclusively; one person uses electronic funds transfer, and 2% combine cash and another payment method such as Mobile Money. They receive their primary source of income annually (40%); monthly (10%); weekly (6%); daily (14%); depending on the harvest (29%), 45% have no other source of income. They declare that, on average 18.26 €(median = 7.62 €, $\sigma = 42.12$ €with an interquartile range of 8.67 €) is a minimum to live per month and per person.

4.5. Profitability of growing maize or soybean

In our survey, 78% of producers claim that growing maize is profitable for them, whereas growing soybean is profitable for 90% of them. The first column of Table 5 displays the answers concerning the factors influencing profitability while, in the second column, solutions for better profitability, suggested by the producers, are displayed. In brackets is the number of answers.

The market influences profitability in various ways: low sale price (19); lack of demand (5); market price fluctuations (5) and mediocre sales (3). Note that producers also face the challenge of marketing their products and are often faced with the unpredictability of market price. Nine producers think that a platform is needed to help them find a marketplace for their agricultural products.

4.6. Workforce

The main tasks of the workforces are ploughing and land preparation, sowing, weeding and harvesting. On average, five household members farm the agricultural land, with an interquartile range of 4. Of course, this number depends on the size of the household. Indeed, it is estimated that 43% of the members of the household members perform agricultural tasks. There are 53% of producers that rely solely on the family labour force; 27% hire daily workers, 15% hire workers for an extended period, and 3% claim that they do not hire additional staff. The remaining count on friends and neighbours. Hypothesis *H*5 is not fully supported.

4.7. Sourcing

Producers either use improved seeds (40% of the respondents) or local seeds (53% of the respondents), the remaining 7% of producers use both. Fertilisers are used by 86% of the respondents; selective herbicide by 91%; total herbicide by 85%; insecticide for products by 30% and insecticide for conservation by 28.5%. As far as sourcing of these products is concerned, farmers mentioned SODECO (51%), even if SODECO do not provide maize and soybean farmers with inputs, followed by the black market (34%), occasionally by suppliers located in Nigeria (7%) or Ghana (5%).

Relying on the information provided by Eclosio, four bags of fertiliser are needed per ha and 2 liters of herbicide are needed per ha. According to the survey, 2.406 litres of selective herbicide ($\sigma = 1.12$) are used by ha and 2.249 liters of total herbicide ($\sigma = 1$) are used by ha. Therefore, the amount of herbicide used are, on aver-

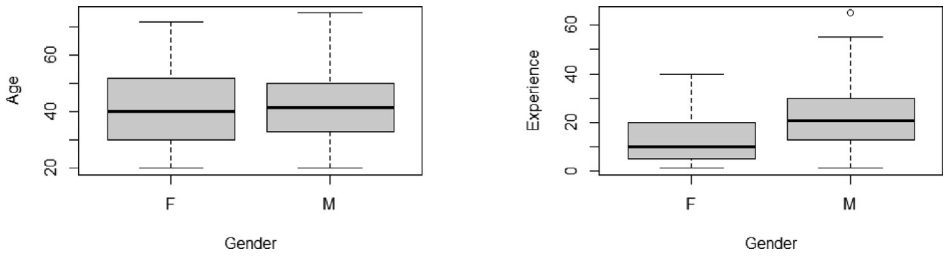

Fig. 3. Age and experience.

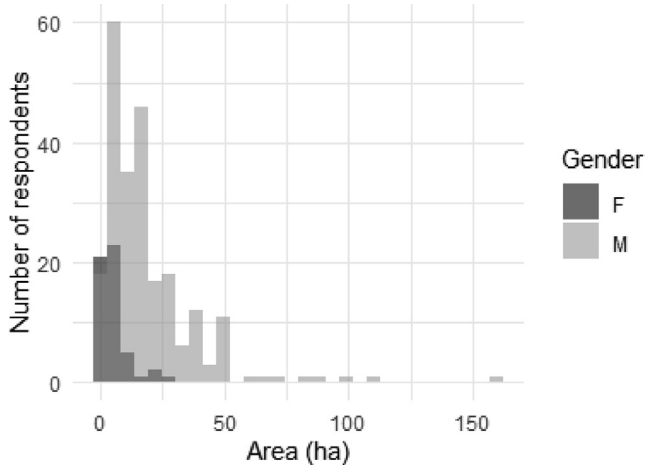

Fig. 4. Fields' area distribution, Female (F) and Male (M).

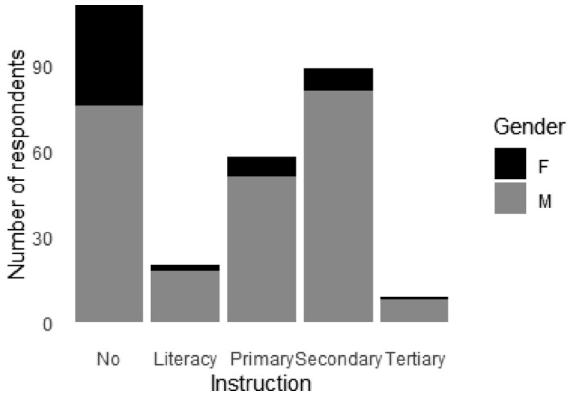

Fig. 5. Educational levels.

Table 5
Profitability: factors and solutions.

Factors	Solutions
the market (32)	increasing funding support (91)
funding(19)	warehousing possibilities (80)
fertility (12)	increasing the ease of obtaining inputs (73)
warehouse (8)	assistance to find a market place (61)
weather-related issues (7)	training and coaching (29)
shortage of agricultural land (6)	access to credit (23)
labour (4)	enlarging agricultural field (14)
quality of the seed(2)	stabilise selling prices (8)
transport (2)	improving the transportation (8)
	support to add value (5)
	support with resource management (4)

age, greater that the required amount. *H*6 is thus supported. However, the obtained data cannot be used to assess the quantity of fertiliser used per ha. On average, the fertiliser costs 17.73 €per 50 kg bags (the standard deviation is $\sigma = 2.47$ €); two liters of selective herbicide is 5.31 €($\sigma = 1.61$ €) and two liters of total herbicide 4.73 €($\sigma = 1.36$ €).

4.8. Production

The maize cultures are considered as the main production by 92% of the respondents against 8% for soybean.

4.8.1. Crop allocation

The vast majority of the fields (83%) are under cultivation (median: 100% of fields are under cultivation). *H*7 is thus supported. The total area under maize/soybean, according to the communes is represented in Figs. 6 and 7.

Comparatively to the figures in Table 3, the area of field used for sowing soybean has increased in all the communes except Nikki and Pérèrè (Table 6 and Figurefmsnew). In N'Dali, the repartition remain quite stable.

To get insight into the evolution of the share of the area between maize and soybean, the t.tests (p-value < 0.001), based on answers to CM1, CM2, CS1 and CS2, indicate that the area under maize decreases in favour of the area under soybean (*H*8 is supported). This result is aligned with the distribution by years of experience in growing maize and soybeans. Indeed, when the years of experience are above 10, more respondents are growing maize (Table 7) than soybean. The trend reverses when the number of years of experience is smaller.

4.8.2. Quantity produced

The quantities harvested, expressed in bags of 100 kg/ha, seem to be greater for improved maize (18.12) than for local maize (17.02) with a p-value = 0.2; and for improved soybean (13.70) than for local soybean (12.88) with a p-value = 0.1. Regarding the inputs, the quantities are greater for maize with inputs (19.26) than without (11.26) with a p-value< 0.001; and greater for soybean with inputs (14.12) than without (11.82), p-value = 0.03. The total quantities of maize are 53% improved, and 88% with inputs; while for the soybean, the proportions are 53% for improved and 75% with inputs.

Regarding the respondents that cultivate maize, on average and in bags, the harvest quantity is 93; 64 are sold, 14 are consumed, 7 are still stored and 6 are lost. For the respondents that cultivate soybean, the harvest quantity is 40; 36.7 are sold, 0.7 is consumed, 2.5 are still stored and 0.8 is lost.

To satisfy family consumption before a new harvest, 24% of the respondents have to buy maize from the market; 81% of them at a higher price than they sold it. There are 8% who buy soybean from the market, 65% of them at a higher price than they sold it.

4.8.3. Production costs

The crops are stored in 100 kg bags. The respondents assess the cost to produce one hectare of maize to 153.64 € with a standard deviation of $\sigma = 79.3$ €; and the cost to produce one hectare of soybean to 123.91 €, $\sigma = 64.93$ €.

4.9. Warehouse

Due to a lack of space, producers do not have access to enough storage facilities. Sofagrin®, is used to control pests in stored grains, alternative methods, including in particular the use of insecticide plants, are also used (Gueye et al., 2011).

The interviewers' team requested a visit of the premises used to store the products, under the guidance of producers and managers of producer or processor groups. These are individual storage rooms that are nothing more than rooms in their homes used for storage, or collective premises that are storage warehouses managed by the Unions Communales des Producteurs (UCP) and built with funding from Swiss Cooperation. There is a lack of a proper procedure for managing the few available warehouses. Producers store the products in polyester bags put on boards, often in their small attics or bedrooms. *H*9 is thus supported. The kinds of storage usually used (question W3) are bedroom storage (185); Braided straw attic (2); Banco attic (1); Storage in a warehouse (82); Bedroom and warehouse storage (17). Sofagrin and palm tree fruit are generally used as a product to keep away anything that might harm the crops in the storage of maize and soybean.

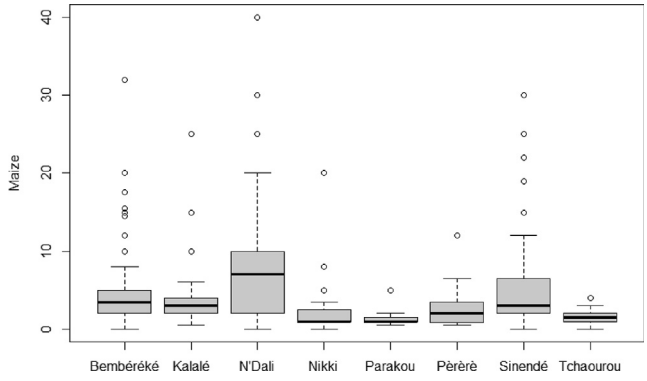

Fig. 6. Distribution of maize areas according to the communes.

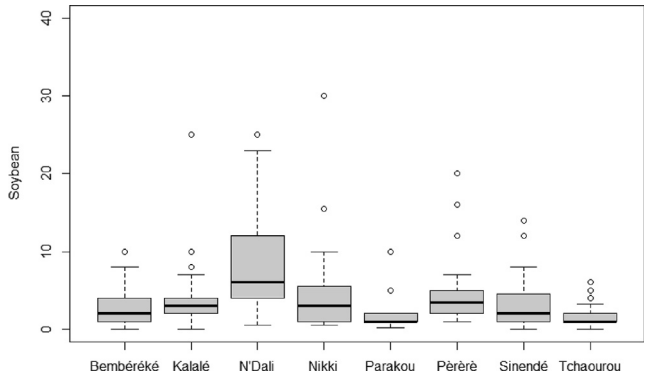

Fig. 7. Distribution of soybean areas according to the communes.

To avoid damage to their products in storage, they use planks/bricks to avoid depositing on the floor (54), and various products: insecticide (50), against rodents (16) and traditional (5). The climate is a usual factor in the deterioration of their stock for 25% of the respondents. Having a storage infrastructure is necessary for 93% of the respondents ($H10$ is supported). The vast majority of the respondents store their crops waiting for the price to improve (89%); to pay school fees (29%); to consume later (23%), for another important expense (19%); to enable their family to have extra money after the harvest period (8%) and to minimise hazards or risks (7%). The reasons why they are not currently storing one of their crops is because there is no storage space available nearby (24%); the money is needed after the harvest (6%); storage is too expensive (4%), and there is no surplus to store the crops (3%).

Considering farming as a business and the utilisation of warehouses are two dependent variables (p-value > 0.1 from χ^2 test); 37% of respondents who consider their farming profession as a business use warehouses, while 28% of those who do not consider their activity as a business use them. There is no statistically significant difference between groups who store in a warehouse and those who store at home. Respondents who store in a warehouse suffer an average loss of 6% as opposed to 7% (p-value > 0.1) in terms of quantities of maize for those who store at home; and for soybeans, the average loss is 2% for both groups. Moreover, 6% of respondents who store in a warehouse have to buy maize as opposed to 15% for those who store at home (p-value < 0.001 from χ^2 test). Regarding soybean, only 3% of respondents who store in a warehouse have to buy some of it, as opposed to 11% for those who store at home. Warehousing also permits producers to increase their earning potential by allowing them to benefit from seasonal price increases; 94% of those who store in a warehouse say they consider selling at the market price compared to 79% of those who store at home (p-value < 0.001). Moreover, 97.5% consider that the ideal location of the warehouse should be close to their village; 5 of them precised near an asphalt road, and seven respondents have no idea.

4.10. Sales and distribution

A majority of producers (89%) do not have a sales contract for one of their agricultural products ($H12$ is not supported) but they know in advance customers to whom they sell their crops. These customers usually come from the city. Note also that Cluster N'Dali comes to set prices and acts as an umbrella organisation to group products for purchase.

Table 6
Area of field under maize over the areas under maize and soybean in %.

	Bembéréké	Kalalé	N'Dali	Nikki	Parakou	Pérèrè	Sinendé	Tchaourou
INSAE (2013)	87	73	48	24	73	14	90	52
Our survey	68	50	49	34	43	34	67	48

Table 7
Distribution by years of experience in growing maize and soybeans.

		[0,1]	[2,3]	[4,5]	[6,7]	[8,9]	10 and more
Bembéréké	Maize	1	2	8	2	2	27
	Soybean		8	12		5	10
Kalalé	Maize		2	4	1		23
	Soybean		4	4	1	1	19
N'Dali	Maize		1			1	39
	Soybean		2	8	6	5	26
Nikki	Maize		2	4	1	5	21
	Soybean		3	7	3	6	14
Parakou	Maize		3	1	2	1	10
	Soybean		3	3	2	2	7
Pérèrè	Maize			2	1		15
	Soybean			3	2		13
Sinendé	Maize		4	2	2	2	25
	Soybean		16	7	2	2	11
Tchaourou	Maize		5	7	3	1	27
	Soybean		16	9	4	2	11

Producers sell their crops when the price is high (50%); just after the harvest (43%); just before a party (4%) and for the start of the new school year (4%). They sell them to a wholesaler (87%); retailer (56%), or directly to the final consumer (8%), almost all of them in the village or in a local market (*H*11 is supported). The reasons are: that they get the best price on this market (66%); they are members of a cooperative (12%); they do not have access to transport to other markets (9%), or they do not produce enough to transport to a larger market (3%). A majority of respondents (83%) claim to charge market price. When the agreed upon price is not equivalent to the current market price, they believe their customer has unfairly taken advantage of them.

They sell their maize 36.46 € per bag (interquartile range 6.1) and their soybean 64.2 € (interquartile range 6.1). Subtracting the production cost, this leads to a benefit of 548.63 € per ha of maize and 681.01 € per ha of soybean.

The challenges they face in getting their agricultural products to customers are transportation (53%), distance to market (27%), lack of storage facilities (36%), lack of refrigeration facilities (11%), products damaged during transportation (9%) and unreliable intermediaries (3%). Note that 25% do not face any challenge.

Since some producers are selling their products to Cotonou, the average distance to the point of sale is 52.40 km for maize and 60.65 km for soybean; however, the mean value for both crops is 5 km which confirms that producers sell their products locally. Besides, for them, the ideal location for a warehouse before market disposal is close to or in their village.

To transport their products to the market, 44% use a motorcycle; 20% van: 13% taxi; 10% truck and 30% do not use any vehicle. For those using a vehicle, they have to use degraded earth roads (47%); good condition earth roads (21%); track and path (36%) or asphalt road (11%). On average, the transportation of the products to the market costs 9.15 € per km.

4.11. Information flows

More than 90% of the respondents have a mobile phone (*H*13 is supported); 91% consider having a mobile phone as an essential tool. Note that more than one-quarter of the respondents (26%) claim that in the last three years, their farming activities have been seriously affected by weather-related events, pests/illnesses, accidents or other unforeseen events such as market price fluctuations.

4.12. SWOT analysis

A SWOT analysis addressing the strategic capacity of the maize or soybean producers, in order to be competitive on the considered market is provided in Table 8.

5. Discussions

The results contribute to understanding the maize and soybean production in Borgou. Satistical analysis showed that the mean household size of sampled farmers in Borgou is 13.27 (σ= 11.05), which is greater than the mean of 10.9 (σ= 7.1) obtained by Amegnaglo (2018). Moreover, the mean maize yield obtained by his study is 1 347 kg/ha maize, whereas we obtain 1 812 kg/ha for improved maize and 1 702 kg/ha for local maize. Besides the year of the survey, several factors can explain the differences. Amegnaglo (2018) conducted his survey focused on maize in Alibori, Atlantique and Collines departments and more women (27%) were interviewed. The mean farm size is smaller (3.9 ha with σ=4.4). Furthermore, fertilisers are used by 86% of our respondents and only by 57% of farmers in Amegnaglo (2018) which shows that the use of fertilizer significantly increased land productivity. Comparatively, in Pendjari region, in the department of Atacora (North-West of Benin), the maize yield ranges from 600 kg/ha maximum to 1 700 kg/ha (Ogoudedji et al., 2020).

We also determined that respondents sell their maize 0.36 €/kg and their soybean 0.64 €/kg. By comparison, rice smallholder farmers in Benin received a Fairtrade price of 0.82 €/kg, whereas the local market price is 0.56 €/kg for long grain rice and 0.23 €/kg for the lower quality paddy rice (Van den Broeck et al., 2017). The producers perceive that growing soybean is more profitable than growing maize. Consequently, the fields used to cultivate sowing soybean have increased in many communes (Section 4.8.1). However, the maize cultures are considered as the main production. For farmers, soybean is usually a secondary crop often produced by women to increase the low family income. The main process is the transformation of soybean into cheese. Soybean presents interesting nutritional value (e.g. Canaan et al. (2022)) offering a cheaper source of protein, as compared with fish and meat (Floquet et al., 2013), this tackles the SDG 2. According to de Freitas et al. (2022), soybean helps the biological nitrogen fixation, thereby enhancing soil fertility, SDG 15.

Moreover, the majority of the producers sell their products to a wholesaler and do not have a sales contract (Section 4.10). There are organisations between producers that allow them to market their production practically at the level of each commune, even if these are not formal. One of the strategies advocated by the government in the Republic of Benin is very focused on the creation of clusters. These clusters, with the support of Enabel, are very well developed in the south of the country around the rice and pineapple sectors (Enabel, 2020). In the North, the process is underway.

After statistical analysis, the survey results were discussed with field experts such as Eclosio technicians. Based on our meetings and analyses, the areas of focus identified are smallholder farmers, agricultural warehouses, digital technology, agroecological transition, and women empowerment (Table 8).

5.1. Smallholder farmers

The term smallholder often overlaps and may be used interchangeably with small-scale agriculture, family farm, subsistence farm, resource-poor farm, low-income farm, low-input farm or low-technology farm (Heidhues and Bruntrup, 2003). There are many definitions highly depending on the context. Despite SDG indicators 2.3.1 and 2.3.2., which measure labour productivity and income of smallholders, a general and operational definition of smallholders does not exist (Khalil et al., 2017).

Food production's objective is to meet demand and, at the same time, to reduce adverse environmental impacts. In the Borgou department, food security and sustainability depend on how smallholders farm their land (Sanchez, 2015). Farms' categories can be defined on the basis of their relation to markets such as subsistence and near-subsistence smallholders. These smallholders produce essentially for their consumption and with little or no capacity to generate surplus production for the market (Ragetlie et al., 2021). In our survey, 87.5% of the respondents are deprived of assets. Thus, they can be considered subsistence smallholders. Also, the land tenure status of farmers can condition their ability to innovate: some technical innovations are possible on inherited family lands but not on rented lands; land tenure insecurity discourages investment and intensification. Access to tractors is often ensured by the CUMA and facilitation initiatives through the State's Programme for the Promotion of Agricultural Mechanisation (Moumouni-Moussa, 2020; Ströh de Martinez et al., 2016). Due to limited resources (SDGs 1.4. and 2.3.), farmers may be unable to embrace and use new technologies (SDG 17.7).

The land size criterion is often adopted for identifying small farms. Nevertheless, the threshold to consider a farm as small depends on the region. It ranges from 1 to 10 ha in Africa. Note that the farm's size is measured in terms of the operated land, that is, the amount of land effectively used by a farm or a household under different arrange-

Table 8
SWOT analysis related to maize or soybean producers.

Strengths	Weaknesses
• Awareness of the importance of agriculture as an essential contribution to household's consumption • Producer-NGO relations • Producer-wholesaler relations • Cooperative of Agricultural Machinery Users • Storage warehouses built with funding from Swiss Cooperation	• Monitoring performance and profitability • Negotiating power of wholesalers, no sales contract • Lack of control of transport costs • Inventory management • Information systems • Vision of the producers limited in time • Lack of agricultural infrastructures and equipment • Lack of access to markets • Dependent on climatic conditions
Opportunities	**Threats**
• Collaborative model: purchasing/investment; transport; storage/warrantage; sales • Agroecology • Digital technology • Women empowerment • Microfinance institutions • High potential for groundwater	• Access to land • Rainfall disturbance • Exodus of young rural people • Increase of poverty

ments. This land is different from the land owned, or the cultivated land as the former includes fallow land (Khalil et al., 2017). Our findings show that the field area is less than 10 ha for 50% of the respondents (Section 4.2). Moreover, most of the fields (83%) are under cultivation (Section 4.8.1).

The total amount of labour input per holding can also be used as a criterion for identifying small farms. There are 53% of producers that rely solely on the family labour force and, on average, 43% of the household members work agricultural tasks (Section 4.6). However, the number of persons working in a holding is a poor proxy for the total labour input. Indeed, as stated in Khalil et al. (2017), there are part-time, seasonal and casual labour and work in agriculture, which partly stems from the high variability of labour demand. For instance, 21% of our producers declare to combine two activities (Section 4.1). Moreover, relevant characteristics of the farm, such as mechanisation, are uncaptured. Also, data availability is a major challenge.

Several criteria should be used in combination to capture relevant characteristics of the farms. Terlau et al. (2019) provide a typology of smallholder farmers. The authors consider that smallholder farms are usually family operated, own small acreage and lie in suburban areas. Smallholder farmers are low-tech farming enterprises and benefit from their independence in cultivating and marketing crops. Terlau et al. (2019) state that smallholder farms are crucial to national food supplies and economies, and they will play a prominent role in the sustainable food systems in the future.

Smallholder farmers remain highly vulnerable because of lack of education (SDG 4), access to markets (SDG 9.3), especially for women (SDG 5.A), and transportation (SDG 9.1), see Section 4.3. Moreover, they have limited access to information despite the internet (SDG 9. C). According to Terlau et al. (2019), targets focusing on basic needs, such as target 1.1 "eradicate extreme poverty", are chiefly relevant for measuring the performance of smallholder farmers in the social dimension of sustainable development left out by assessment tools such as the carbon footprint and life cycle analysis. Terlau et al. (2019) propose the handprint assessment approach as a tool to measure the positive contribution of the primary sector (food and agriculture) to sustainable development. For the smallholder farmers, handprint assessment addresses four categories (social, environmental, economic, and governance). It adds the basic needs, including access to safe, affordable food, education, and health care, defining basic preconditions for the SDGs and the human welfare of smallholder farmers.

Regarding governance, obtaining credit (SDGs 1.4 and 9.3) is essential as producers borrow money from microfinance institutions to finance their farms. However, the financial needs of the producer are challenging to meet. By its seasonal nature, with a time lag between outflows and inflows, agricultural activity depends on the quality of the resource base, is exposed to unstable weather and prices, and is vulnerable to pests and product deterioration. In addition, farmers in Borgou generally want to borrow simultaneously and often engage in the same activities and are exposed to the same risks.

5.2. Agricultural warehouse

Abraham and Pingali (2020) show that the yield for cereals in Africa rose much less than in other regions of the world between 1961 and 2017. One of the reasons given by the authors is the poor access to essential infrastructures such as storage and roads.

Post-harvest losses vary significantly by crop, stage in the value chain and location (Abass et al., 2014; Tefera, 2012; Kumar and Kalita, 2017). Many storage methods used by farmers present obstacles such as limited access and cost-effectiveness, lack of scalability, and there are not tailored to local situations. Selling grain just after harvest, like 43% of our respondents, or due to households' needs for cash (Section 4.10) leads to a loss of potential income and food insecurity at the household level. Moreover, to satisfy family consumption before a new harvest, about a quarter of the respondents have to buy maize from the market, usually at a higher price (Section 4.10). Household's objective of storing maize is home consumption or for selling as grain prices often increase from harvest to lean season (Baributsa et al., 2014; Baributsa and Njoroge, 2020). Kadjo et al. (2018) find that expected storage losses discourage households whose storage target is to sell later. They also suggest that liquidity is more crucial for households that store mainly for food consumption. As a result, they conclude that low-priced sales at harvest time occur because of liquidity constraints for consumption-oriented households, whereas market-oriented households do so because of technological storage constraints.

In this study, the agricultural warehouse refers to a building designed to accommodate agricultural products, particularly maize and soybean. It is supposed to contribute mainly to preserving these products against damage and bad weather. Therefore, it increases the quality and quantity of the grain because the products are stored in good conditions, which reduces losses and increases the products' selling price. Warehousing also permits producers to increase their earning potential by benefiting from seasonal price increases. It also provides them with the right information to conduct advantageous negotiations and sell their products at market prices, ranked in the second position among the solutions producers suggest for better prof-

itability (Table 5). These findings are consistent with SOS Faim (2016) and with the report of the Développement, Agence Française and Cooperation, Technical Centre for Agricultural and Rural and Development, International Fund for Agricultural (2015). However, if the market price does not increase during the lean season, producers may suffer losses due to storage costs and transportation costs to the warehouse. Therefore, the location of the warehouse should be close to their village (SDG 9).

In further research, modern concentration agricultural warehouses that minimise total logistics costs could also be studied. Indeed, the N'Dali Cluster could guide this kind of development in the Borgou department, which would help stabilise prices and find better markets for the products. Our findings are consistent with Adegbola (2010): better storage and conservation improve profitability and financial capacities of farmers. In addition, seminars or workshops on handover/ownership costs could help farmers control logistics costs.

5.3. Digital technology

Digital technology is perceived as an opportunity to strengthen the capacity of agricultural communities to connect to knowledge banks, networks and institutions and could significantly improve profitability and food security (Benin, 2019). Digital technologies influence agroecological practices such as fertilisation methods, choice of seed varieties, pest control, treatment of crop diseases or conservation techniques. They can be of great help in providing access to training (SDGs 4 and 13.3.) and information (SDG 9.C). In addition, they make it possible to connect the supply of agricultural products, which is mainly rural, with urban demand. This is the case with sales platforms such as described in JINUKUN (2014).

In Benin, digital deployment in agriculture faces the quality of digital infrastructure and networks and the level of education and digital literacy. However, producers with little or no literacy could use some digital tools thanks to the possibility of exchanging voice messages. Access to smartphones is on the rise: from 15 000 users for a population of 6 419 100 in 2000 to 1 375 033 for a population of 11 458 611 in 2017 (Benin, 2019). As already mentioned, more than 90% of the respondents have a mobile phone and consider having a mobile phone as an essential tool.

Nacambo (2020) categorises the digital solutions according to:

- Digital solutions for data collection and decision support which bring together technologies that gather farm data to provide predictive analysis or influence farmers' decisions.
- Digital solutions for production and management of agricultural operations which concern applications that use the data collected to offer various services directly linked to production, such as automatic irrigation or varietal selection.
- Knowledge exchange and sharing platforms which concentrate forums, networks or training sites.

Eclosio and its partners are currently considering an initiative by setting up a platform that also integrates aspects related to digitalisation to facilitate access to the market. The platform could provide a transparent and trustworthy space for farmers and buyers to negotiate fair prices. They are also planning to professionalise the warrantage system that some producers are already using in the area. It will be necessary to think about the best way to set up this platform by making them aware of their responsibilities so that the platform is considered a useful tool.

Access to information on weather forecasts would greatly assist farmers in planning their tasks. Indeed, Griggs et al. (2021) show how weather and climate services may be tailored to improve decision-making across all the SDGs. In addition, it is essential to provide comprehensive information on climate trends and appropriate agricultural adaptation measures to mitigate climate impacts. Fadina and Barjolle (2018) demonstrates that farming experience, educational level, gender and farm size are the most significant factors affecting the adaptation choice of farmers. Agricultural experience enables the identification and implementation of any adaptation strategy. At the same time, education influences the choice of all adaptation strategies. Because they have less capital and resources, smaller farmers are less likely to cope with climate change.

Eventually, blockchain technologies (Ge et al., 2017) could help certify the origin of seeds, crop plots, production processes and, specific target markets and brands.

5.4. Agroecological transition

Unfortunately, many farmers even take the specific fertilisers for cotton that they use on other crops such as maize. Indeed, our results show that 51% of the farmers mentioned SODECO as inputs provider. There is a poor application in terms of dose herbicides in particular on farms (Section 4.7). It is therefore advisable to consider raising awareness in the communities about the effects of herbicides on production resources (soil, surface water, crop products, humans, etc.) and conducting an in-depth study on the use of herbicides in the farming environment.

Moreover, there is a lack of accurate soil mapping to understand the fertility gradient between zones. Therefore, a soil analysis looks pretty relevant to better advise producers. In the same vein, and to limit or reduce the impact of chemical inputs on the environment, Eclosio, through its projects, is gradually leading farmers towards adopting agroecology.

In FAO (2018a), agroecology is defined as "an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems. It seeks to optimize the interactions between plants, animals, humans and the environment while considering the social aspects that need to be addressed for a sustainable and fair food system". Biovision (2021) compares the results for the 17 SDGs under the business as usual and the agroecology scenario for a typical semiarid African country. SDGs 2, 11, 13 and 15 have their performance more than double.

The agroecological transition is taken into account in the objective of the Strategic Plan for the Development of the Agricultural Sector, that is to improve the performance of Benin's agriculture, to make it capable of ensuring food sovereignty, food and nutritional security in a sustainable manner, and to contribute to the economic and social development of the men and women of Benin in order to achieve the SDGs (The World Bank, 2017). Agroecological practices in Benin range from the use of farmer seeds to crop diversification and rotation, water and soil management and conservation, and biological and mechanical control (JINUKUN, 2014).

The independence of smallholder farmers in cultivating and marketing crops (Section 5.1) may lead to high biodiversity (SDG 15) and makes them more resilient to economic crisis (SDG 9). The biodiversity level should be improved to help reduce malnutrition (Section 2). Indeed, there is very little fruit and vegetables in the usual household consumption (Houssou et al., 2020; Houinato et al., 2019).

The sector faces several challenges, namely its dependence on rainfall, combined with insufficient irrigation systems. Benin has a high potential for groundwater, which has not been exploited to date (Section 4.3).

5.5. Women empowerment

Agriculture is the main activity for 81% of the men and for 68% of the women. It is considered a business for 68% of the men and 77% of

the women. More women (47%) are self-financing than men (35%). Women's disadvantages in terms of professional experience, education and revenues result, in general, to less access to financial services, less social and spatial mobility and, ultimately, lower incomes than men (Walther et al., 2019). However, across rural Africa, women farmers are taking advantage of Savings and Loans Group to expand their businesses. Using this approach improves nutrition, business development and sustainable land management (UN Women, 2021). Baborska et al. (2020) also mention the establishment of financing and insurance mechanisms that are adapted and accessible to the different types of farms and categories of actors in the agricultural sector, including women. These initiatives may be the reason why our empirical results do not exactly corroborate the statement in Atozou et al. (2017): "women's perceptions of agricultural land rights in Benin show that women in rural Benin neither have access to land and nor participate in land management decisions". However, we agree that gender inequality is still a paramount concern, and appropriate policies should articulate the allocation of land to women and customised policies in villages to increase the autonomy of women in meeting basic needs.

6. Conclusion

The study contributes to earlier theories and empirical studies on the maize and soybean sectors in Borgou. It provides insights to ensure the sustainable production of maize and soybean on which producers and many consumers depend. Indeed, if their basic needs are satisfied, farmers can be both beneficiaries and agents of sustainable development in low-income countries. Smallholder farmers, in particular, need affordable and simple technology. Indeed, most of the respondents are deprived of assets, and agriculture is an essential contribution to household consumption needs. One of the study's key findings is the role of a storage system in the profitability and attractiveness of the agricultural sector in Borgou. It includes the optimal location of agricultural stores not far from large harvesting areas. In further research, modern concentration agricultural warehouses that minimise total logistics costs could also be studied.

Moreover, access to credit is essential to boost agricultural productivity and profitability. Hence, the findings of the study have social implications in terms of poverty reduction in rural areas. The lack of agricultural mechanisation linked to farmers' financial constraints and difficulties in accessing credit also limit farmers' productivity and the competitiveness of Beninese agricultural products. Producers also face the challenge of marketing their products and are often faced with the unpredictability of the market price.

A digital platform could help them find a marketplace for their agricultural products and provide a transparent and trustworthy space for farmers and buyers to negotiate fair prices. This would be a valuable tool as most producers have a mobile phone.

As underlined in Njoroge et al. (2017), decision support tools may offer feasible alternatives for the development of specific nutrient recommendations. For example, investing in soil analysis could result in better fertiliser recommendations for smallholder farmers and ask for a more cost-effective approach. The agroecological transition is considered in the objective of the Strategic Plan for the Development of the Agricultural Sector. Finally, appropriate policies should help increase the autonomy of women in meeting basic needs.

The study attempts to analyse the maize and soybean production in Borgou using direct and personal interviews. Ideally, we should have run randomly assigned participation to the survey, but farmers' availability during the harvest is almost non-existent. Moreover, it would have been interesting to distinguish the realities of maize from those of soybeans in two SWOT analyses, but more relevant data are required. The results obtained on the one hand for maize and soybeans and the other hand for the Borgou department need adaptations to extend to the national or even regional level. This is the case, for example, with perishable goods such as pineapple and bananas, which need specific cold temperature warehouses for their conservation and management.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Appendix

Tables 9–16.

Table 9
Questions used to determine the access to land.

Code	Questions	Anwser type
L1	How did you acquire access to your land?	Purchase; Lease; Inheritance; Other
L2	What is the area of your field?	Quantitative
L3	How many hectares of farmland do you own?	Quantitative
L4	How many hectares of farmland do you rent?	Quantitative
L5	Who owns your land?	Qualitative
L6	Is the size of your field sufficient?	Yes/No

Table 10
Questions related to finance.

Code	Questions	Anwser type
F1	How do you finance your farm?	Self-financing; Bank loans; Both
F2	Which organisations do you borrow from?	Qualitative
F3	How much do you rent one hectare of land?	Quantitative
F4	What is the financial situation of your household?	4 levels
F5	How often do you receive your main source of income?	Annually; monthly; weekly; daily; depending on the harvest.
F6	Are there other ways in which you obtain an income?	Processing agricultural products; Providing a service; Renting land; Other; No other means.
F7	What is the minimum amount your household needs* to live on per month (for personal expenses)?	Quantitative
Pay	How are you usually paid for what you sell?	Cash; Cheque; On an account in a bank; Electronic funds transfer; Mobile money; Payment in kind (such as crops, labour); Prepaid payment card; Other
F8	Do you consider your farm to be a business?	Yes/No/Do not know
F9/ F10	Is growing maize/soybean profitable?	Yes; No; Neutral
F11	what factors influence the profitability of your business?	Qualitative
F12	What solutions do you propose for better profitability?	Qualitative

* Amount that covers only your basic needs for food, transportation, cooking fuel, and clothing.

Table 11
Questions related to workforce.

Code	Questions	Anwser type
WF1	How many members of the household farm the agricultural land?	Quantitative
WF2	What types of outside labour do you employ?	Qualitative
WF3	For what purpose?	Ploughing; Land preparation; Sowing; Weeding; Harvesting; Other
WF4	What is your principal activity?	Qualitative
WF5	What is your other activity, if any?	Qualitative

Table 12
Questions related to raw material.

Code	Questions	Anwser type
R1	What varieties of products do you grow?	Improved; Local; Other to be specified
R2	What agricultural inputs do you use?	Nothing; Fertilizers; Total herbicide; Selective herbicide; Insecticide for products; Insecticide for conservation; Other to be specified
R3	Where do you buy your agricultural inputs?	Fertilizers/Ghana/SODECO/Black market/Approved seed companies/Other to be specified
R4	How much do you buy your fertilizers	Quantitative
R5	How much do you buy your total herbicide?	Quantitative
R6	How much do you buy your selective herbicides?	Quantitative
R7	How much do you buy your insecticide for products?	Quantitative
R8	How much do you buy your insecticide for conservation?	Quantitative
R9	How much fertiliser do you use per ha cultivated?	Quantitative
R10	How much total herbicides used per ha cultivated?	Quantitative
R11	How much selective herbicides do you use per ha cultivated?	Quantitative
R12	How much insecticide for products do you use per ha cultivated?	Quantitative
R13	How much insecticide for conservation do you use per ha cultivated?	Quantitative

Table 13
Questions related to crop allocation.

Code	Questions	Anwser type
C1	What is the total area under cultivation?	Quantitative (ha)
C2	What is the total uncultivated area?	Quantitative (ha)
CM1/CS1	What is the total area under maize/soybean?	Quantitative (ha)
CM2/CS2	What is the area sown by maize/soybean in the last harvest?	Quantitative (ha)
CM3/CS3	How many years have you been growing maize/soybean?	Quantitative

Note that the interviewer has to check that $C1 + C2 = L2$ and that $CM1 + CSs \leqslant C1$.

Table 14
Questions related to maize/soybean flows.

FM1/FS1	What is the quantity of maize/soybean obtained in the last harvest?	Quantitative
FM2/FS2	What is the quantity of maize/soybean consume since the last harvest?	Quantitative
FM3/FS3	What is the quantity of maize/soybean sold since the last harvest?	Quantitative
FM4/FS4	What is the quantity of maize/soybean currently available?	Quantitative
FM5/FS5	What is the quantity of maize/soybean you consume per year?	Quantitative
FM6/FS6	Do you ever buy maize/soybean from the market to satisfy family consumption before a new harvest?	Yes/No
FMS	If so, do you buy it at a higher or lower price?	Higher/Lower

Table 15
Questions related to storage.

WM1/	WS1	What is the quantity of maize/soybean stock available from the last harvest just before the new harvest?
	Quantitative	
WM2/	WS2	What is the quantity of maize/soybean stock currently available?
	Quantitative	
W3	What kind of storage do you usually use to preserve your product?	Bedroom storage; Braided straw attic; Banco attic; Roof storage; Storage in the warehouse; Bedroom and warehouse storage
W4	How do you condition the crops for storage?	In 100 kg bags; Outdoors on the ground; Other
W5	Where do you store your crops?	Qualitative
W6	What are the difficulties encountered when storing the products?	Qualitative
W7	How much maize/soybean do you lose because of poor storage?	Quantitative
W8	What do you need in terms of adequate storage infrastructures?	Qualitative
W9W	Is the climate a usual factor in the deterioration of your stock?	Yes/No/Other factors
W10	What means do you use to avoid damage to your stored production?	Qualitative
W11	Why do you store your crops?	I'm waiting for the price to improve; To minimise hazards or risks; To enable my family to have extra money after the harvest period; to pay school fees; for another important expense; To consume later; Other; Don't know
W12	Why are you not currently storing one of your crops?	No storage space available nearby; Storage is too expensive; There is no surplus to store the crops; It is not a good idea to store crops; I need to use the money after the harvest; Other; Don't know

Table 16
Questions related to sale and distribution.

S1	Do you have a sales contract for one of your agricultural products?	Yes; No; Don't know
S2	When do you sell your maize/soybean?	Just after the harvest; When the price is high; Just before a party; For the start of the new school year.
S3	To whom do you sell your agricultural products?	Cooperative; Wholesaler; Manufacturer; Retailer; Directly to the final consumer; Directly to a government agency; Intermediary/ Trading house; Agro-industrial company; Others; Don't know
S4	Where do you normally sell your agricultural products?	On the farm to a neighbour or a travelling salesman; In the village; Local market; Regional market; Field; Other; Don't know
S5	Why do you sell your agricultural products there?	Members of a cooperative; I get the best price on this market; I do not have access to transport to other market so I don't produce enough to transport to a larger market; Other; Don't know
S5	Why do you sell your agricultural products there?	Members of a cooperative; I get the best price on this market; I do not have access to transport to other market so I don't produce enough to transport to a larger market; Other; Don't know
S6	When you sell your agricultural produce, do you get the market price?	Yes; No; Don't know

(*continued on next page*)

Table 16 (*continued*)

S1	Do you have a sales contract for one of your agricultural products?	Yes; No; Don't know
S7	If not why don't you get the current market price?	Too few customers; My clients take advantage of me; I have to pay high commission rates to intermediaries; Corruption; No access to transport for others; Poor product quality; Other; Don't know
SM8/ SS8	Quantitative	How much do you sell your maize/soybeans on the market?
S9	What challenges do you face in getting your agricultural products to your customers?	Distance to market; Transportation; Goods or products damaged during transportation; Lack of storage facilities; Lack of refrigeration facilities; Unreliable intermediaries; I don't face any challenges; Other
S10	How far away is your point of sale?	Quantitative
S11	In your opinion, what would be the ideal location for a warehouse prior to market disposal?	Qualitative
S12	How do you transport your products from the shop to the market?	Van; Truck; Taxi; Motorcycle; Bicycle; Walking
S13	Which roads do you use to get to the market?	Asphalt road; Degraded road; In earth and good condition; Track and path
S14	How much does the transportation of the products to the market cost?	Quantitative

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