CLIMATE RISK PROFILE SERIES

ADAPTING GREEN INNOVATION CENTRES TO CLIMATE CHANGE: ANALYSIS OF VALUE CHAIN ADAPTATION POTENTIAL

Rice, soybean, and poultry value chains in Alibori, Borgou, Collines, and Zou Departments, **Benin**

Alliance
Bioversity International
CIAT
International Center for Tropical Agriculture
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CGIAR
RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security
CCAFS

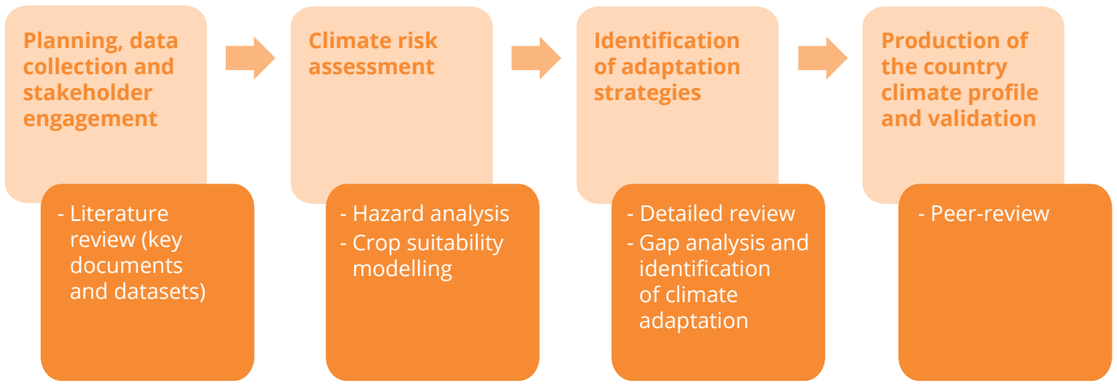
ABOUT THE REPORT

Climate change is affecting agriculture more than any other sector. Increased frequency and severity of drought, flood, heat, and unseasonable rainfall heavily impact rainfed agriculture, ultimately resulting in production losses. In that context, The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) through its climate action lever, are developing climate risk profiles for agricultural value chains in developing countries at the national and subnational level. These profiles build on past work conducted by CIAT and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)in collaboration with the World Bank and other partners, including FAO, USAID, DFID[1].

The present report aims to provide a climate and vulnerability analysis of the Green Innovation Centres (GIC) target commodity value chains. Herein we identify climate change- related vulnerabilities, hazards, and opportunities for adaptation to the same. Ultimately, our goal is to foster awareness of risks and adaptation priorities in the selected value chains and inform climate investments and planning through the recommendations on priority innovations to manage climate risks.

The report begins with an extensive literature reviews of the selected value chains and their key challenges and adaptation strategies. Climate hazards and crop suitability modelling offer insights into potential future scenarios under climate change. These results inform potential adaptation approaches, which are prioritized by in-country experts and stakeholders through an online survey. Finally, the results are peer-reviewed by the GIC country office and the Alliance scientific staff.

The **Green Innovation Centres** for the Agriculture and Food Sector (GIC) founded by German Federal Ministry for Economic Cooperation and Development (BMZ) and led by the German Agency for International Cooperation (GIZ) in collaboration with local ministries and programmes, aims to promote agricultural innovation under the *ONEWORLD No Hunger* initiative. Through the GIC, GIZ aims to generate employment raise farmers' income, and improve farmers' education and skills by funding training in good agricultural practices, water management, post-harvest processing, and entrepreneurship.



1 https://ccafs.cgiar.org/publications/csa-country-profiles

HIGHLIGHTS

- This study focuses on four departments in Benin: Alibori and Borgou in the northeast and Collines and Zou in the centre and south, respectively **(Chapter 1, pg.7).**
- Benin's agricultural sector contributes 28% of the country's GDP, and the most important cash crop is cotton **(Chapter 2, pg.8).**
- Key food staples include cassava, yams, and maize **(Chapter 2, pg.8).**
- The agricultural sector comprises 39% of employment in Benin and is an important source of income for women, constituting 30% of female employment **(Chapter 2, pg.8).**
- Although decentralization efforts are being carried out in the country, including in the agricultural sector, sub-national institutions at the local level still lack financial autonomy and may need to strengthen their technical and human resources capacity **(Chapter 4, pg.17).**
- The most pressing climate hazards in the study area include drought, heat stress, and flooding **(Chapter 5, pg.18).**
- Drought and heat stress impact all four departments, while flooding mainly affects Alibori **(Chapter 5, pg.18).**
- The most promising adaptation options involve the use of new crop varieties that are more tolerant to drought and floods, best practices for soil fertilization, and micro-irrigation techniques **(Chapter 6, pg.24-25).**
- For poultry, the main adaptation strategies involve improvement of zoo-sanitary surveillance and epizootic control systems and training for the construction of animal shelters **(Chapter 6, pg.25).**
- Conclusively the adaptation potential for the selected value chains is promising. Interventions that could facilitate adaptation include technical assistance to promote climate-smart agricultural practices; better, more reliable information available to producers; improved access to inputs; and broader access to financial services **(Chapter 7, pg.31).**

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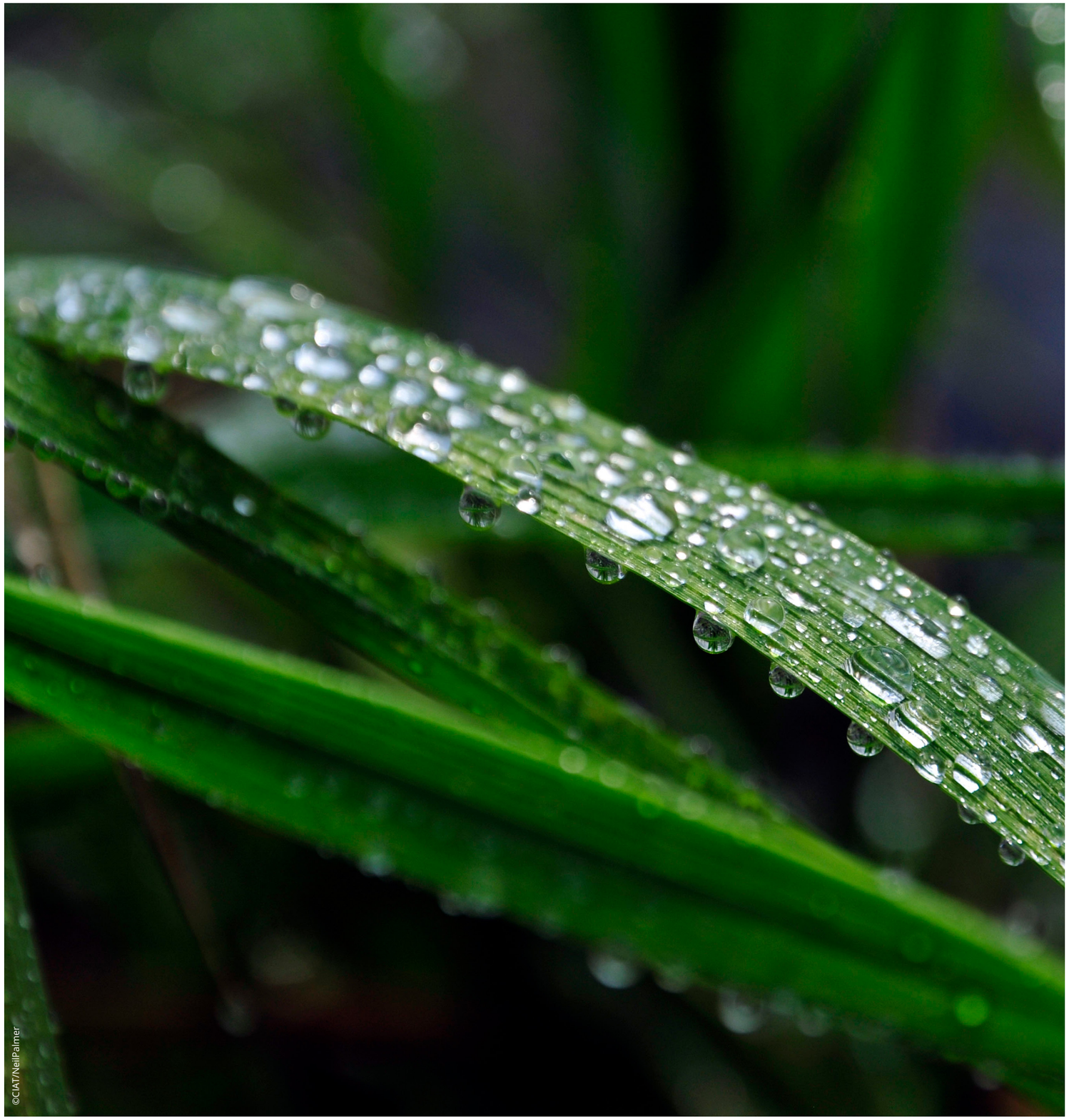

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ACRONYMS AND ABBREVIATIONS

CCR-B	Association of Benin Rice Farmers
CIAT	International Center for Tropical Agriculture
DEDRAS	Organization for the Sustainable Development, Strengthening and Self-Promotion of Community Structures
ESOP	Service Companies and Producer Organizations (Entreprises des services et organisations de producteurs)
ESSOR	Solidarity Company for Rural Services
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FCFA	Franc of the Financial Community of Africa (currency)
GDP	Gross Domestic Product
GIZ	German Agency for International Cooperation
IFAD	International Fund for Agricultural Development
ILO	International Labour Organization
INRAB	National Institute for Agricultural Research
INSAE	National Statistics and Economic Analysis Institute (Institut National de la Statistiques et d'Analyse Economique)
IIRR	International Institute of Rural Reconstruction
FUPRO	Federation of the Producers' Union of Benin (Féderation de l'Union des Producteurs de Benin)
MAEP	Ministry of Agriculture, Livestock and Fisheries
NGO	Non-governmental organization
ONASA	National Office for Food Security Support (Office National d'Appui a la Securité Alimentaire)
PANA1	Integrated Adaptation Program for the Fight against the Harmful Effects of Climate Change on Agricultural Production and Food Security in Benin
PDA	Agricultural Development Poles
PPP	Purchasing power parity
ProAgri	Promoting Agriculture in Benin Program
PSO	Operational Strategic Plan
R&D	Research and development
RCP	Representative Concentration Pathway
SDDAR	Master Plan for Agricultural and Rural Development
ZEF	Center for Development Research (University of Bonn)

1. INTRODUCTION

The agricultural sector is one of Benin's most important economic sectors, second only to the services sector. The main cash crop has historically been cotton, and it currently accounts for 35% of export income. Nevertheless, the country is trying to diversify, and palm oil (*Elaeis guineensis*), cashew (*Anacardium occidentale*), and shea nuts and butter (*Vitellaria paradoxa*) are gaining importance as export crops. The most important food crops are cassava, yams, and maize. Agriculture contributes 39% of employment in the country. Benin is highly vulnerable to climate change, and projected temperature increases and changes in rainfall patterns will negatively affect rain-fed crop production. These trends may threaten food security and may undermine the livelihoods of rural populations, particularly in the poorest areas of the country, the Atacora and Alibori Departments. Some government initiatives, but mainly programs and projects promoted by international cooperation and organizations, aim to improve the sector's knowledge of climate change risks, reduce its vulnerability, and strengthen its adaptive capacity.

International cooperation organizations and the private sector have collaborated with the government to supplement its efforts. One key collaboration includes the German Agency for International Cooperation (GIZ), the Ministry of Agriculture and Rural Development, and other local non-governmental organizations (NGOs). Together, these organizations are establishing Green Innovation Centres for the agriculture and food sector under the "ONEWORLD No Hunger" initiative, which is being implemented in selected regions in the southwest and southeast Ivorian cocoa belt. The Green Innovation Centres are also implemented in other African countries targeting different value chains (Ethiopia, Zambia, Malawi, Mozambique, Cameroon, Togo, Nigeria, Ghana, Benin, Burkina Faso, Kenya, Mali, Tunisia). Through the Green Innovation Centres, GIZ aims to enhance farmers' incomes, create employment, improve farmers' technical and management skills, and develop awareness of biodiversity and environmental protection. In Benin, the Green Innovation Centres are focusing on three value chains: rice, soybeans, and poultry.

This document presents a climate and vulnerability analysis of the soybean, rice, and poultry value chains in four departments: Alibori, Borgou, Collines, and Zou. It is intended to inform stakeholders, policymakers, and the private sector about risks and opportunities related to climate change in these value chains. It will also help integrate climate change into the national development agenda. This climate risk profile is an output of a collaboration with the International Center for Tropical Agriculture (CIAT), now part of the Alliance of Bioversity International and CIAT. Information was collected through literature review, survey, and interviews with experts from the three value chains. Also, we carried out climate modeling, a crop suitability analysis.

This climate risk profile is organized into six sections. The first describes the importance of agriculture to people's livelihoods in the four departments. Section two highlights the policies, strategies, and programs implemented in the three value chains that address climate change, while the third section discusses the governance and institutional resources and capacity. The fourth section discusses the main climatic hazards affecting the three value chains and presents climate modeling results for projected climatic change-related hazards and crop suitability maps. Additionally, it offers an analysis of vulnerabilities and risks posed by these hazards to the respective value chains. The ongoing on-farm adaptation strategies adopted by farmers to cope with these hazards are

Figure 1. Map of the selected regions

Benin is located in West Africa, east of Togo, West of Nigeria and South of Burkina Faso and Niger. The regions of study are the Alibori, Borgou, Collines and Zou Departments

2. AGRICULTURAL CONTEXT

KEY MESSAGES

- Agriculture is central to Benin's economy and an important source of income and employment, yet the sector is characterized by low productivity.
- In Alibori, Borgou, Collines, and Zou, a significant proportion of the population faces poverty, and most people live in rural areas that tend to have less access to electricity and water than urban areas do.
- Food security and attendant health concerns like stunting, low birth weight, and anaemia are significant issues in Benin.
- Land insecurity is a significant problem in the agricultural value chain; most landowners are men.
- This climate risk profile focuses on soybeans and rice, two crops that present important growth opportunities, and poultry, a key meat value chain that is crucial to food security.

discussed in the fifth section. The sixth section provides a synthesis and recommendations.

2.1. Economic relevance of farming

Benin's economy is heavily reliant on the informal re-export and transit trade with Nigeria, which is estimated at approximately 20% of the gross domestic product (GDP), and on agriculture (World Bank, 2019). Agriculture, forestry, and fishing value-addition, as a percentage of GDP, was 28 % in 2018 (World Bank, 2020), and this sector contributed 75% of export earnings (FAO, 2018). Cotton is Benin's most important cash crop, contributes to approximately 35% to Benin's export revenues, and serves as the main source of income for 3 million people (FAO, 2020a). Other relevant export crops include cashews, shea nuts and shea butter, pineapples, palm oil, and cocoa and coffee (FAO, 2020a). The primary food crops are cassava, yams, maize and rice, in that order (FAO, 2020b). In 2019, the agricultural sector contributed 39% of total employment, 47% of male employment, and 30% of female employment (World Bank, 2020).

Agricultural revenues remain low, generally in the range of US$69-US$93 monthly per household (FinMark Trust, 2019). The sector is characterized by low productivity and low technical capacity (Ministry of Planning and Development, 2018). Nevertheless, some modern agricultural companies are increasingly spearheading initiatives to establish modern farms by investing capital in land for perennial plantations of oil palm, cashews, citrus, and mangoes, and for intensive poultry farming (Ministry of Agriculture, 2010a).

2.2. People and livelihoods

In 2018, Benin's population was 11,485,048 people, of whom 49.9% were male and 50.1% were female (World Bank, 2020). 47% of the population lives in urban areas, and 53% in rural areas, although the proportion of the urban population has been increasing through time. In the study area, the most populous department is Borgou in the northern part of the country, which had 1,214,249 inhabitants in 2013 or 12% of country's total population in that year, followed by Alibori with a population of 867,463, Zou with a population of 851,558, and Collines with a population of 717,477 (Open Data for Africa, 2018). The male and female populations are almost equivalent in all four departments. There is a high proportion of rural population in all four departments; Alibori has the highest proportion at 76%, and Borgou the lowest at 56.4%.

More than three-quarters of the Benin's population (76.2%) lived under US$3.20 per day in 2015 (2011 purchasing power parity) (World Bank, 2020). Access to electricity remains low in rural areas at 18.3%, compared to urban areas at 67.4%. 58.2% of people in rural areas and 75.7% of the urban population had access to drinking water in 2017 (World Bank, 2020). 75.4% of the population in rural areas practiced open defecation in 2017 compared to 29.3% in urban areas (World Bank, 2020). 82.4% of Benin's population in 2018 had a mobile cellular subscription (World Bank, 2020). In 2015 in the study area, access to electricity was low; on average, just 11.2% of households had access to electricity. An average of 46% of households in the four departments had access to potable water. That percentage was highest in Collines at 62% of households, and lowest in Alibori at 33% (Open Data for Africa, 2018). The average poverty rate in the area is of 31%, and Alibori has the highest prevalence of poverty at 35%, while Collines has the lowest at 24%.

Food security is an issue. Benin continues to import products from neighbouring countries to cover its needs: rice, market garden produce, frozen products and especially frozen chicken, eggs, and milk (Ministry of Planning and Development, 2018). Purchasing power is low (LANDac, 2016). Meanwhile, the prevalence of stunting among children under 5 years old was 32% in 2018 and 38% in rural areas (World Bank, 2020). The prevalence of low birth weight was of 17% in 2015 (Global Nutrition Report, 2020). 47% of women of reproductive age have anaemia (Global Nutrition Report, 2020). **Agriculture is the backbone of rural areas, it provides a source of income and livelihoods to 70% of the rural population (Houndjo et al., 2018).** Most smallholders practices mixed crop and livestock production. The most important crops in terms of production volume are cassava, which comprised 25% of total production in 2018; yams at 22%; and maize at 11% (FAO, 2020b). In terms of harvested area, the most important crop is maize, which occupied 27% of the total harvested area in 2018, followed by cotton at 14%. Cattle are the most important livestock in terms of volume, accounting for 48% of total meat production in 2018, followed by chicken at 17% and goats at 7% (FAO, 2020b).

Subsistence farming is widespread, and marketing is not well developed. Food-processing activities are limited, and there is little value added to agricultural products due to a lack of knowledge about quality and preservation and due to the inaccessibility of small-scale mechanization methods to process products (ILO, 2013).

2.3. Agricultural activities

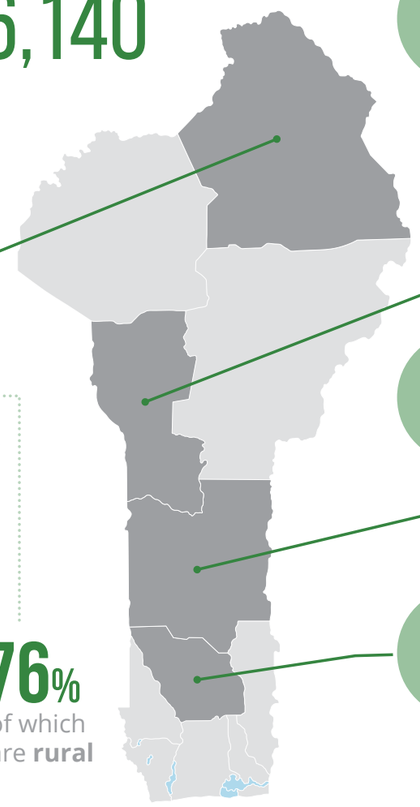
Agricultural land encompassed 33% of the country's total land area in 2016, and arable land 24% in the same year (World Bank, 2020). Agriculture in Benin is characterized by the predominance of a mixed crop-livestock farming systems (Houndjo et al., 2018). Small-farmers practise land cropping using the traditional method of slash-and-burn cultivation (Houndjo et al., 2018). The livestock production system depends on grazing resources, which mainly entail annual foraging on natural pasture and forest lands. A significant amount of feed comes from crop residues, agro-industrial by-products, and other farm products (Houndjo et al., 2018).

The proportion of land with titles in 2015 was 4%, and the government plans to increase that to 14% by 2025 (Ministry of Planning and Development, 2018). Customary tenure predominates in rural areas, and usually lacks certificates or any kind of formal registration (LANDac, 2016). Most women only have user rights to land through their male relatives, and customary practice generally excludes them

Figure 2. Livelihoods and agriculture in Benin

DEMOGRAPHICS

BENIN'S POPULATION
11,496,140



Alibori (9%)
867,463 inhabitants
50% 50%
76% of which are **rural**

Borgou (12%)
1,214,249 inhabitants
50% 50%
56% of which are **rural**

Collines (7%)
717,477 inhabitants
50% 50%
73% of which are **rural**

Zou (9%)
851,580 inhabitants
50% 50%
67% of which are **rural**

ACCESS TO BASIC NEEDS

% of the population suffering from **absolute poverty**

Alibori	35%
Borgou	30%
Collines	24%
Zou	34%

% of households with access to **electricity**

Alibori	5%
Borgou	13%
Collines	8%
Zou	19%

% of households with access to **potable water**

Alibori	33%
Borgou	48%
Collines	62%
Zou	43%

Youth literacy rate (15-30 years)

Alibori	26%
Borgou	47%
Collines	66%
Zou	63%

FOOD SECURITY

% of people **undernourished**

Alibori	Borgou	Collines	Zou
18%	21%	4%	30%

Population suffering from **food insecurity**

Alibori	Borgou	Collines	Zou
12%	13%	7%	10%

% of **household income** spent on food

Alibori	Borgou	Collines	Zou
52%	42%	40%	43%

% children **stunting**

Alibori	Borgou	Collines	Zou
40%	41%	29%	38%

% children **wasted**

Alibori	Borgou	Collines	Zou
10%	7%	2%	2%

FARMING

% of people **employed** in **agriculture**

Alibori	Borgou	Collines	Zou
56%	44%	44%	20%

% of **women** with **title deeds**

Alibori	Borgou	Collines	Zou
95%	74%	49%	35%

LAND USE

Cash crops*

Cotton	Oil palm	Rice	Maize
393,368T	29,192T	234,144T	1,354,344T

* National data, not disaggregated

AGRICULTURAL INPUTS

Distribution of **freshwater** resources*

Livestock	Irrigation
11%	35%

Industry	Rural
23%	12%

Urban
19%

Fertilizers (% of households)

	Organic manure	Chemical fertilizer
Alibori	49%	58%
Borgou	19%	38%
Collines	5%	15%
Zou	3%	19%

Pesticides (% of households)

	Herbicides	Insecticides/ Fungicides
Alibori	35%	6%
Borgou	38%	25%
Collines	2%	6%
Zou	3%	2%

ND: Not Disclosed

from land ownership (LANDac, 2016). In 2011, 85% of landowners in rural areas were male, while only 15% were female (INSAE, 2012). The primary way of acquiring land is through inheritance. 57% of male and 51% of female landowners have achieved land tenure in this way. Purchase is the second commonest way for men to become landowners; 24% of male landowners acquired their tenure through purchase. In the case of women, the second commonest means of land acquisition is through donation (INSAE, 2012). The land insecurity faced by farmers constitutes a major handicap to agricultural intensification and investment (Ministry of Agriculture, 2010a). The problems linked with land access include the long wait and elevated costs to obtain rural land titles (up to 5 years), the large proportion of unused land, and the difficulty young people have in buying land (FAO, 2018).

Agriculture depends heavily on rainfall because irrigation is uncommon. Regarding input use, in 2013, 26% of Beninese farmers used chemical fertilizers, while 13% used organic ones (Open Data for Africa, 2018). 38% declared they did not use any type of input (Open Data for Africa, 2018). Among the regions under study, input use is most pronounced in Alibori, followed by Borgou. Because it is an important cotton producer, Benin has historically used significant amounts of fertilizers, insecticides, and herbicides, resulting in soil degradation.

2.4. Agricultural value chain commodities

The value chains analysed in this study are soybeans, rice, and poultry. Soybeans and rice are not the most important crops in terms of volume or area compared with cassava, yams, and maize, but they present great potential to be developed under the Climate-Smart Agriculture framework.

2.4.1. Soybeans

Soybeans are grown in all regions of Benin. In 2018, the country produced 221,977 tons of soybeans, comprising 2% of crop production that year, and the cultivated area amounted to about 199,844 ha (FAO, 2020b). Production is mainly concentrated in northern Benin, in the departments of Atacora, Donga, Borgou, and Collines (Ollabodé et al., 2017; Zoundji et al., 2015). Soybean production has been increasing since 2014; in 1999 production was of 1443 tons; since then, it has multiplied by a factor of 150 (FAO, 2020b; Ministry of Agriculture, 2017b).

Most producers are male (64%) and between 25 and 50 years old (85%) (Zoundji et al., 2015). Women are generally occupied with domestic activities such as food processing (Afouda et al., 2019). 61% of soybean farmers are unable to read or write. 72% are part of a farmers' organization (Zoundji et al., 2015). Most producers are informally organized; they use oral agreements with collectors and buyers. Farmers sell to collectors, who in turn sell to wholesalers, who then sell to exporters or supply oil producers (Hounhouigan et al., 2019). Soybean oil producers are the main customer for soybean farmers, especially for small farmers; they consume about 41% of the total production (Hounhouigan et al., 2019). Except for soybean oil, most soybean products like cheese, milk, and yoghurt are processed in small-scale businesses run by women who use traditional practices (Hounhouigan et al., 2019).

A key commercialization actor is the Sojagnon Association, which is a local NGO that promotes agricultural development by supporting the soybean value chain through partnerships with chain actors and other organizations. Sojagnon focuses on improvement of the marketing system, but also supports professionalization of farmers, access to inputs, and women's entrepreneurship (Hounhouigan et al., 2019). It has helped promote soybeans to export markets in Turkey, the United Arab Emirates, Belgium, and Togo (IAEA, 2020). Another NGO, the Organization for the Sustainable Development, Strengthening and Self-Promotion of Community Structures (DEDRAS), also supports soybean producers through the Soy Industry Support Project (Afouda et al., 2019), including women who process soy products like cheese and milk (Afouda et al., 2019). The Farmers Business School, promoted by GIZ, is also an important support program; for example, it has benefited at least 50% of soybean in Borgou (Afouda et al., 2019). The Soybean Consortium of Benin is a multi-stakeholder platform set up in 2011 by a group involved in promoting the soybean sector with technical and financial support from the International Fertilizer Development Centre; it links actors such as Sojagnon and DEDRAS (Agboton et al., 2018).

Most farmers use seeds from the previous season's harvest or buy seeds from nearby markets; only 24% buy them from the Fédération de l'Union des Producteurs du Bénin (FUPRO) or the Centre d'Action Régional pour le Développement Agricole (Hermann Batamoussi et al., 2016; Kpenavoun Chogou et al., 2018; Zoundji et al., 2015). Use of chemical inputs like fertilizers and herbicides is low at 27% of farmers, and most use animal traction (Kpenavoun Chogou et al., 2018; Zoundji et al., 2015).

Soybeans are mainly used for human consumption in forms such as milk, germ, cheese, and porridge; few are intended for animal feed (Ollabodé et al., 2017). Increased soybean production could lead to improved food security and to more balanced diets, because its high protein content and the fact that it can be consumed in different forms.

2.4.2. Rice

Benin produced 459,313 tons of rice, about 3% of the total agricultural production volume in 2018; this represents a 96% increase since 2014 (FAO, 2020b); the production area was 135,185 ha (FAO, 2020b). Rice is the foremost import product in Benin, and it accounts for more than half of import volume and over 40% of import value (ZEF et al., 2017). The key regions for lowland rice production are Zou and Collines, where cultivation is mostly rain-fed with only one rain harvest per year (Maertens & Vande Velde, 2017; Ministry of Agriculture, 2010b).
Most producers are men (79%) with an average age of 42 years, and most plots are smaller than 1 ha (Balaro et al., 2015). Women contribute 70% of family labour and are mainly involved in activities like sowing, transplanting, weeding, harvesting, and transport (Ministry of Agriculture, 2010b).

About 63% of production occurs in floodplains, 20% is strictly rainfed, and 17% is rainfed and irrigated (Balaro et al., 2015). Dehulling is done either after parboiling or by direct dehulling. Manual husking is widely practiced throughout the country but yields and quality are low as reflected by heterogeneous rice grains and broken rice. Hulling after parboiling is the most widespread processing system in Benin, and it reduces breakage, improving the nutritional quality of rice and its conservation (Balaro et al., 2015). Finally, mechanical or semi-mechanical husking is carried out in mini rice mills in municipal factories, and its adoption is increasing. Most industrial rice mills have been installed with the support of international cooperation and are managed by farmers' organizations like the *Société Nationale pour la promotion Agricole*, the Promoting Agriculture in Benin Project by GIZ (ProAgri), the Projet d'Appui à la Fillière Riz du Bénin, and Entreprises des services et organisations de producteurs (ESOP).

Farmers usually commercialize rice through spot markets with traders collecting paddy rice at the farm gate, or they sell it in the nearest markets (Maertens & Vande Velde, 2017). Rice commercialization is also done through ESOP or the Office National d'Appui a la Sécurité Alimentaire (ONASA). ESOP aims to connect farmers to markets in a sustainable way (Maertens & Vande Velde, 2017). It provides training and other services to farmer groups to improve production quality. They use with the contract-farming approach, involving contracts between groups of farmers and ESOP for the delivery of high-quality rice (Maertens & Vande

Velde, 2017). These contracts are usually written before the start of the agricultural season, and they include a fixed price for that season, payment modalities, and quality specifications pertaining to variety, impurities, and humidity (Maertens & Vande Velde, 2017). White rice from rice mills is usually commercialized through ONASA (Balaro et al., 2015).

Land is most often obtained through heritage or donation (Adegbola et al., 2003). Most producers use family labour, followed by hired workers and cooperation between farmers (Adegbola et al., 2003). The use of inputs such as chemical fertilisers or herbicides is uncommon since access to them is limited. Fertilizers used in cotton production are also used on rice because they are cheaper. Some agricultural projects and programs facilitate credits to buy inputs: examples include ProAgri and the Programme for the Protection and Management of Natural Resources (Ministry of Agriculture, 2010b).

Although rice demand in Benin has increased through time, 43% of the population prefers imported rice, while 37% prefers local rice (Ministry of Agriculture, 2010b). Nevertheless, the rice value chain could contribute to food security because local consumption is non-negligible. In the lowlands, land use could be optimized by implementing crop rotation with legumes to provide an additional source of food and income for farmers (IIRR, 1990).

2.4.3. Poultry

The poultry sector in Benin involves mainly chicken, ducks, and guinea fowl (Sodjinou et al., 2015). Most of the information found in the literature focused on the chicken meat and eggs value chains, which will be presented in this subsection.

Chicken meat production is the most important meat value chain after cattle. In 2018, Benin produced 14,561 tons of chicken meat, comprising 17% of its total meat production, and 15,355 tons of eggs. These figures represent a 13% increase for both since 2014 (FAO, 2020b). The country had 26.5 million chickens that year (FAO, 2020b). In 2013, 93% of the poultry were of a local breed, and 7% an improved breed (FAO, 2015). The volume of production that year was of 24,045 tons of poultry meat from indigenous chicken, comprising 66% of total production, and 12,436 tons of non-indigenous chicken (FAO, 2020b). 64% of Benin's poultry production is concentrated in the Littoral and Atlantique Departments, followed by 15.5% in both Zou and Collines (FAO, 2015). Borgou and Alibori generate only 3% of poultry production (FAO, 2015).

According to the classification made by the National Union of Poultry farmers of Benin, traditional farmers are those that have up to 499 poultry heads, while commercial farmers have between 500 and 25,000 (FAO, 2015). 50% of Beninese poultry farmers are classified as traditional, located mainly in the centre and the north of the country, while the bigger poultry farms are all located in the south (FAO, 2015). In 2012, the majority of commercial exploitation of poultry was concentrated in the Atlantique and Littoral Departments at 48%, with just 11% occurring in Zou and Collines, and just 7% in Alibori (the last three departments are part of the study area) (FAO, 2015).

Traditional poultry farmers have very low biosecurity levels, often characterized by outdoor breeding, a lack of shelter for the poultry, and irregular veterinary assistance mainly dependent on government services. Their poultry breeds are local, and their food security is between good and weak (FAO, 2015). Small-scale farmers mainly produce a local breed called "bicycle poultry" (FAO, 2015). In Borgou, 75% of poultry farmers are male. 48.3% are aged 50 or older, and 26% are between 30-50 years old. 25% were classified as illiterate, 62% as having received some level of schooling, and 75% as trained in poultry farming, respectively. 64.3% practise poultry farming as their main activity (Idrissou et al., 2018). Idrissou et al. classify farmers into three groups: traditional poultry farmers with 33-43 heads, semi-modern farmers with up to 165 heads, and modern poultry farms with up to 937 heads. 39% are classified as traditional poultry farmers, 32% as semi-modern, and 29% as modern poultry farmers. Among these three classifications, traditional poultry farmers include the highest proportion of women at 64% (Idrissou et al., 2018). 75% of farmers in Borgou specialize in laying hens; the rest produce both meat and eggs (FAO, 2015).

Poultry can be sold in primary, secondary, and consumer collection markets (FAO, 2015). About 80% of the poultry bought in rural areas is transported to the urban markets of Cotonou, Abomey-Calavi, Parakou, and Porto-Novo (FAO, 2015). Farmers rely on traders to sell their produce. 38% of traders primarily use "taxi-brousse" to transport the produce to the markets, 30% use trucks, and 32% use other means of transport (FAO, 2015). Very small producers use the poultry for self-consumption and sell any surplus in the local markets. Eggs, for example, could be sold at FCFA 60-75 at the farm gate in 2013, and at FCFA 75-100 at the market (FAO, 2015).

Current national production is not enough to satisfy domestic demand for poultry meat and eggs (FAO, 2015). Chicken meat accounts for 7% of Benin's import volume and 14% of import value (ZEF et al., 2017). A portion of the imported poultry meat is then re-exported to neighbouring countries like Nigeria or Togo (FAO, 2015). The Strategic Plan for Agricultural Recovery identifies poultry farming as key to promoting food security (FAO, 2015; Idrissou et al., 2018) In particular, small-scale farming enables rural families to have better nutrition and an additional source of income (FAO, 2015).

2.5. Agricultural sector challenges

The National Development plan identifies the following major challenges facing the agricultural sector: poor productivity due to high dependence on rainfall, rudimentary tools, low organization of farmers, sub-optimal use of irrigation technologies, insufficient water management and a deficit of hydro-agricultural infrastructure, and sub-optimal use of climate-sensitive technologies (Ministry of Planning and Development, 2018).

In addition, decreasing agricultural productivity pushes people out of crop production as it becomes difficult to make a living, increasing rural-urban migrations. Policy does not support or promote sustainable land management techniques, and the expansion of farmland as soil productivity decreases results in land degradation, exacerbates deforestation, and reduces the availability of pastoral land for semi-nomadic groups (Engel et al., 2017). Moreover, there are problems related to land tenure insecurity, particularly for women, and the unavailability of cultivable land (FAO, 2018; Ministry of Planning and Development, 2018; Ollabodé et al., 2017; Zoundji et al., 2015).

Degraded soils in the lowlands, where cotton production was important, make farmers vulnerable. According to the Ministry of Agriculture, the agricultural sector has a poor capacity to adapt to climate change because of its lack of water control and high dependency on rain, its low consumption of fertilizers, and the inaccessibility of good-quality seeds adapted to new climatic realities (Ministry of Agriculture, 2010a).

The rice value chain, meanwhile, faces substantial post-harvest losses due to inefficient market coordination, poor storage facilities, and the remoteness of the main rice production areas combined with poor roads and transport infrastructure (Maertens & Vande Velde, 2017).

Finally, low access to credit and the overall absence of a financing policy adapted to the characteristics of the agricultural sector together limit its growth and adaptive capacity, which most severely impacts small farmers (FAO, 2015, 2018; Ministry of Agriculture, 2010b; Ministry of Planning and Development, 2018; Zoundji et al., 2015).

3. POLICIES, STRATEGIES AND PROGRAMS ON CLIMATE CHANGE

KEY MESSAGES

- Several programs and policies help the agricultural sector adapt to climate change.
- In addition, increasing numbers of programs and policies support soybeans specifically.
- Many programs and policies focus on rice, including initiatives of the Africa Rice Center, and often emphasizing enhanced access to irrigation and inputs.
- The poultry sector receives support through the Agricultural Development Poles (PDA) as well as the National Breeding Program and the Annual Action Plan of the Benin Poultry Interprofessional Sector.

Five programs and policies were identified that address the agricultural sector's vulnerabilities to climate change at a general level and could benefit the soybean, rice, and poultry value chains directly or indirectly. First, the Master Plan for Agricultural and Rural Development (SDDAR) was designed and made operational with the development of the Operational Strategic Plan (PSO). The priority axes for the intervention selected in the SDDAR and the PSO are poverty reduction, consideration of rural women, strengthening of food security, job creation, restoration of macro-economic balance, and conservation of the ecological heritage (FAO, 2018). Second, the Climate Change Adaptation and Resilience Strategies in the Agriculture Sector program, launched in 2016 by the National Institute for Agricultural Research, contributes to research and development (R&D) pertaining to the competitiveness of the sector in the realm of climate change (Ministry of Living Environment and Sustainable Development, 2019). Third, the Integrated Adaptation Program for the Fight against the Harmful Effects of Climate Change on Agricultural Production and Food Security in Benin (PANA1), established in 2015 by the national government, aims to build the capacity of farming communities to adapt to climate change in regions with a high risk of food insecurity (PANA1, 2015). Fourth, the Agricultural Development and Market Access Support Project, funded by the government and the International Fund for Agricultural Development (IFAD), aims to strengthen conventional value chains such as rice, corn, cassava, and soybeans (24 heures au Bénin, 2020). Specifically, it focuses on *de-risking* agriculture through adaptation to climate change and through bolstering an insurance scheme that targets smallholder farmers (IFAD, n.d.). Finally, the Communal Approach for Agricultural Markets is an initiative supported by IFAD and the Dutch government that aims to strengthen access to inputs and agricultural innovations, market access and professionalization, agricultural finance access, information and communication technology for agriculture, and public-private partnerships in the agriculture sector.

Increasing numbers of policies and programs are directed toward soybean farming. These policies, although not directly related to climate change, aim to consolidate an emergent sector that could be more likely to adopt measures for climate change adaptation in the context of environmental uncertainty. Firstly, in 2019, the Beninese government launched the National Development Program for the Soybean sector and promoted the Soybean Commercialization Campaign 2019-2020, which aims to support value chain actors to access necessary assets and services to improve soybean production (SOJAGNON, 2018). Secondly, in the Rural Economic Growth Support Project, the soybean sector is included for promotion (IFAD, 2016). This project supports input supply, production, transformation, and commercialization of the crop and also encourages the organization of value chain actors to reinforce their coordination (Ministry of Agriculture, 2017b). Thirdly, soybeans are identified as a locomotive sector for several Agricultural Development Poles (PDA), because they are most developed and constitute potential sources of growth for rural communities. Soybeans are specifically relevant in Zou, Collines, southern Alibori, and Borgou (Ministry of Agriculture, 2017a). Finally, the Agriculture Promotion Program highlights that the value added in specific sectors like rice and soybeans has increased permanently and simultaneously with social and environmental standards (Ministry of Agriculture, 2017b).

Numerous policies focus on the rice value chain in Benin; an increasing number of policies and programs have focused on improving access to inputs and strengthening irrigation systems. Since rice is mostly grown under flood plain and rain-fed systems, production is tied to climate variability. Therefore, the establishment of irrigated systems is a key measure for climate change adaptation. For example, the Beninese government has provided farmers with new technologies like water pump machines and financial credit to promote paddy field irrigation during the long dry season (Africa Rice, 2018; Bouraima et al., 2015). Also, local rice production has increased because of improved inputs like seeds and fertilizer (Africa Rice, 2018; Totin et al., 2012). More recently, in 2019, more than 250 ha of new perimeters were irrigated with tube wells in Malanville and Karimama, and 1,835 ha are in operation for rice and market gardening. On the other hand, the Africa Rice Center has advanced specific programs in Benin to deal with climate change vulnerabilities. For example, in 2010 the Africa Rice Center implemented the smart-valleys approach to improve water control and soil fertility in the context of climate change (Africa Rice Report, 2018) ; and, in 2018, the Center also supported the creation of the NGO African Innovation Services to work towards sustainable businesses in the rice value chain.

The poultry value chain is regarded as a key sector for several PDA, including the Niger Valley, southern Alibori, northern Borgou, Western Atacora, Southern Borgou, Donga, and Collines, in addition to Ouémé, Atlantique, and Mon, three departments that together are home to 71% of poultry farms (Ministry of Agriculture, 2017a). One program and one plan were identified that focus on this value chain. Firstly, the National Breeding Program has as its main objective strengthening the animal seed certification process. Its goals also include the continuation of pilot actions in the introduction, adaptation, multiplication, and dissemination of improved breeders of cattle, sheep, goats, poultry, and pigs; the construction and rehabilitation of storage, conservation, processing, and marketing infrastructure for animal products; and the provision of construction, equipment, and support for the operation of mini poultry slaughterhouses (Ministry of Agriculture, 2017a). Secondly, in 2019, the Ministry of Agriculture, Livestock and Fisheries supported the Annual Action Plan of the Benin Poultry Interprofessional Sector, which aims to make the sector more visible and supports transformation and professionalization, mainly through the National Poultry days of Benin (La Nation, 2019). This three-day event allows all actors of the value chain to come together for poultry exhibitions, tasting sessions, and panels on topics such as "development of poultry production and employability" and "Standards and quality of poultry products: guarantee of increased consumption and improvement of the nutritional status of populations". This kind of policy addresses the fact that poultry farmers have a low level of technical training, need to improve quality standards and lack of an established

4. GOVERNANCE, INSTITUTIONAL RESOURCES AND CAPACITY

KEY MESSAGES

- Important government agents include the Ministry of Agriculture (MAEP), the Ministry of Planning and Development, the National Institute for Agricultural Research (INRAB), the National Statistics and Economic Analysis Institute (INSAE), and relevant directorates.
- Support from NGOs and international cooperation are crucial to foster the implementation of beneficial policies.
- Farmers' organizations also have an essential role to play in agriculture's response to climate change.
- Improving adaptive capacity and productivity must become a priority for national programs and policy; local authorities, meanwhile, require further capacity and finance to better support farmers.

trading organization or network (FAO, 2015).

At the government level, the main actors involved in the agriculture sector are the Ministry of Agriculture (MAEP), the Ministry of Planning and Development, the National Institute for Agricultural Research (INRAB), and the National Statistics and Economic Analysis Institute (INSAE). The Ministry of Agriculture has decentralised technical services and territorial agencies for agricultural development. The most active directorates in the study area are the directorate for agricultural innovation, quality, and entrepreneurial training; the directorate for planning and monitoring; the directorate for rural legislation, support for professional organizations, and agricultural entrepreneurship; and the directorate for animal husbandry. All these directorates are involved in the implementation of the GIZ country package.

Nevertheless, governance in Benin has been characterized by disparities between the formulation of well-designed policies, and the extent of their implementation. For example, there is an ongoing decentralization process in the agricultural sector, which may allow for local administrative bodies to have more control and responsibility for rural development. However, financing still depends on the central government, and progress in decentralisation varies between regions. Moreover, local administrative bodies often lack technical, financial, and human resources (Engel et al., 2017).

Given this context, international cooperation and NGOs play an important role in rural development. GIZ for example is actively involved in the four departments under study through several programs aimed at enhancing agricultural productivity, food security, employment, gender equality, and sustainable economic development. Other such organizations include the International Fund for Agricultural Development (IFAD), the Africa Rice Center, and Songhaï, all of which empower and assist rural communities, youths, and women to help them strengthen their agricultural and entrepreneurial capacities in sectors such as rice, corn, cassava, and soybeans.

Farmers' organizations are key partners in the implementation of agricultural policies, programs, and projects. Some of the most important farmer organizations are FUPRO, an umbrella organization of farmers' organizations; the Association of Benin Rice Farmers (CCR-B); the Association of Soybean Producers; the Association of Young Modern Farmers; the Federation of Seed Producers of Benin. The latter four organizations support the implementation of the GIZ country package. Private-sector actors such as the Solidarity Company for Rural Services (ESSOR) also contribute to rural development; ESSOR, for example, has trained farmers in rural areas in innovation, and business management and relationships in Zou, Collines, and Borgou.

National policies and R&D do not address the overall low levels of productivity, and extension services lack adequate capacities and means to support farmers and increase access to input supplies. For a long time, governmental technical assistance was cotton-oriented, which affected the development of food value chains (ABC Taxa, 2017). Moreover, current agricultural policies on the ground fail to address environmentally sustainable productivity and diversification objectives, often contributing to the deterioration of natural resources (Engel et al., 2017). Initiatives directly addressing climate change adaptation are often carried out by international organizations or cooperation agencies in partnership with local NGOs or farmers' organizations. Therefore, climate change should be integrated into agricultural and development policies and programs comprehensively. Additionally, it is necessary to strengthen the institutional capacity of local authorities and provide them with more

5. CLIMATE CHANGE-RELATED RISKS AND VULNERABILITIES

KEY MESSAGES

- Droughts and heat stress are major climate hazards in all four departments; Alibori is also especially vulnerable to flooding.
- Projections of suitability for rice and soybeans vary depending on the department, climate scenario, and crop variety; African rice, however, is likely to become highly suitable in all four departments, and soybeans are likely to become more suitable in Zou.
- Climate hazards as perceived by stakeholders include floods, droughts, changes in precipitation, and high temperatures.
- A survey of experts indicated that pressing climate hazards include floods and droughts for the rice value chain, high temperatures for poultry, and droughts and dry spells during the growing season for soybeans; these results are often but not always consistent with the literature.

financial autonomy, so they can better support the agricultural sector.

5.1. Farmers' perceptions on climate change

Farmers' perceptions of climate change in Benin is generally well aligned with published data (Callo-Concha 2018). Approximately 60% of farmers surveyed perceived decreases in rainfall and increases in temperature over the previous 10 years. These perceptions are supported by literature, which identified temperature rise and changes in precipitation patterns as major climatic hazards (Government of Benin, 2015). Both farmers and the literature identify increased pests and disease, decreased crop yields, decreased water availability, drought, and reduced livestock populations as hazards resulting from these climatic changes. Farmers perceived livestock disease and increased wind storms as results of climate change; these hazards are not yet captured in the literature.

All farmers surveyed acknowledge that the contribution of farming activities to climate change is significant or highly significant (Callo-Concha 2018). Farmers named activities such as burning vegetation, cutting down trees, and clearing landscapes for agricultural production as major contributors to climate change. This indicates a strong foundational understanding of the linkages between agricultural management decisions and climate change among Beninese farmers, suggesting potentially good receptivity to climate-oriented optimization of management practices.

5.2. Climate change and variability: historic and future trends

The climate models show that drought, heat stress, floods and a decrease of the growing season are the main hazards in the four departments studied in Benin. Drought is a recurring hazard. In Alibori, moisture stress increases significantly, especially in the southeast, and also in northern Borgou since these two departments are contiguous. In Collines and Zou, the number of consecutive dry days increases from an average of 20-25 per year to an average of 60 per year by 2060 (Figure 3). Heat stress is also a hazard in all four departments. The number of days with maximum temperature above 35°C is projected to average 150 by 2060 in both Borgou and Alibori, and 140 by 2060 in both Collines and Zou (Figure 4). Floods may be a hazard in Alibori, where the maximum 5-day running average precipitation increases significantly (Figure 5). **The start of the growing season may change significantly in all four departments.** In Alibori, it may start earlier, particularly in the northern part of the department. In Borgou, the southern part is the most affected, with the growing season delayed. Collines and Zou may also experience delays in the start of the growing season. The length of the growing season may also decrease in all four departments, with the most significant changes in northern areas. In Borgou, the length of the growing season may fall from an average of 175 days to an average of 80 days by 2060, and in Alibori, from an average of 125 days to an average of 75 days by 2060

Figure 3. Historical (left), future projected (center) and projected change (right) for the maximum number of consecutive dry days within the year (average of last 30 years) for Alibori, Borgou, Collines and Zou Departments, Benin.

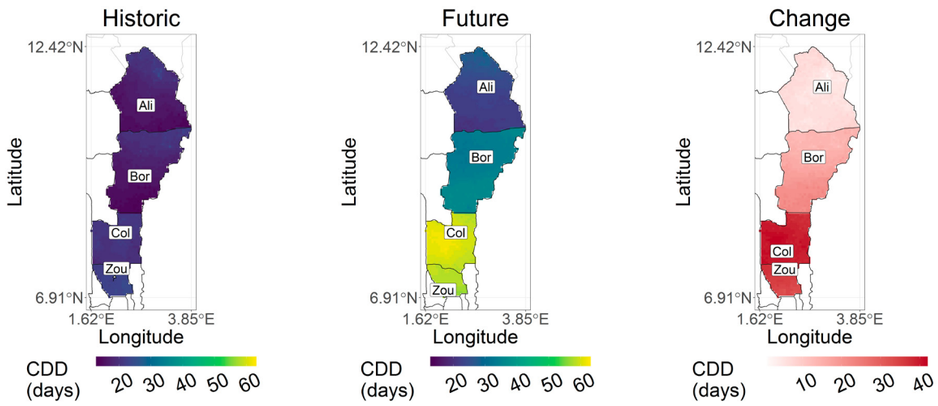


Figure 4. Historical (right), future projected (center), and projected change (right) for the total number of days with maximum temperature greater or equal to 35°C in the year (average of last 30 years) for Alibori, Borgou, Collines and Zou Departments, Benin.

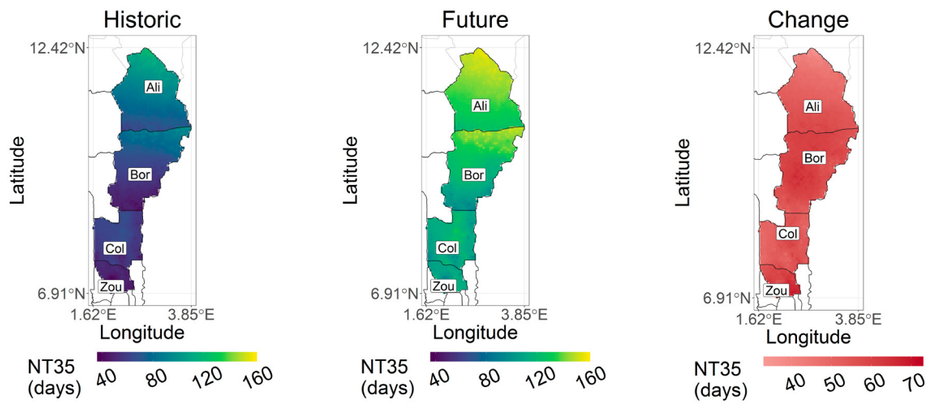


Figure 5. Historical (left), future projected (center), and projected change (right) for the maximum 5-day running average precipitation in millimeters (average of last 30 years) for Alibori, Borgou, Collines and Zou Departments, Benin.

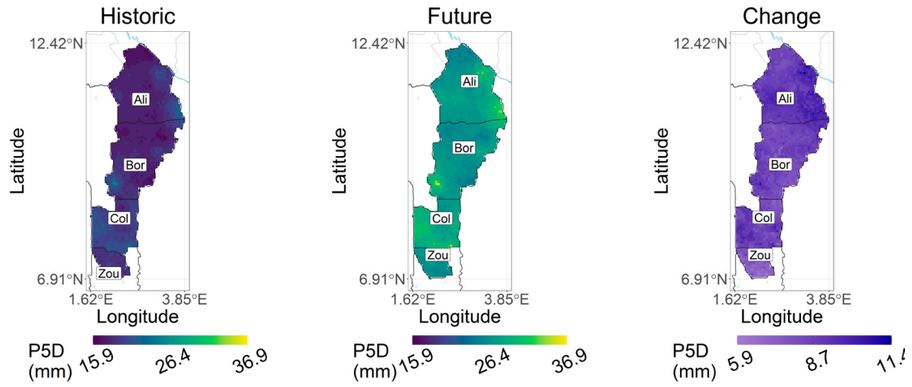
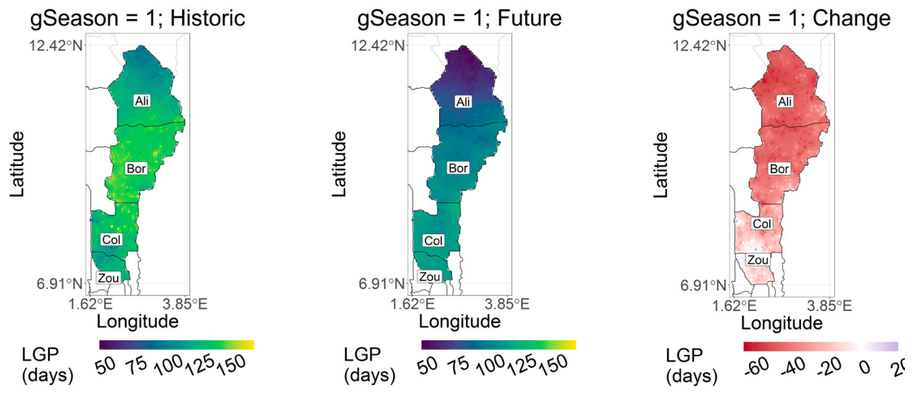


Figure 6. Historical (right), future projected (center), and projected change (right) for the length (days) of the first growing season (average of last 30 years) for Alibori, Borgou, Collines and Zou Departments, Benin.



(Figure 6).

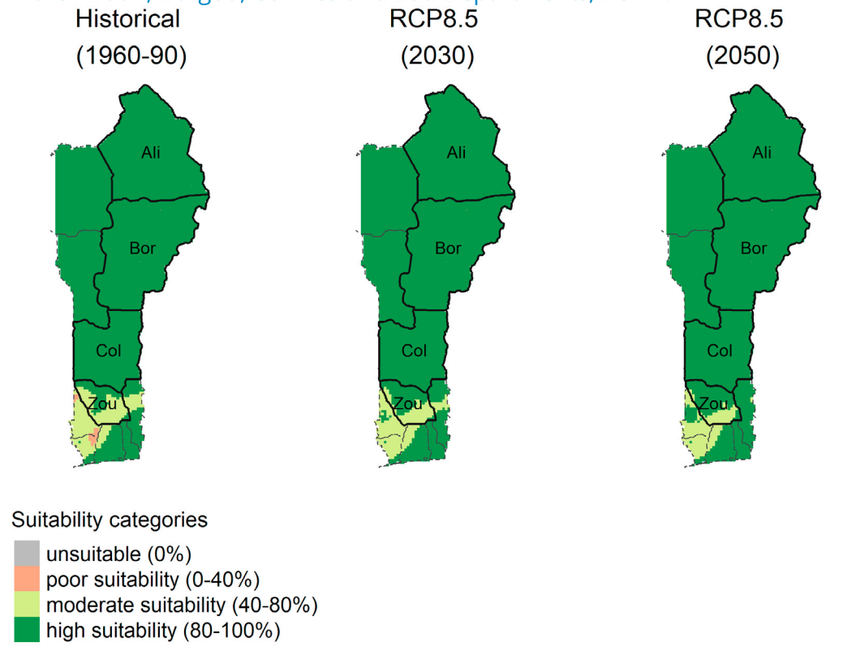
5.3. Crop suitability analysis

For the suitability analysis, we considered African rice. **Overall, under the Representative Concentration Pathway (RCP 8.5), African rice has moderate to high suitability in Alibori and Borgou.** In the future, suitability may decrease slightly towards the east in Alibori, while in Borgou, it increases. Suitability may become high in all the departments by 2050 under both scenarios. Collines and Zou have historical moderate to poor suitability at 40-50%, but this may change in the future under both scenarios, becoming moderate to high in Collines, mainly in the southeast, and moderate in Zou (Figure 7).

Soybeans are projected to experience just slight changes in suitability under both scenarios in almost all departments. The most significant changes are observed in Zou. Historically, soybeans have had high suitability in the other three departments, and moderate to high suitability in Zou, which under climate change would present new suitabilities. In the four departments, there is no significant change in suitability under either scenario.

Figure 7. Historical and future (scenario RCP 8.5, periods 2030 and 2050) suitability of rice production in the Alibori, Borgou, Collines and Zou Departments, Benin.

Figure 8. Historical and future (scenario RCP 8.5, periods 2030 and 2050) suitability of soybean production in the Alibori, Borgou, Collines and Zou Departments, Benin.



5.4. Climate vulnerabilities across agriculture value chain commodities

The survey carried out in September 2020 by CIAT provided information from 30 experts. The results of this survey are presented below.

The two main hazards identified by the experts for rice are floods and droughts. Droughts primarily affect the on-farm stage of the value chain with a major to severe impact, while the impact on the input and post-harvest stages is low to moderate, and the impact on the marketing stage is low. Floods affect mainly the on-farm stage, while the impact on all other stages is low, and in the case of the post-harvest stage, low to moderate.

This is partly consistent with the literature, which identifies flooding and reduced rainfall and streamflow as main hazards. Yields may suffer under irregular precipitation and fewer but increasingly intense rains that increase the risk of flooding. In addition, since a large proportion of rice is rainfed in Benin, and rice has high water requirements, droughts may affect plant growth. Another hazard identified in the literature is heat stress, which may result in increased heat-induced sterility or in the shortening of the growing season (Van Oort & Zwart, 2017).

For the poultry value chain, the main hazard identified by the experts is high temperatures, which have a major impact on the on-farm stage, while the impact on the input and post-harvest stages is moderate, and low in the marketing stage of the value chain. In the literature, we identify changes in precipitation such as decreased rainfall or heavy rains as the second most pressing hazard, likeliest to affect the on-farm and the post-harvest stages.

High temperatures are also a key hazard identified in the literature for the poultry value chain that may decrease the reproductive capacity of the chickens. They may also lead to greater water consumption and more frequent heat stress, which results in a decline in the animal's physical activities including eating and grazing, which in turn may lead to growth reduction. Heat stress may also limit the productivity of laying hens, along with egg production and egg quality since the animals divert their energy to keeping their body temperature constant. Given high temperatures, the availability of water is essential, since chickens use water to regulate their body temperature. Excessive rains also present a risk because animal shelters are often made of rustic materials, so violent rains, storms, or strong winds may damage them.

Regarding the soybean value chain, droughts and dry spells during the growing season were identified as the two primary hazards. Drought affects mainly the input and on-farm stages with a moderate to major impact, while the impact on the post-harvest and marketing stages is low. Dry spells affect mainly the on-farm stage with a major to severe impact, while impacts are low to moderate on the input and post-harvest stages, and low on the marketing stage.

These results are not consistent with the literature, which identifies the main hazards to soybeans in Benin as heat stress and changing rain patterns, such as late rains, decreased rainfall, and early cessation of rains. Heat stress affects the growing season by hastening plant development, especially the grain filling stage, resulting in lower yields. Changes in rain patterns may result in the disruption of sowing dates, disrupting agricultural schedules and reducing yields. The lengthening of the dry season is also indicated as a hazard, but less frequently than heat stress and changes in rainfall.

6. ADAPTATION TO CLIMATE CHANGE AND VARIABILITY

KEY MESSAGES

- Farmers in each value chain under study have some adaptative capacity; however, limited access to necessities makes adaptive transformation difficult.
- The development of new rice and soybean varieties adaptive to climate change is a promising strategy, in conjunction with intensive rice cultivation systems.
- Improvement of zoo-sanitary surveillance and epizootic control systems and training in the construction of animal shelters are crucial adaptive strategies for the poultry value chain.

6.1. On-farm adaptation strategies

On-farm adaptation practices and the adaptive capacity of farmers will vary depending on the characteristics of the value chain and the level of organization of the farmers in question, since farmers' organizations and associations generally provide support.

For the soybean value chain, most farmers are male, 61% cannot read or write. In general, the use of fertilizers and herbicides is low, which may make farmers more vulnerable to climate change. Most farmers sell their produce to collectors, which means they do not have direct contact with markets and may have limited market knowledge, both locally and for exports. A significant number of farmers (72%) are part of an organization or association, which means they may have better access to training and assistance, inputs, and credit, which enables them to strengthen their adaptive capacity. Although women are not directly involved in the production process, many women nonetheless depend on the value chain because they run or work in small businesses that process soybeans into cheese, milk, yoghurt, and other products. Their adaptive capacity may be low, since they do not directly influence soybean production.

Ongoing adaptation practices for the soybean value chain include switching to short-cycle varieties, the use of nitrogen-15 isotopic techniques to measure and increase the crops' amounts of nitrogen and improve yields, and the use of bacteria to enhance soybeans' ability to fix nitrogen.

For the rice value chain, most producers are smallholders, production is mainly rain-fed, and they produce one harvest a year. The use of inputs such as fertilizers and herbicides is low. All these conditions make rice farmers highly vulnerable to climate change. Most producers sell their rice through traders who collect the products at the farm, which may limit their market knowledge because they rely on these traders to access markets. Nevertheless, rice producers are mostly well organized, and this may help them strengthen their adaptive capacity. For example, ESOP provides training, helps ensure quality standards, and assures a fixed price for the season. Current adaptation practices for rice include the following: the smart-valleys approach, introduced in 2010, which improves water control and soil fertility management and increases rice productivity; the development and distribution of rice varieties tolerant to drought or flooding; and the adoption of an integrated production and pest management program (Africa Rice, 2018; FAO, 2020a).

The poultry value chain involves a high proportion of traditional farmers (50%). Most of these are characterized by low biosecurity levels, outdoor breeding, and irregular veterinary assistance, which makes them highly vulnerable to climate change. Producers sell their products through traders who collect them at the farm for lower prices than if they were sold in the village market, and so these producers may have limited knowledge of markets. Taken together, all these characteristics constrain poultry farmers' adaptive capacity. A few ongoing adaptation practices for the poultry value chain were identified in the literature: these include best practices for breeding, improvement of reproductive techniques, and improvement of animal feed.

Table 1. Specific practices within each practice group relevant to the focus value chains

PRACTICE GROUPS	RICE VALUE CHAIN	SOYABEAN VALUE CHAIN	POULTRY VALUE CHAIN
Disease management			• Improvement of the national zoo-sanitary surveillance and epizootic control systems
Improved rice management	• Intensive rice cultivation systems		
Integrated nutrient management		• The use of bacteria to enhance nitrogen fixation	
Production best practices	• Shifting the date of sowing	• Shifting the date of sowing	• Training in the construction of animal shelters • Improvement of integrated farming systems adapted to climate conditions
Variety improvement	• Varieties that prevent water deficits • Varieties with a shorter development cycle • Development of varieties tolerant to droughts, submergence, and floods	• Varieties that prevent water deficits • Varieties with a shorter development cycle	• Crossbreeding poultry to improve resistance to climate shocks
Water management		• Integral management of water resources in agricultural systems • Development of micro-irrigation	
Finance		• The promotion of agricultural credits • Professionalization of family farming	

Finally, low access to basic necessities like water, electricity, and sewage, information and communication technologies, infrastructure, and financing and credit also curbs growth and adaptive capacity, especially of small farmers.

6.2. Overall ranking of the adaptation strategies

This section presents key adaptation strategies for the two most important hazards selected for each value chain. This information was gathered from a survey of experts that asked them to rank adaptation strategies for each hazard and each stage of the value chain.

For rice, the most promising adaptation strategies are the development of varieties tolerant to droughts, submergence, and floods, and intensive rice cultivation systems. These strategies are especially favorable at the input and on-farm stages, although the latter is promising at all stages of production (Table 1).

For the poultry value chain, the most promising strategies in response to high temperatures are the improvement of the national zoo-sanitary[2] surveillance and epizootic[3] control systems, and training in the construction of animal shelters (Table 2). For changes in precipitation, the most promising adaptation strategies are crossbreeding poultry to improve resistance to climate shocks, and the improvement of integrated farming systems adapted to climate conditions.

For the soybeans value chain, the most promising adaptation strategies are in the case of drought the use of bacteria to enhance the crops' ability to fix more nitrogen, and the professionalization of family farming and the promotion of agricultural credits. In the case of dry spells during the growing season, the most promising strategies are the development of micro-irrigation and integral management of water resources in agricultural systems.

Other adaptations strategies include, for example, the development of varieties with a shorter development cycle that can enable farmers to avoid the most stressful periods of the year for plants, shift the date of sowing, and select varieties to prevent water deficits. The shortening of the growth cycle has improved the yield of many varieties in many annual crop species.

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2 Refers to the cleanliness of animals or animal products.

3 An epizootic disease is a disease event in an animal population analogous to an epidemic in humans. It has the potential for very serious and rapid spread, and may cause serious economic or public health consequences and are of major importance in the international trade of animals and animal products (DAERA, UK).

- **Table 2.** Adapting to climate change: strategies across major value chain commodities

RICE	INPUT	ON-FARM	POST-HARVEST	MARKETING
Drought	• No significant impact	• Photosynthesis inhibition • Reductions in biomass production and the life cycle of the plant • Decreased plant growth • Significant reduction in grain because rice is highly susceptible to water stress during the reproductive stage	• Lower yields	• No information
Magnitude of impact	LOW-MODERATE	MAJOR-SEVERE	LOW-MODERATE	LOW
Promising adaptation options	• Intensive rice cultivation system • Development and distribution of rice varieties that are tolerant to drought or flooding			
Floods	• No information	• Proliferation of pests and disease • Destruction of young plants before they have fully established by early season flash-flooding in inland valleys • Destruction of crops	• Flooding of storage units • Rice storage compromised by humidity	• Negative impacts on infrastructure and transportation
Magnitude of impact	LOW	MAJOR-SEVERE	LOW-MODERATE	LOW
Promising adaptation options	• Development of flood- and submergence-tolerant rice varieties • Intensive rice cultivation systems			
Strategies to mitigate both hazards				
Farmers' coping strategies	• Early sowing or the use of early maturing rice cultivars to avoid high temperatures at grain filling • Gravity irrigation			
On-going adaptation strategies	• The smart-valleys approach which helps improve water control and soil fertility management and increase rice productivity • The development and distribution of rice varieties that are tolerant to drought or flooding • The adoption of integrated production and pest management programs			

SOY BEANS

	INPUT	ON-FARM	POST-HARVEST	MARKETING
Drought	• No information	• Reduced water content, root activity, chlorophyll content of leaves, soluble protein, and biomass of the crop in cases of prolonged drought • Reduction in the grain storage capacity, resulting in decreased grain weight and yield, in cases of drought during the grain filling stage	• Lower yields	• No information
Magnitude of impact	LOW-MODERATE	MAJOR-SEVERE	LOW-MODERATE	LOW
Promising adaptation options	• Use of bacteria to enhance the crops' ability to fix nitrogen • Professionalization of family farms			
Increased dry spells during the growing season	• No information	• Shortening of the growth period • Disruption of sowing dates, which affects agricultural schedules and reduces yields	• Lower yields	• No information
Magnitude of impact	LOW-MODERATE	MAJOR-SEVERE	LOW-MODERATE	LOW
Promising adaptation options	• Development of micro-irrigation • Integral management of water resources in agricultural systems			

Strategies to mitigate both hazards

Farmers' coping strategies	• Switching to short-cycle varieties • Modification of agricultural calendars
On-going adaptation strategies	• The use of nitrogen-15 isotopic techniques to measure and increase the amounts of nitrogen available to soybeans and improve yields • The use of bacteria to enhance the crops' ability to fix nitrogen

POULTRY

	INPUT	ON-FARM	POST-HARVEST	MARKETING
High temperatures	• May require the construction of better shelters for the animals • Higher water needs	• May result in a decrease in reproductive capacity • May induce greater water consumption and more frequent heat stress which results in a decline in the animal's physical activities (eating and grazing), which in turn may result in growth reduction • May limit the productivity of laying hens since the animals divert their energy to maintaining body temperature constant, which results in lower egg production or lower quality • Higher temperatures facilitate the prevalence of zoonotic diseases	• May affect the storage of eggs	• No information
Magnitude of impact	LOW	MODERATE-MAJOR	MODERATE	LOW
Promising adaptation options	• Improvement of the national zoo-sanitary surveillance and epizootic control systems • Training for the construction of animal shelters			
Changes in precipitation	• May require the construction of better shelters for the animals (better materials, more resistant).	• Paired with higher temperatures, animals use more water to regulate their temperature • Low availability of water may affect animal growth and reproduction • Henhouses and shelters are often made of rustic materials, hence violent rains, storms or strong winds may affect them	• No information	• No information
Magnitude of impact	MODERATE	MAJOR	MODERATE	LOW
Promising adaptation options	• Crossbreeding poultry to improve resistance to climate shocks • Improvement of integrated farming systems adapted to climate conditions			

Strategies to mitigate both hazards

Farmers' coping strategies	• No information
On-going adaptation strategies	• Best practices for breeding • Improvement of reproductive techniques • Improvement of animal feed

7. SYNTHESIS AND RECOMMENDATIONS

The most pressing hazards expected to affect the study area are droughts, heat stress, and floods. Droughts may affect all four departments under study and present a major risk for rice and poultry. Rice in Benin is mainly rain-fed; hence reduced rainfall and droughts could result in lower yields for this crop. For the poultry value chain, meanwhile, if the chickens have less water available to drink, that affects how they regulate their body temperature, leading to decreased egg production or disease.

Heat stress may also impact the soybean, rice, and poultry value chains in all four departments. For rice, higher temperatures may result in the shortening of the growing period and heat-induced sterility. For soybeans, excessive heat affects plant growth, causes lower yields, and may affect agricultural schedules. When faced with heat stress, meanwhile, chickens reduce their feed intake to regulate their internal temperature, which decreases their growth and productivity. Higher temperatures also increase the prevalence of zoonotic diseases.

Flooding is likely to have the most serious consequences in Alibori for all three value chains. Intense rains following dry periods increase the risk of flooding and may destroy rice crops. For soybeans, excessive rain may affect soil humidity, affecting plant growth and lowering yields. And for poultry, in traditional farming systems, animals are effectively outdoors without a shelter, or if they do have shelter, henhouses and shelters are often made of rustic materials. Heavy or violent rains, storms, or strong winds may damage them.

The survey indicated that droughts and floods are the main hazards affecting the rice value chain, and their impacts are more severe during the on-farm and post-harvest stages. The most promising adaptation strategies in the case of floods are the development of flood- or submergence-tolerant rice varieties and the adoption of intensive rice cultivation systems. The most promising strategies adaptation strategies for droughts, meanwhile, are the development and distribution of rice varieties tolerant to droughts or flooding and the adoption of intensive rice cultivation systems.

For soybeans, drought and increased dry spells during the growing season were the primary hazards. The most promising adaptation strategies for droughts are the use of bacteria to enhance soybeans' ability to fix nitrogen and the professionalization of family farms. For increased dry spells during the growing season, the most promising strategies are the development of micro-irrigation and integral management of water resources in agricultural systems.

For the poultry value chain, the most urgent hazard was high temperatures, and in the literature, we identified changes in rainfall, such as decreases or heavy storms, as another major hazard. For high temperatures, the most promising adaptation strategies are the improvement of the national zoo-sanitary surveillance and epizootic control systems and training in the construction of animal shelters. For changes in rainfall, the most promising adaptation strategies are crossbreeding poultry to strengthen resistance to climate shocks and improving integrated farming systems adapted to climate conditions.

Many of these strategies are being implemented with the support of international organizations such as GIZ or IFAD in partnership with local NGOs or farmers' associations, such as Sojagnon and ESOP, among others. The poultry value chain is perhaps a lower priority promising compared to the other two value chains, as a limited number of adaptation strategies was identified through the literature.

Overall, these strategies can help improve producers' income levels, food security, and overall wellbeing. However, more local government institutions need to get involved for impacts to be long-lasting. In addition, structural issues must be addressed, such as improving access to basic necessities like water and electricity; information and communication technology like the internet, phones, and radios; and road networks.

Going forward, a variety of opportunities for collaboration, funding, and synergies exist for these practices (Table 3). Several organizations and programmes are well positioned to offer general support across all potential activities, including:

- The Integrated Adaptation Program for the Fight against the Harmful Effects of Climate Change on Agricultural Production and Food Security in Benin (PANA1)
- The Agricultural Development and Market Access Support Project, funded by the government and the International Fund for Agricultural Development (IFAD)
- The Communal Approach for Agricultural Markets is an initiative supported by IFAD and the Dutch government
- Agricultural Development Poles (PDA)
- Agriculture Promotion Program
- Ministry of Agriculture, Livestock and Fisheries
- Ministry of Agriculture (MAEP)
- Ministry of Planning and Development
- National Institute for Agricultural Research (INRAB)
- National Statistics and Economic Analysis Institute (INSAE)
- German Agency for International Cooperation (GIZ)
- International Fund for Agricultural Development (IFAD)
- Africa Rice Center, and Songhaï
- Fédération de l'Union des Producteurs de Benin (FUPRO)
- Association of Young Modern Farmers
- Solidarity Company for Rural Services (ESSOR)
- The Master Plan for Agricultural and Rural Development (SDDAR)
- Operational Strategic Plan (PSO).
- The Climate Change Adaptation and Resilience Strategies in the Agriculture Sector program by the National Institute for Agricultural Research

Further, several barriers challenge the general implementation of climate-aware programming in Benin. Climate change could be more fully integrated into government policy, and local authorities need better institutional capacity and financial resources. Farmers grapple with low access to basic necessities like water, electricity, and sewage, information and communication technologies, infrastructure, and financing and credit.

Table 3. Practice-group specific potential strategies and considerations for advancing CSA at scale

PRACTICE GROUP	PARTNERSHIPS	BARRIERS	EXISTING AND POTENTIAL FUNDING	SYNERGIES
Disease management	• International Fund for Agricultural Development (e.g. through the Communal Approach for Agricultural Markets initiative) • Dutch government (e.g. through Communal Approach for Agricultural Markets initiative)	**Farm level barriers:** • Low biosecurity levels • Finance constraints **Institutional barriers:**** • Limited extension services • Irregular veterinary assistance	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Supports both productivity and environmental/ land restoration goals
Integrated nutrient management	• Beninese government, e.g. through the National Development Program for the Soybean sector, the Soybean Commercialization Campaign 2019-2020, and the Rural Economic Growth Support Project • Association of Soybean Producers • Sojagnon Association	**Farm level barriers:** • Limited use of inputs • Knowledge gaps • Financial constraints **Institutional barriers:**** • Limited extension services • Weak land tenure security • Poor financial service availability	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Improved soil health supports yields and water retention, thus increasing both market stability and climate resiliency
Improved rice management	• Africa Rice Center • Association of Benin Rice Farmers (CCR-B) • Entreprises des services et organisations de producteurs (ESOP) • ProAgri • The Programme for the Protection and Management of Natural Resources	**Farm level barriers:** • Low use of inputs • Mostly rain-fed with one harvest per year • Knowledge gaps • Financial constraints **Institutional barriers:**** • Limited extension services	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Supports climate-resiliency and yields, thus improving market stability
Production best practices	• Association of Benin Rice Farmers (CCR-B) • International Fund for Agricultural Development (e.g. through the Communal Approach for Agricultural Markets initiative) • Dutch government (e.g. through Communal Approach for Agricultural Markets initiative) • Beninese government, e.g. through the National Development Program for the Soybean sector and the Soybean Commercialization Campaign 2019-2020 • National Breeding Program • Ministry of Agriculture, Livestock and Fisheries, e.g. through the Annual Action Plan of the Benin Poultry Interprofessional Sector • Association of Soybean Producers • Sojagnon Association • The Farmers Business School, promoted by GIZ	**Farm level barriers:** • Limited use of inputs among soybean and rice farmers • Lack of shelter for poultry **Institutional barriers:** • Insufficient training • Limited extension services • Widespread illiteracy. • Little market knowledge and few connections to markets • Suboptimal access to basic necessities	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Supports climate-resiliency and yields, thus improving market stability

PRACTICE GROUP	PARTNERSHIPS	BARRIERS	EXISTING AND POTENTIAL FUNDING	SYNERGIES
Variety improvement	• National Institute for Agricultural Research • International Fund for Agricultural Development (e.g. through the Communal Approach for Agricultural Markets initiative) • Dutch government (e.g. through Communal Approach for Agricultural Markets initiative) • Beninese government, e.g. through the National Development Program for the Soybean sector and the Soybean Commercialization Campaign 2019-2020 • Beninese government's Rural Economic Growth Support Project • National Breeding Program • Association of Benin Rice Farmers (CCR-B) • Association of Soybean Producers • Federation of Seed Producers of Benin • Sojagnon Association. • Centre d'Action Régionale pour le développement Agricole • Fédération de l'Union des Producteurs de Benin (FUPRO)	**Farm level barriers:** • Common use of recycled soybean seeds • Outdoor poultry breeding • Common use of local poultry breeds **Institutional barriers:**** • Limited extension services • Poor finance services	• International research funding offers robust support; diversification toward local and culturally important crops needed	• Climate-resilient varieties help stabilize harvest quantities, thus supporting stable markets
Water management	• Beninese government, e.g. through the National Development Program for the Soybean sector and the Soybean Commercialization Campaign 2019-2020 • Association of Soybean Producers	**Institutional barriers:**** • Limited extension services • Sub-optimal infrastructure • Limited finance	• Public and private interests with good blended finance potential	• Effective water management reduces erosion and flooding to support productivity and land restoration efforts
Finance	• International Fund for Agricultural Development (e.g. through the Communal Approach for Agricultural Markets initiative) • Dutch government (e.g. through Communal Approach for Agricultural Markets initiative) • Beninese government, e.g. through the National Development Program for the Soybean sector and the Soybean Commercialization Campaign 2019-2020 • Association of Soybean Producers	**Institutional barriers:**** • Lack of service providers • Poor understanding of real farmer risk • Poor de-risking mechanisms • Low involvement on private sector	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Enable on-farm investments in soil fertility, optimized management techniques, and climate resiliency

** based on literature

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